American Journal of
EPIDEMIOLOGY

Volume 134
Number 11
December 1, 1991

Sponsored by the Society for Epidemiologic Research

ORIGINAL CONTRIBUTIONS

Homicide and the Prevalence of Handguns: Canada and the United States, 1976 to 1980

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As compared with Americans, Canadians in the 1970s possessed one tenth as many handguns per capita. To assess whether this affected the total criminal homicide rate, the mean annual criminal homicide rates of Canadian provinces were compared with those of adjoining US states for the period of 1976 to 1980. No consistent differences were observed; criminal homicide rates were sometimes higher in the Canadian province, and sometimes higher in the adjoining US state. Major differences in the prevalence of handguns have not resulted in differing total criminal homicide rates in Canadian provinces and adjoining US states. The similar rates of criminal homicide are primarily attributable to underlying similar rates of aggravated assault. *Am J Epidemiol* 1991;134:1245–60.

firearms; homicide; violence

Editor's note: *For a discussion of this paper and the author's response, see pages 1261 and 1264, respectively.*

The homicide rate in the United States doubled between the 1960s and the 1970s (1). The increased numbers of handguns being used in killings raised public concern, leading to the Gun Control Act of 1968 (2). Nevertheless, there is still debate over whether a change in the prevalence of handguns would change rates of homicide (2–5).

Sloan et al. (6) recently compared homicide rates for 1980 to 1986 in Seattle, Washington, and Vancouver, British Columbia, under the assumption that a roughly fourfold difference in handgun prevalence between these two otherwise similar cities should be reflected in their respective hom-

Received for publication June 5, 1989, and in final form February 21, 1991

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The author is indebted to Joanne Lacroix and Dr. Paul Reed for providing access to unpublished data from the Canadian Centre for Justice Statistics; to J. Harper Wilson and Cindy Brice for providing access to unpublished data from the US Federal Bureau of Investigation; and to Dr. Paul Blackman for providing access to unpublished data from the Decision-Making Information survey

The data from the Decision-Making Information survey are now available from the Inter-University Consortium for Political and Social Research, Ann Arbor, Michigan

icide rates. The average annual homicide rate in Seattle (11.3 homicides per 100,000 population) was indeed significantly greater than that in Vancouver (6.9 per 100,000 population; relative risk = 1.63; 95 percent confidence interval 1.38–1.93). The difference was almost entirely accounted for by a fivefold greater firearm homicide rate in Seattle.

However, as noted by Blackman et al. (7), among non-Hispanic whites, who made up 79 and 76 percent of the populations of Seattle and Vancouver, respectively (6), average annual homicide rates in the two cities were essentially identical: 6.2 vs. 6.4 homicides per 100,000 population (6). Furthermore, so few blacks and Hispanics resided in Vancouver (6) as virtually to preclude meaningful comparison with the blacks and Hispanics of Seattle. This leads to the tentative conclusion that if the homicide data of Sloan et al. were subjected to a Mantel-Haenszel summary odds ratio (8), stratifying by race, the differences in homicide rates between Seattle and Vancouver would cease to be statistically significant. This conclusion is necessarily tentative, since Sloan et al. are disinclined to calculate a summary odds ratio stratified by race (Sloan JH, University of Washington, personal communication, 1989).

Pending the availability of raw data from Sloan et al., a broader study was made of criminal homicide and the prevalence of handguns in Canadian provinces and adjoining US states, to determine whether major differences in the prevalence of handguns are associated with differences in the criminal homicide rate.

MATERIALS AND METHODS

Criminal homicide is a subset of homicide that excludes legally justifiable homicides (9). Aggravated assault is an assault committed with the intent to cause death or serious bodily injury (9). US data on criminal homicides and aggravated assaults are from the US Federal Bureau of Investigation. Canadian data are from the Canadian Centre for Justice Statistics. Both countries maintain uniform crime-reporting registries of all homicides and aggravated assaults known to the police; the two registries use equivalent definitions of homicide and assault (9–11).

Rates of criminal homicide and aggravated assault are compared by state, province, and city for Canada and the United States for the period 1976 to 1980. To control for variations in rates resulting from small numbers, the rates for 1976 to 1980 are averaged and presented as a 5-year mean. For the period 1976 to 1980, 93 percent of Canadian (10) and 94 percent of US firearm homicides (US Federal Bureau of Investigation, unpublished data) were classified as to type of firearm used, namely, handgun, rifle, or shotgun.

To control for the effect of metropolitan areas upon homicide rates, homicide rates by state and province are presented both including and excluding metropolitan areas of greater than 1 million population in 1980. For Canada, these comprise Montreal, Toronto, and Vancouver. For the US border states, these comprise New York City, Buffalo, Detroit, Minneapolis, and Seattle.

National estimates of the US prevalence of privately owned handguns are from Wright, Rossi, and Daly (4), based upon a 1978 random national household survey conducted by Decision-Making Information (hereafter referred to as the "US survey"). National data on the prevalence of privately owned handguns in Canada are from a random national household survey conducted for the Ministry of the Solicitor General in 1976 (12). The US survey data permit an estimation by state of the prevalence of privately owned firearms in the United States, (US survey, unpublished data). To maximize sampling power, the US survey was limited to 39 states. The Canadian survey data permit an estimation by province of the prevalence of privately owned firearms (12). Owing to the sampling frame employed by the Canadian survey, the Atlantic provinces (Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick) and the prairie provinces (Manitoba, Saskatchewan, and Alberta) cannot be analyzed indi-

vidually. The Yukon and the Northwest Territories were not included in the survey.

The 1976 Canadian Gun Ownership and Use Survey is the only national survey of the prevalence of privately owned handguns to have been undertaken in Canada. For this reason, the comparative analysis of homicide and assault rates in Canada and the United States is limited to the years 1976 to 1980. For the same reason, although there are more recent US surveys of handgun prevalence, the present analysis relies upon the 1978 survey conducted by Decision-Making Information.

Data on the prevalence of firearms are presented both as the number of firearms per 1,000 population and as the number of firearms per 100 households. Variations in the aggregation of provinces in tabular presentations reflect variations in the aggregation of provinces in the primary sources.

Data on socioeconomic conditions and racial composition by state and province are from the 1980 US census of the population (13, 14) and the 1981 Canadian census of the population (15, 16). The indices of socioeconomic status are per capita income and percentage of households with >1.0 residents per room, the latter being an index previously developed for studying homicide rates in comparable populations of blacks and whites in the United States (17).

