RESEARCH REPORT

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Alcohol-attributable mortality and potential years of life lost in Canada 2001: implications for prevention and policy

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ABSTRACT

Background Alcohol is one of the most important risk factors for burden of disease. **Objective** To estimate the number of deaths and the years of life lost attributable to alcohol for Canada 2001 using different ways to measure alcohol exposure. **Methods** Distribution of exposure was taken from a major national survey of Canada, the Canadian Addiction Survey, and corrected for per capita consumption from production and sales. For chronic disease, risk relations were taken from the published literature and combined with exposure to calculate age- and sex-specific alcohol-attributable fractions (AAFs). For injury, AAFs were taken directly from available statistics. Information on mortality, with cause of death coded according to the International Classification of Diseases version 10 (ICD-10) was obtained from Statistics Canada. **Results** For Canada in 2001, 4010 of all deaths in the group below 70 years of age were attributable to alcohol, 3132 in men and 877 in women. This constituted 6.0% of all deaths in Canada in this age group, 7.6% for men, and 3.5% for women. The 4010 deaths are a net figure, already taking into account the deaths prevented by moderate consumption of alcohol. Main causes of alcohol-attributable death were unintentional injuries, malignant neoplasms and digestive diseases. Ischaemic heart disease (IHD) was the biggest cause of death prevented by alcohol, with 78.7% of all alcohol-attributable prevented deaths in the age groups of 70 years and above. A total of 144 143 years of life were lost prematurely in Canada in that year, 113 079 years in men and 31 063 years in women. **Discussion** Regardless of the assumptions made, alcohol is a major contributor to mortality in Canada. The impact of alcohol on social life is not confined to mortality, as other studies indicated that alcohol is linked even more strongly to disability and social harm. Alcohol-attributable harm could be substantially reduced, however, if known effective policies were introduced.

Keywords Alcohol-attributable fraction (AAF), alcohol consumption, Canada, mortality, potential years of life lost (PYLL), relative risk (RR).

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INTRODUCTION

Alcohol is accountable for high levels of mortality, morbidity and social problems. More than 60 causes of death have been attributed to alcohol consumption (Schultz *et al.* 1991; Corrao *et al.* 1999; Rehm *et al.* 2003a,b). Results from studies investigating deaths attributable to alcohol vary by country and methodology (e.g. Schultz *et al.* 1990; English *et al.* 1995; Single *et al.* 2000; Britton *et al.* 2003; Centers for Disease Control & Prevention 2004; White *et al.* 2004).

From a public health perspective, alcohol consumption has been shown to have adverse consequences, such as various cancers, hypertension, cirrhosis of the liver, pancreatitis, alcohol dependence, accidents and violence (English *et al.* 1995; Rehm *et al.* 2003a, 2004). On the other hand, when consumed in moderation, there was evidence of a decreased risk of ischaemic heart disease (IHD) (Doll *et al.* 1994; Klatsky 1994; Chick 1998; Puddey *et al.* 1999; Rehm *et al.* 2003c). In addition, according to current epidemiological standards, there has been some evidence of a protective effect of moderate consump-

tion on ischaemic stroke, diabetes, cholethiasis or gallstones (Ashley *et al.* 2000). For other conditions such as peripheral vascular disease, cognitive functioning (Eckardt *et al.* 1998; Chick 1999), stress reduction (Baum-Baicker 1985; Hauge & Irgens-Jensen 1990), mood elevation (Pohorecky 1991; Castaneda *et al.* 1996, 1998) and other subjective psychosocial effects, the evidence was neither consistent nor conclusive (Ashley *et al.* 2000).

All-cause mortality as a summary measure thus has a *J*-shaped relationship with alcohol consumption, at least for people older than 40 years of age, when the main protective effects of alcohol on IHD become evident (English *et al.* 1995; Rehm & Bondy 1998; Rehm *et al.* 2001a; Gmel *et al.* 2003a; White *et al.* 2004). This *J*-shaped relationship indicates that low to moderate drinkers have a lower mortality risk compared to the abstainers, whereas the mortality risk for highest level drinkers is higher than that of both moderate drinkers and abstainers.

The exact shape of the curve depends on the underlying mix of causes of death and the patterns of drinking (Rehm *et al.* 2004). Thus, the relationship between consumption and all-cause mortality cannot be used to derive precise estimates of alcohol-attributable mortality. Instead a disease-specific approach is necessary. The current paper uses such a disease-specific approach to estimate the number of deaths and potential years of life lost for Canada in 2001.

METHODS

The aim of the present study was to estimate the proportion of deaths 'caused' or 'prevented' by alcohol and premature deaths in Canada for the year 2001. In the following paragraphs, three elements necessary for this estimate are described: measurement of exposure, determination of risk relationships and attributable fractions and outcome information.

Prevalence of alcohol consumption in Canada

To measure alcohol consumption, we followed the approach of English *et al.* (1995) and used four drinking categories based on average volume of alcohol consumed (see Table 1 for definition). These specific drinking categories have been used, because most meta-analyses give results based on these categories (see Rehm *et al.* 2003a; for an overview of meta-analyses).