At the level of states and provinces, all differences in homicide and assault rates will be "statistically significant," given the large populations. For this reason, rates are presented without confidence intervals.

RESULTS

Populations living in the Canadian provinces and adjoining US states share a common geography, a common climate, and common primary industries (e.g., farming and forest products). More quantitatively, in a comparison of the 1980 US census and the 1981 Canadian census, the percentage of the population that is white did not differ by more than seven percentage points between Canadian provinces and adjoining US states, after major metropolitan centers had been excluded (table 1). Similarly, the percentage of crowded households (i.e., >1.0 residents per room) did not differ by more than four percentage points (table 1). With two exceptions, Idaho and Alaska, the annual per capita income in US states differed from that in adjoining Canadian provinces by less than 1,000 dollars, when both were expressed in 1980 US dollars (table 1).

In 1978, there were an estimated 35 million handguns in private hands in the United States (4), or approximately 160 handguns per 1,000 population. In 1976, there were an estimated 280,000 handguns in private hands in Canada (12), or approximately 12 handguns per 1,000 population. For states and provinces along the US-Canadian border, the surveys of handgun prevalence in Canada (12) and the United States (US survey, unpublished data) indicate that, in the latter half of the 1970s, there were 4 to 10 times as many handguns per 1,000 population in the US border states as compared with handguns in adjoining Canadian provinces, and 3 to 10 times as many handguns per 100 households (table 2). In contrast, the prevalence of rifles and shotguns was approximately equal (table 3).

For the years 1976 to 1980, the mean annual rates of criminal homicide in Canada ranged from 1.1 per 100,000 in Newfoundland to 16.9 in the Yukon (figure 1) (10). In the United States, rates of criminal homicide ranged from a mean annual rate of 1.2 in North Dakota to 16.1 in Nevada (9).

Along the US-Canadian border (table 4), rates of criminal homicide were higher in the provinces of New Brunswick (2.9) and Quebec (3.0) than in the adjoining states of Maine (2.7), New Hampshire (2.6), and Vermont (2.8). Rates of criminal homicide were higher in the province of Manitoba (3.7) than in the adjoining states of Minnesota (2.4) and North Dakota (1.2). Rates of criminal homicide were higher in the Yukon (16.9) than in the adjoining state of Alaska (11.6).

Conversely, rates of criminal homicide were higher in the states of Washington (4.7), Idaho (4.9), and Montana (4.7) than in the adjoining provinces of British Colum-

TABLE 1. Socioeconomic conditions and racial composition on the US-Canadian border, by state and province*

Canada (1981 census)				United States (1980 census)			
Province	% white (1981)	% crowded† (1981)	Per capita income‡ (1980)	State	% white (1979)	% crowded† (1980)	Per capita income‡ (1979)
New Brunswick	99	3.8	6,615	Maine	99	3.1	6,547
Quebec	98	2.8	8,303	New Hampshire	99	2.4	7,906
(excluding Montreal)	(99)	(3.0)	(7,695)	Vermont	99	2.5	7,012
Ontario	95	1.9	8,838	New York	80	4.9	8,510
(excluding Toronto)	(97)	(1.5)	(8,270)	(excluding New York City and Buffalo)	(93)	(2.4)	(8,754)
				Michigan	85	3.1	8,726
				(excluding Detroit)	(93)	(2.9)	(8,984)
Manitoba	90	3.1	7,560	Minnesota	97	2.3	8,457
				(excluding Minneapolis)	(97)	(2.3)	(8,402)
				North Dakota	96	2.7	7,283
Saskatchewan	92	2.8	7,952	Montana	94	3.8	7,479
Alberta	92	2.3	9,819	Idaho	96	4.5	7,091
British Columbia	89	2.2	9,711	Washington	91	2.9	9,163
(excluding Vancouver)	(92)	(2.4)	(9,140)	(excluding Seattle)	(92)	(2.9)	(8,275)
Yukon	81	6.3	10,149	Alaska	77	10.1	11,569

* Sources: Statistics Canada. *1981 Census of Canada: Population* and *1981 Census of Canada: Occupied Private Dwellings.* Ottawa: Statistics Canada, 1984 and 1983, respectively. US Bureau of the Census. *1980 Census of the Population. Volume 1. Characteristics of the Population* and *1980 Census of Housing Volume 1. Characteristics of Housing Units.* Washington, DC: US GPO, 1981 and 1982, respectively.

† Households with >1.0 residents per room.

‡ Expressed in 1980 US dollars.

bia (3.6), Alberta (3.4), and Saskatchewan (3.8). Rates of criminal homicide were higher in the states of New York (11.3) and Michigan (10.1) than in the adjoining province of Ontario (2.1).

The high rates of homicide in New York and Michigan represent the one noteworthy disparity between US and Canadian rates of criminal homicide along the US-Canadian border (figure 1). However, the criminal homicide rate of New York State (11.3) was dominated by that of New York City (22.7) (9). When New York City was excluded, the rate of criminal homicide for the rest of the state of New York was 3.4 per 100,000 population. Likewise, the rate of criminal homicide in Michigan (10.1) was dominated by that of Detroit (41.9) (9). When Detroit was excluded, the rate of criminal homicide for the rest of Michigan was 5.0 per 100,000. When Toronto (1.8) was similarly excluded from Ontario (2.1), the rate of criminal homicide for the rest of the province of Ontario was 2.3 per 100,000 population (Canadian Centre for Justice Statistics, unpublished data).

During the years 1976 to 1980, there were 43,691 handgun homicides in the United States (US Federal Bureau of Investigation, unpublished data), or an annual rate of 2.5 handgun homicides per 10,000 handguns in the general US population. For the years 1976 to 1980 in Canada, there were 304 handgun homicides (10), or an annual rate of 2.2 handgun homicides per 10,000 handguns in the general Canadian population.

These data would suggest that the rate at which homicides are committed with hand-

TABLE 2. Prevalence of privately owned handguns on the US-Canadian border, by state and province*

Canada (1976)			United States (1978)		
Province	Handguns per 100 households	Handguns per 1,000 population	State	Handguns per 100 households	Handguns per 1,000 population
Atlantic provinces†	4	12	Maine	NA‡	NA
Quebec	1	4	New Hampshire	NA	NA
			Vermont§	14	48
Ontario	4	12	New York	12	45
			Michigan	33	110
Prairie provinces†	5	15	Prairie states‖	36	125
British Columbia	9	32	Idaho	NA	NA
			Washington	33	122
Yukon†	NA	NA	Alaska	NA	NA

* Sources: Stenning PC, Moyer S. *Firearms Ownership and Use in Canada: A Report of Survey Findings, 1976.* Toronto, Canada: University of Toronto, 1981 1978 Decison-Making Information survey of US households (unpublished data).

† Owing to the sampling frame employed by the Canadian Gun Ownership and Use Survey (1976), the Atlantic provinces (Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick) and the prairie provinces (Manitoba, Saskatchewan, and Alberta) cannot be analyzed individually The Yukon was not included in the survey

‡ Not available. To maximize sampling power, the US survey (1978) was limited to 39 of the US states

§ A gun collector was excluded from the Vermont state survey sample as a statistical outlier

‖ Minnesota, North Dakota, and Montana.

TABLE 3. Prevalence of privately owned rifles and shotguns on the US-Canadian border, by state and province*

Canada (1976)			United States (1978)		
Province	Rifles and shotguns per 100 households	Rifles and shotguns per 1,000 population	State	Rifles and shotguns per 100 households	Rifles and shotguns per 1,000 population
Atlantic provinces†	100	275	Maine	NA‡	NA
Quebec	47	142	New Hampshire	NA	NA
			Vermont§	79	265
Ontario	56	179	New York	82	297
			Michigan	71	241
Prairie provinces†	106	336	Prairie states‖	96	329
British Columbia	72	243	Idaho	NA	NA
			Washington	71	262
Yukon†	NA	NA	Alaska	NA	NA

* Sources: Stenning PC, Moyer S. *Firearms Ownership and Use in Canada: A Report of Survey Findings, 1976.* Toronto, Canada. University of Toronto, 1981 1978 Decision-Making Information survey of US households (unpublished data).

† Owing to the sampling frame employed by the Canadian Gun Ownership and Use Survey (1976), the Atlantic provinces (Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick) and the prairie provinces (Manitoba, Saskatchewan, and Alberta) cannot be analyzed individually. The Yukon was not included in the survey.

‡ Not available To maximize sampling power, the US survey (1978) was limited to 39 of the US states.

§ A gun collector was excluded from the Vermont state survey sample as a statistical outlier.

‖ Minnesota, North Dakota, and Montana.

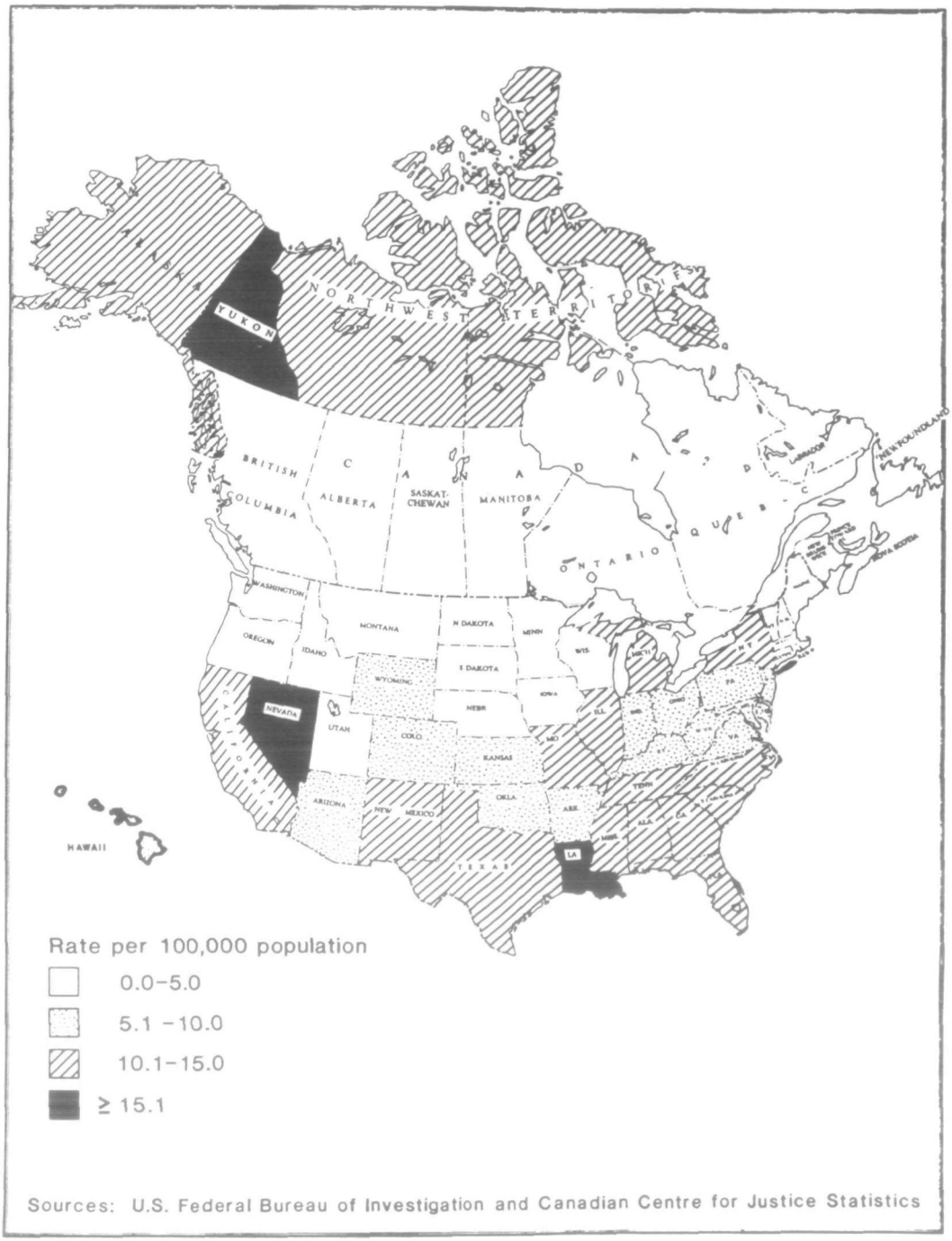

FIGURE 1. Mean annual criminal homicide rates in Canada and the United States, by state and province, 1976 to 1980. (Map outline used by permission of the American Map Corporation, Maspeth, New York.)

guns is primarily a function of the prevalence of handguns in the general population. To assess whether this relationship holds true at the level of states and provinces, rates of criminal homicide committed with handguns were determined for the Canadian provinces and adjoining US states (table 5). After the major metropolitan centers were

TABLE 4. Mean annual rates of criminal homicide on the US-Canadian border, by state and province, 1976–1980*

Canada		United States	
Province	Deaths per 100,000 population	State	Deaths per 100,000 population
New Brunswick	2.9	Maine	2.7
Quebec	3.0	New Hampshire	2.6
(excluding Montreal)	(3.3)	Vermont	2.8
Ontario	2.1	New York	11.3
(excluding Toronto)	(2.3)	(excluding New York City and Buffalo)	(3.0)
		Michigan	10.1
		(excluding Detroit)	(5.0)
Manitoba	3.7	Minnesota	2.4
		(excluding Minneapolis)	(1.8)
		North Dakota	1.2
Saskatchewan	3.8	Montana	4.7
Alberta	3.4	Idaho	4.9
British Columbia	3.6	Washington	4.7
(excluding Vancouver)	(4.9)	(excluding Seattle)	(4.3)
Yukon	16.9	Alaska	11.6

* Sources: Canadian Centre for Justice Statistics. *Homicide Statistics, 1980.* Ottawa, Canada: Statistics Canada, 1982. US Federal Bureau of Investigation *Uniform Crime Reports for the United States.* Washington, DC: US GPO, 1976–1980.

excluded, the handgun homicide rates (table 5) by state and province were roughly proportional to the prevalence of handguns (table 2) by state and province, with the notable exception of Quebec. Despite having the lowest reported handgun prevalence of a Canadian province, Quebec had the highest handgun homicide rate in Canada. Possible reasons for this apparent discrepancy will be presented in the discussion. After major metropolitan centers and Quebec were excluded, the annual number of handgun homicides per 10,000 privately owned handguns exhibited a range of 0.7 to 1.7 for Canadian provinces and 0.5 to 1.5 for US border states.

To assess whether variations in rates of criminal homicide by state and province primarily reflect similar underlying variations in rates of aggravated assault, the mean annual aggravated assault rates in Canadian provinces, 1976 to 1980, were compared with those of adjoining US states (table 6). As with rates of criminal homicide, no consistent differences were observed. Rates of aggravated assault were sometimes higher in the Canadian province, sometimes higher in the adjoining US state.

If variations in the prevalence of handguns indeed have no effect upon the total homicide rate, then the probability of an aggravated assault ending in death and thereby becoming a homicide—that is, the "case fatality rate"—will be unrelated to the prevalence of handguns. To state the hypothesis another way, if the case fatality rate for aggravated assaults is a function of the prevalence of handguns, then the case fatality rate would be systematically higher in US border states than in adjoining Canadian provinces.

When the number of homicides per 100 aggravated assaults was determined by state and province (table 7), no consistent differences were observed. Of 11 US border states, five had higher case fatality rates than the

TABLE 5. Mean annual rates of criminal homicide committed with handguns on the US-Canadian border, by state and province, 1976–1980*

Canada		United States	
Province	Deaths per 100,000 population	State	Deaths per 100,000 population
Atlantic provinces	0.1	Maine	0.7
Quebec	0.5	New Hampshire	0.6
(excluding Montreal)	(0.4)	Vermont	0.4
Ontario	0.2	New York	4.8
(excluding Toronto)	(0.2)	(excluding New York City and Buffalo)	(0.6)
		Michigan	4.4
		(excluding Detroit)	(1.7)
Prairie provinces	0.1	Minnesota	0.7
		(excluding Minneapolis)	(0.5)
		North Dakota	0.4
		Montana	1.6
British Columbia	0.3	Idaho	1.8
(excluding Vancouver)	(0.4)	Washington	1.7
		(excluding Seattle)	(1.5)
Yukon and Northwest Territories	0.3	Alaska	4.7

* Sources: Canadian Centre for Justice Statistics. *Homicide Statistics, 1980.* Ottawa, Canada: Statistics Canada, 1982 Owing to small numbers, data on handgun homicides, by province, are published in aggregate form US Federal Bureau of Investigation. *Uniform Crime Reports for the United States.* Washington, DC. US GPO, 1976–1980.

TABLE 6. Mean annual rates of aggravated assault on the US-Canadian border, by state and province, 1976–1980*

Canada		United States	
Province	Aggravated assaults per 100,000 population	State	Aggravated assaults per 100,000 population
New Brunswick	62	Maine	161
Quebec	75	New Hampshire	83
(excluding Montreal)	(101)	Vermont	111
Ontario	135	New York	328
(excluding Toronto)	(137)	(excluding New York City and Buffalo)	(135)
		Michigan	306
		(excluding Detroit)	(262)
Manitoba	179	Minnesota	93
		(excluding Minneapolis)	(68)
		North Dakota	42
Saskatchewan	168	Montana	159
Alberta	162	Idaho	194
British Columbia	146	Washington	245
(excluding Vancouver)	(165)	(excluding Seattle)	(229)
Yukon	321	Alaska	307

* Sources: Canadian Centre for Justice Statistics. *Crime and Traffic Enforcement Statistics.* Ottawa, Canada: Statistics Canada, 1976–1980. US Federal Bureau of Investigation. *Uniform Crime Reports for the United States.* Washington, DC: US GPO, 1976–1980.

TABLE 7. Homicides per 100 aggravated assaults on the US-Canadian border, by state and province, 1976–1980*

Canada		United States	
Province	Homicides per 100 aggravated assaults	State	Homicides per 100 aggravated assaults
New Brunswick	4.7	Maine	1.7
Quebec	4.0	New Hampshire	3.1
(excluding Montreal)	(3.3)	Vermont	2.5
Ontario	1.6	New York	3.4
(excluding Toronto)	(1.7)	(excluding New York City and Buffalo)	(2.2)
		Michigan	3.3
		(excluding Detroit)	(1.9)
Manitoba	2.1	Minnesota	2.6
		(excluding Minneapolis)	(2.6)
		North Dakota	2.9
Saskatchewan	2.3	Montana	3.0
Alberta	2.1	Idaho	2.5
British Columbia	2.5	Washington	1.9
(excluding Vancouver)	(3.0)	(excluding Seattle)	(1.9)
Yukon	5.3	Alaska	3.8

* Sources: Canadian Centre for Justice Statistics. *Homicide Statistics, 1980* and *Crime and Traffic Enforcement Statistics.* Ottawa, Canada. Statistics Canada, 1982 and 1976–1980, respectively. US Federal Bureau of Investigation. *Uniform Crime Reports for the United States.* Washington, DC: US GPO, 1976–1980.

adjoining Canadian province, whereas six had lower case fatality rates (Idaho adjoins rural British Columbia). This corresponds well to what would be expected if handgun prevalence does not influence case fatality rates in any systematic manner.

This interpretation of table 7 assumes that the prevalence of handguns in US states exceeds that in adjoining Canadian provinces, even where actual data are not available (table 2). As it is, wherever handgun prevalence data are available for both sides of the US-Canadian border, the prevalence of handguns in the US state is 3 to 10 times greater than in the adjoining Canadian province; that is, the "prevalence ratio" is 3 to 10 (table 2). When data on handgun prevalence are not available for states and provinces, this is for reasons independent of the hypothesis being tested. Therefore, it is reasonable and ordinary to assume that the handgun prevalence ratio across such parts of the border are similar to those parts where the prevalence ratio is known. This assumption can be confirmed indirectly by observing, for example, that, for the years 1976 to 1980, 41 percent of the homicides in Alaska were committed with handguns (US Federal Bureau of Investigation, unpublished data), whereas only 2 percent of the homicides in the Yukon and the Northwest Territories were committed with handguns (10).

DISCUSSION

In this study, it is observed that adjoining US states and Canadian provinces had similar rates of criminal homicide (table 4), even though the prevalence of privately owned handguns was 3 to 10 times greater in US border states than in adjoining Canadian provinces (table 2). From this, the plain conclusion might be that major differences in the prevalence of handguns are not associated with corresponding differences in rates of criminal homicide, a conclusion consistent with similar observations made in comparisons of the white populations of Seattle and Vancouver (6). Before proceeding to such a plain conclusion, however, it is necessary first to examine the underlying assumptions of the analysis.

How accurate is the diagnosis of homicide?

The study design is invalidated if the diagnosis of homicide is insufficiently accurate to permit the conclusion that the homicide rates of adjoining states and provinces are indeed similar (table 4). If the diagnosis of homicide has poor sensitivity and specificity, rates of criminal homicide in Canada may actually be substantially lower than in the US border states, despite the statistics.

Because of the social and legal repercussions, putative homicides are subjected to intense scrutiny. Thus, for example, autopsy is performed on approximately 90 percent of US homicide victims (1, 18). This should lead to high sensitivity and specificity in the diagnosis, and indeed, for a random sample of 426 US death certificates—including 49 homicides—blinded independent review of all pertinent medical and legal records led to the conclusion that for death certificates carrying a diagnosis of homicide, the sensitivity was 96 percent and the specificity was 99 percent (18). This represents a degree of accuracy seldom matched in epidemiologic research.

Of course, the present study of criminal homicide relies upon police rather than medical records, since death certificates do not distinguish between criminal and legally justifiable homicide. To judge the accuracy of the police records, it is necessary to determine whether they refer to the same deaths as do the medical records. In a case-by-case comparison of police and medical examiner records in seven cities across the United States, Zahn and Riedel (19) found that of 1,332 deaths described as homicide in either the police or medical examiner records, 1,248 (94 percent) were thus described in both record systems. With only minor discrepancies, police and medical records are reporting the same deaths as homicides. It follows that the police records have the same high level of sensitivity and specificity as the medical records. Not surprisingly, over time, enumerations of homicide in Canadian and US police records have differed from enumerations in death certificates by only about 5 percent (20–23).

It could be argued theoretically that Canadians are substantially overreporting homicides, thereby explaining away the apparent similarity of US and Canadian homicide rates along the border. However, given the severe repercussions of a falsely positive declaration of homicide, an assumption of Canadian overreporting is improbable. The conclusion is that the similarity of rates of criminal homicide in US border states and adjoining Canadian provinces is real and not the result of statistical artifact.

How accurate are handgun surveys?

It is common knowledge that the prevalence of privately owned handguns is much higher in the United States than in Canada. However, this does not preclude the a priori possibility that the prevalence of handguns in individual US states, particularly along the Canadian border, may be similar to those in Canada. If this were so, there would be no need to look further for an explanation of the similar homicide rates observed along the US-Canadian border. Therefore, the accuracy of the surveys must be examined in more detail, to permit assurance that the differences observed (table 2) are real.

The 1976 Canadian Gun Ownership and Use Survey was a national randomized household survey of 30,000 households, designed and conducted by Statistics Canada, the Canadian equivalent of the US Census Bureau (12). The 1978 US survey was a national randomized survey (or, more precisely, 39 randomized state surveys) of 1,500 households, designed and conducted by Decision-Making Information, a private polling organization (4). Both organizations used recognized and approved survey methodologies, the details of which are discussed elsewhere (4, 12). The Canadian survey instrument was pretested (12). It is not known whether the US survey was pretested, but its broad findings were virtually identical with those of a second US national randomized household survey of handgun ownership, also conducted in 1978 but by a different and independent polling organization (4). (The second survey, conducted by Cam-

bridge Reports, did not obtain data on numbers of handguns per household (4), so its findings were not detailed enough for the purposes of the present analysis.)

Since the Canadian and US surveys were designed and conducted independently of one another, there are differences between the two surveys that could lead to systematic biases relative to one another. The US survey consisted of face-to-face interviews, whereas the Canadian survey was a combination of face-to-face, telephone, and proxy interviews. The Canadian survey universe consisted of all noninstitutionalized residents aged ≥15 years (12), whereas the US survey universe consisted of all noninstitutionalized residents aged ≥18 years who were also registered voters (4).

For the purposes of the present analysis, the differences in age cutoff are of no importance; the number of handguns possessed by minors and not also considered the property of an adult in the same household must be negligible. That the US survey was limited to registered voters raises the possibility of skewing in various directions for various reasons. Fortunately, the 1978 Decision-Making Information survey results are comparable to those of the 1978 Cambridge Reports survey, which sampled all adults aged ≥18 years, regardless of voter registration status. Of the household respondents surveyed, 25 percent in the Decision-Making Information survey reported possessing one or more handguns, as compared with 24 percent in the Cambridge Reports survey (4). Thus, the net effect of limiting the Decision-Making Information survey to registered voters appears to have been negligible.

The size of the Canadian survey sample precludes the possibility that random artifacts would significantly affect the reliability of findings by province. The smaller US poll was not immune to random artifact in the smaller state surveys. In the case of Vermont, a gun collector was excluded from the state survey sample as a statistical outlier (table 2).

It has often been contended that handgun surveys are inherently invalid, owing to the supposedly sensitive nature of the subject, but no evidence has ever been put forward to demonstrate that survey respondents choose not to answer handgun questions correctly (for further discussion, see Wright et al. (4)). In the US survey, as with other handgun surveys (4), only 1 percent of respondents refused to answer any questions regarding gun ownership. This compares favorably with the 10 percent refusal rate typical of survey questions regarding household income (4). In a validation study, Kellermann et al. (24) demonstrated that, among registered handgun owners, only one out of 35 respondents (3 percent) gave an apparently untruthful answer to a handgun survey.

In theory, the 3 to 10 times greater prevalence of handguns observed in US border states as compared with adjoining Canadian provinces could be a statistical artifact if, in responding to the surveys, US citizens had exaggerated the number of handguns they reported possessing, or if Canadians had underreported the number of handguns in their possession. As there is no basis for supposing US residents overreport handgun ownership, the question is whether Canadians are underreporting. The Canadian survey instrument was validated through pretesting (12), so that would appear not to be an issue, and the Canadian survey results can be regarded as valid, with one possible exception: Although handgun homicide rates (table 5) generally parallel handgun prevalence (table 2), Quebec had the highest handgun homicide rate in Canada, despite having the lowest reported prevalence of handguns. It seems contradictory to assume that the citizens of Quebec have an avid preference for using handguns as weapons while showing little interest in possessing them as property. A more logical explanation may perhaps be found in the historical circumstances.

In 1969–1970, the Quebec separatist movement entered into open conflict with existing Canadian political institutions, resulting in kidnappings of government officials and widespread popular unrest and civil disturbances. In the end, the Canadian central government in Ottawa forcibly suppressed these separatist aspirations by im-

posing martial law (accompanied by mass arrests) in Quebec during the October Crisis of 1970 (25). All of this was recent history at the time of the 1976 Canadian Gun Ownership and Use Survey. Under the circumstances, Quebec citizens may have been reluctant to give candid responses to a handgun survey originating from the central government in Ottawa. The survey instrument was indeed pretested and found to be valid, but the pretesting was conducted in Ontario (12). Therefore, the actual prevalence of handguns in Quebec may be substantially greater than is indicated by the Canadian survey.

After these considerations have been taken into account, then, the handgun surveys by state and province demonstrate with adequate reliability and validity that the prevalence of handguns in US border states is 3 to 10 times greater than that in adjoining Canadian provinces. The true variations in prevalence are undoubtedly somewhat different from those conveyed in table 2, but the three- to tenfold difference in prevalence across the border cannot be explained away as statistical artifact (with the possible exception of Quebec vs. Vermont).

Are Canadians more willing to use handguns?

A handgun homicide requires 1) a dangerously violent incident, 2) possession of a handgun, and 3) willingness to use the handgun. As with cultural variations in the means of suicide, it cannot be presumed that Canadians and Americans have an equal willingness to use handguns in homicides. Thus, if Canadians are peculiarly avid to use such handguns as are available to them or, conversely, Americans in US border states are peculiarly unwilling to use handguns in homicides, the similarity of homicide rates observed across the border (table 4) may simply reflect equivalent rates of handgun homicides, despite gross differences in the prevalence of handguns (table 2). However, rates of handgun homicide are not equivalent in Canadian provinces and adjoining US states (table 5)—again, with the exception of Quebec.

Are Canadians more prone to violence?

Criminal homicides may be considered a subset of aggravated assaults—the lethal subset. Conversely, aggravated assaults may be regarded as dangerously violent incidents that could have ended in homicide, but didn't. It follows that a society with a high incidence of assault and a low prevalence of handguns can have the same homicide rate as a society with a low incidence of assault and a high prevalence of handguns, provided handgun prevalence influences the probability that an assault will end in homicide. Thus, if, as compared with US border states, Canadian provinces have a lower prevalence of handguns (which they do) *and* a higher incidence of assaults, then the two effects may cancel each other out, resulting in Canadian homicide rates similar to those in adjoining US border states.

However, as with criminal homicides, the mean annual rate of aggravated assault in the Canadian provinces from 1976 to 1980 was approximately the same as in the adjoining US states (table 6). No consistent differences were observed. Tables 4 and 6 suggest that variations in rates of criminal homicide along the US-Canadian border primarily reflect similar underlying variations in rates of aggravated assault. The correspondence is less than perfect, which is to be expected; in contrast to criminal homicides, only about half of all aggravated assaults are reported to the police (26). When the assumption that handgun prevalence influences the probability that an assault will end in homicide is tested, the number of homicides per 100 aggravated assaults does not differ consistently between Canadian provinces and adjoining US states (table 7).

It should be noted that aggravated assault—with or without a lethal outcome—is the final common pathway of the multifactorial processes leading to dangerous violence in a society. Therefore, even without an actual delineation of those processes, two societies with equal rates of aggravated as-

sault are, by definition, equally prone to incidents of dangerous violence. Thus, the populations in the Canadian provinces and adjoining US states are indeed equally prone to incidents of dangerous violence (table 6).

It may be argued that handgun prevalence in the general population has no effect upon homicide rates, because the small subset of the population that commits homicide will gain access to handguns regardless of how scarce or common they may be in the general population. However, if this actually accounted for the parity of homicide rates in Canadian provinces and adjoining US states, there would also be a parity of handgun homicide rates, which is not the case (table 5).

Are there confounding variables?

For the analysis as a whole, no attempt has been made to control for age, sex, race, or urban status. The underlying assumption has been that populations living in Canadian provinces are sufficiently similar to populations living in adjoining US states that there is no general need to control for such variables. If this assumption is incorrect, however, controlling for such confounding variables might increase the relative risk of homicide in US border states—as compared with adjoining Canadian provinces—leading to the conclusion that the higher prevalence of handguns in US border states is indeed associated with higher rates of criminal homicide. If, on the other hand, controlling for such confounding variables decreases the relative risk, or leaves it unchanged, then the original conclusion stands, namely, that major differences in handgun prevalence are not associated with differences in rates of criminal homicide.

The most extensive control for confounding variables has been performed by Sloan et al. (6). For the years 1980 to 1986, the mean annual rate of criminal homicide in the state of Washington was 5.0 homicides per 100,000 population (9). In the adjoining province of British Columbia, the mean annual rate of criminal homicide was 3.8 homicides per 100,000 population (27). Thus, the relative risk of criminal homicide in Washington as compared with British Columbia was 1.3. After adjusting for age, sex, race, ethnicity, and urban status—i.e., by confining the comparison to non-Hispanic whites living in Seattle and Vancouver—the relative risk of criminal homicide was 1.0 (6).

In the present analysis, some rough controls can be made for urban status. For example, there are no major cities in either the province of New Brunswick or the adjoining state of Maine (figure 1). For 1976 to 1980, the mean annual rate of criminal homicide was 2.7 per 100,000 population in Maine and 2.9 in New Brunswick (table 4), or a relative risk of 0.9. Again, it was observed that there are no urban populations in Canada comparable to those of New York City and Detroit. Therefore, New York City and Detroit were excluded when the homicide rates for Michigan and New York were compared with those of Ontario (Toronto was also excluded from the analysis). Doing so reduced the relative risk of criminal homicide from 5.0 to 2.0 (table 4).

In each instance, then, controlling for potential confounding variables actually strengthens the original conclusion rather than weakening it. It is unlikely that the analysis is adversely confounded by demographic factors.

Another potential confounding variable is the prevalence of firearms other than handguns. If there are many more rifles and shotguns per 1,000 population in the Canadian provinces than in adjoining US states, this may effectively compensate for the relative dearth of handguns in Canada, thereby leading to a spurious conclusion about handguns and homicide rates. However, the prevalence of rifles and shotguns is similar in Canadian provinces and adjoining US states (table 3), so rifles and shotguns are unlikely to confound the analysis.

Are the findings confounded by underlying differences in culture? As previously noted, aggravated assault is the final common pathway for all processes leading to incidents of dangerous violence in a society. Therefore, it can be observed empirically

that populations in Canadian provinces and adjoining US states have equivalent propensities for dangerously violent incidents (table 6), even if the specific underlying cultural processes differ somewhat. Therefore, confounding by cultural differences is unlikely. In conclusion, the findings of this analysis are unlikely to be invalidated by confounding.

Is there an ecologic fallacy?

Let us first review the basics (28). Epidemiology normally seeks to determine the association between exposure variables (x) and disease outcomes (y) at the level of the individual (i). In ecologic analysis, individuals are aggregated into groups wherein the association between x and y is unknown at the level of the individual. Instead, the unit of analysis is the group (j), wherein the independent variable (X) is the proportion of exposed subjects (or mean exposure) within each group and the dependent variable (Y) is the rate of disease within each group (29). The ecologic fallacy occurs when the unwary investigator infers that the unobserved regression of y_{ij} on x_{ij} at the individual level is the same as the observed regression of Y_j on X_j at the group level, that is

$$y_{ij} \mid x_{ij} = Y_j \mid X_j.$$

As is demonstrated by Robinson (30), this is generally incorrect, often badly so.

As is further demonstrated by Firebaugh (31), aggregated data analysis avoids the ecologic fallacy if, and only if, the group exposure (X_j) has no effect on disease risk (y_{ij}) at the individual level, controlling for the individual's exposure value (x_{ij}), where

$$y_{ij} = a + \beta_1 x_{ij} + \beta_2 X_j + \epsilon$$
$$(i = 1,2\ldots n; j = 1,2\ldots m).$$

However, ascertainment of such a condition requires knowledge of x_{ij} and y_{ij} that, if known, would eliminate the perceived need to work with aggregated data in the first place. If, however, the group exposure (X_j) is the same as each individual exposure (x_{ij}), that is, $x_{ij} = X_j$, then X_j will have no independent effect upon y_{ij}, controlling for x_{ij}. In other words, the analysis of grouped data avoids the ecologic fallacy, provided that individuals are aggregated into homogeneous groups wherein each individual has the same exposure to the risk factor as does the group as a whole. For example, the efficacy of a state's helmet use law in preventing deaths and head injuries can be studied using ecologic data because the law not only applies to the state but equally to each individual within the state; it is not necessary to conduct household surveys to determine who is exposed to the law, since we know that the law applies to everyone.

In Canada, handguns have been strictly regulated for almost a century, with registration of all handguns required by national law since 1934 (32). There is no such national law in the United States, although such a law will be necessary if the United States is to ever reduce its handgun prevalence to Canadian levels (4). For this reason, as regards exposure to national handgun control laws, comparisons between Canada and the United States do not entail an ecologic fallacy because each individual's exposure to the law (or its absence) is known implicitly from what is known about each country as a whole. Thus, we can study the effect of national handgun control upon the prevalence of handguns and, in turn, the homicide rate. Since the unit of analysis is ultimately the individual, the present study compares (in 1976, the baseline year) 21,445,000 Canadians living in provinces adjoining the United States (20) and 39,742,000 Americans living in states adjoining Canada (1), for a total (n) of 61,187,000.

CONCLUSIONS

After detailed consideration of possible alternative explanations, it appears that, for the data presented in this analysis, the plain conclusion is the correct conclusion: When Canadian provinces and adjoining US states are compared, three- to tenfold differences in the prevalence of handguns have not resulted in consistently different rates of crim-

inal homicide. In the relative absence of handguns, dangerously violent Canadians commit their assaults using other means which are, on the average, as lethal as handguns.

That Canada and the United States have the same annual rate of handgun homicides per 10,000 privately owned handguns might suggest that reducing the prevalence of handguns in the United States would lead to a reduction in the homicide rate. However, this attractive proposition is true if, and only if, equally lethal means are not substituted for the absent handguns. The completeness with which Canadians have indeed substituted such means indicates that the proposition is untenable.

How generalizable are these results? The transcontinental scope of the analysis indicates that they apply to a substantial array of geographic and cultural settings—from Maine to Alaska, from New Brunswick to the Yukon (figure 1). Although most of the comparisons lie between populations with comparatively low homicide rates, the highest homicide rate of any state or province was in the Yukon (figure 1); however, only 2 percent of the criminal homicides in the Yukon and Northwest Territories were committed with handguns (10), as compared with 41 percent of the criminal homicides in Alaska (US Federal Bureau of Investigation, unpublished data). Therefore, the findings appear to apply to regions with high homicide rates as well as to regions with low homicide rates. Likewise, Sloan et al. (6) have demonstrated that the findings apply not only to rural populations, but to appropriately matched metropolitan populations as well.

It has been recently stated by Sproule and Kennett that, "in a clear demonstration of the benefits of Canadian gun control," US homicide rates are much higher than Canadian homicide rates (33, p. 249). However, their conclusion is based solely upon comparisons of the national homicide rates, without regard to regional variations (figure 1). The present analysis makes a more appropriate comparison between Canadian provinces and adjoining US states.

In its *Promoting Health/Preventing Disease: Objectives for the Nation*, the US Public Health Service has recommended that the number of handguns in private ownership be reduced by 25 percent, to reduce homicide rates (34). However, major differences in handgun prevalence have not resulted in consistently different homicide rates in Canadian provinces and adjoining US states. Homicide rates along the US-Canadian border (table 4) primarily reflect underlying rates of aggravated assault (table 6), and Canadians are as assaultive as their US neighbors. Canadians fully compensate for the relative dearth of handguns in Canada by effectively utilizing other means for killing one another. It can be presumed that Americans would be no less resourceful under comparable circumstances. As regards homicide rates, it can be inferred that major efforts to reduce handgun prevalence in the United States would be of doubtful utility, even if successful.

REFERENCES

1. National Center for Health Statistics. Vital statistics of the United States. Hyattsville, MD: US Department of Health and Human Services, 1960–1980.
2. Bruce-Briggs B. The great American gun war. The Public Interest 1976;45:37–62.
3. Cook PJ. The role of firearms in violent crime: an interpretive review of the literature. In: Wolfgang ME, Weiner NA, eds. Criminal violence. Beverly Hills, CA: Sage Publications, Inc., 1982:236–91.
4. Wright JD, Rossi PH, Daly K. Under the gun: weapons, crime and violence in America. New York, NY: Aldine Publishing Company, 1983.
5. Kleck G. The relationship between gun ownership levels and rates of violence in the United States. In: Kates D, ed. Firearms and violence: issues of public policy. Cambridge, MA: Ballinger Publishing Company, 1984:99–135.
6. Sloan JH, Kellermann AL, Reay DT, et al. Handgun regulations, crime, assaults, and homicide: a tale of two cities. N Engl J Med 1988;319:1256–62.
7. Blackman PH, Stolinsky DC, Gryder JW. Handgun regulations, crime, assaults, and homicide: a tale of two cities. (Letter). N Engl J Med 1989;320:1214–16.
8. Armitage P, Berry G. Statistical methods in medical research. 2nd ed. Oxford, England: Blackwell, 1987.
9. US Federal Bureau of Investigation. Uniform crime reports for the United States. Washington, DC: US GPO, 1976–1986.

10. Canadian Centre for Justice Statistics. Homicide statistics, 1980. Ottawa, Canada: Statistics Canada, 1982.
11. Canadian Centre for Justice Statistics. Crime and traffic enforcement statistics. Ottawa, Canada: Statistics Canada, 1976–1980.
12. Stenning PC, Moyer S. Firearms ownership and use in Canada: a report of survey findings, 1976. Toronto, Canada: University of Toronto, 1981.
13. US Bureau of the Census. 1980 census of the population: Volume 1. Characteristics of the population. Washington, DC: US GPO, 1981.
14. US Bureau of the Census. 1980 census of housing: Volume 1. Characteristics of housing units. Washington, DC: US GPO, 1982.
15. Statistics Canada. 1981 census of Canada: population. Ottawa, Canada: Statistics Canada, 1984.
16. Statistics Canada. 1981 census of Canada: occupied private dwellings. Ottawa, Canada: Statistics Canada, 1983.
17. Centerwall BS. Race, socioeconomic status, and domestic homicide, Atlanta, 1971–72. Am J Public Health 1984;74:813–15.
18. Moyer LA, Boyle CA, Pollock DA. Validity of death certificates for injury-related causes of death. Am J Epidemiol 1989;130:1024–32.
19. Zahn MA, Riedel M. National versus local data sources in the study of homicide: do they agree? In: Waldo GP, ed. Measurement issues in criminal justice. Newbury Park, CA: Sage Publications, 1983:103–20.
20. Leacy FH, ed. Historical statistics of Canada. 2nd ed. Ottawa, Canada: Statistics Canada, 1983.
21. Dominion Bureau of Statistics. Vital statistics. Ottawa, Canada: Queen's Printer and Controller of Stationery, 1950–1962.
22. World Health Organization. World health statistics annual. Geneva, Switzerland: World Health Organization, 1960–1980.
23. Cantor D, Cohen LE. Comparing measures of homicide trends: methodological and substantive differences in the Vital Statistics and Uniform Crime Report time series (1933–1975). Soc Sci Res 1980;9:121–45.
24. Kellermann AL, Rivara FP, Banton J, et al. Validating survey responses to questions about gun ownership among owners of registered handguns. Am J Epidemiol 1990;131:1080–4.
25. Bothwell R, Drummond I, English J. Canada since 1945. Toronto, Canada: University of Toronto Press, 1981.
26. National Criminal Justice Information and Statistics Service. Criminal victimization in the United States. Washington, DC: US GPO, 1976–1980.
27. Canadian Centre for Justice Statistics. Homicide in Canada, 1986: a statistical perspective. Ottawa, Canada: Statistics Canada, 1987.
28. Centerwall BS. Exposure to television as a risk factor for violence. Am J Epidemiol 1989;129:643–52.
29. Morgenstern H. Uses of ecologic analysis in epidemiologic research. Am J Public Health 1982;72:1336–44.
30. Robinson WS. Ecological correlations and the behavior of individuals. Am Sociol Rev 1950;15:351–7.
31. Firebaugh G. A rule for inferring individual-level relationships from aggregate data. Am Sociol Rev 1978;43:557–72.
32. Friedland ML. Gun control: the options. Criminal Law Q 1976;18:29–71.
33. Sproule CF, Kennett DJ. Killing with guns in the USA and Canada 1977–1983: further evidence for the effectiveness of gun control. Can J Criminol 1989;31:245–51.
34. US Public Health Service. Promoting health/preventing disease: objectives for the nation. Washington, DC: US GPO, 1980.