The prevalence data of different levels of current alcohol consumption were collected between 2003 and 2004 through the Canadian Addiction Survey (CAS) (Canadian Centre on Substance Abuse 2004). This survey was selected because it collected good alcohol consumption exposure data which are temporally closest to the mortality data. As alcohol consumption has been relatively stable in Canada over the past years, the difference of 2–

Table 1 Prevalence of alcohol consumption in Canada 2003/2004† according to age, sex and drinking category.

Drinking categories	*Overall (all ages)*	*15–29 years*	*30–44 years*	*45–59 years*	*60–69 years*	*70–79 years*	*80+ years*
Abstention and very light drinking*							
Female	66.9	59.0	62.1	65.3	68.4	70.5	72.6
Male	40.4	30.2	35.1	40.0	45.0	48.3	51.5
Drinking category I*							
Female	24.9	34.8	31.0	27.1	23.2	20.7	18.1
Male	46.8	51.6	48.6	45.5	42.4	40.4	38.3
Drinking category II*							
Female	6.3	3.2	4.3	5.5	6.6	7.4	8.2
Male	6.5	8.7	8.2	7.6	7.1	6.7	6.4
Drinking category III*							
Female	1.9	3.0	2.6	2.2	1.8	1.5	1.1
Male	6.3	9.4	8.1	6.8	5.5	4.6	3.8
Total	100	100	100	100	100	100	100

Drinking categories	*Females*	*Males*
Abstainer or very light drinker	0–< 0.25 g/day	0–< 0.25 g/day
Drinking category I	0.25–< 20 g/day	0.25–< 40 g/day
Drinking category II	20–< 40 g/day	40–< 60 g/day
Drinking category III	40+ g/day	60+ g/day

†Average volume of alcohol consumption has been based on a smoothed quantity frequency measure derived from the Canadian Addiction Survey, corrected for per capita consumption. For further explanations of this measure please see text. *The drinking categories were based on the following definitions (see National Health and Medical Research Council, Australia 1992; English *et al.* 1995)

3 years between mortality and exposure data seems to be negligible.

The CAS was based on a regionally stratified two-stage (telephone household, respondent) random sample. The survey used random-digit-dialling methods via computer assisted telephone interviewing. The sampling frame was based on an electronic inventory (Statplus) of all active telephone area codes and exchanges in Canada. Within selected households, one respondent aged 15 years or older who could complete the interview in English or French was selected according to the most recent birthday of household members. The selected individuals were interviewed by professional interviewers using a structured questionnaire. The sample was drawn randomly from the whole of Canada taking into consideration age, sex and region to avoid sample bias. This survey had a sample size of 13 909 men and women, and a 47% response rate for individuals. It was decided to use this survey despite the relatively low response rate because it had the necessary exposure measures for the intended calculations, large sample size to allow provincial calculations and closest temporal proximity to the mortality data. In addition, it has been shown that higher response rates in surveys did not essentially change the results with respect to the distribution of alcohol consumption (Gmel & Rehm 2004). To strengthen the confidence in these data and to ensure that characteristics of CAS sample are similar to the Canadian population, this sample was weighted to correspond to the age and sex distribution of the Canadian population.

Different measures for alcohol exposure were used, including a quantity frequency (QF) measure, where usual frequency and usual quantity per drinking occasion were asked in separate questions and then combined to derive overall volume. A 7-day protocol was also used where, starting with the day before the survey, consumption of each of the past 7 days was asked (for further explanation see Gmel & Rehm 2004). As QF is a more reliable measure to indicate individual volume (Gmel & Rehm 2004), we used this measure for our main scenario, and the 7-day protocol as one of the sensitivity analyses. Sensitivity analyses were conducted as it has been shown clearly that method of assessment has an important impact on estimated alcohol-attributable mortality and other harm (Rehm *et al.* 1999).

For per capita consumption (for a definition see Rehm *et al.* 2003d), numbers were taken from the Global Alcohol Database (http://www3.who.int/whosis). As the CAS accounted for only 30% and 40% of the per capita consumption (including unrecorded consumption), depending on which measure was used, we scaled the two highest alcohol consumption categories of the QF upwards in our main scenario by the factor of underreporting for QF. In other words, we multiplied the age and sex-specific prevalence rates by 2.7 to reflect the true per capita consumption based on the coverage rate of 36.6% or the QF. Per capita consumption, when including unrecorded consumption, is usually considered as the best measure for overall consumption in a country (Gmel & Rehm 2004). Of course, this measure has the disadvantage that it cannot give any indication of sex- or age-distributions of drinking (Rehm *et al.* 2003d).

Computing alcohol-attributable deaths

The alcohol-attributable fraction (AAF) is generally defined as the proportion of the disease in the population that will disappear if alcohol is removed (Walter 1976, 1980). Since alcohol may 'cause' or 'prevent' deaths, the AAF can be positive or negative. AAFs were assessed for different specific causes of natural and unnatural deaths by two methods:

- AAFs for chronic disease were calculated by combining exposure and relative risk estimates from meta-analyses. Relative risk here denotes the ratio of the probability of developing, in a specified period of time, a disease among those exposed to alcohol, compared with the probability of developing this disease for abstainers.
- AAFs for injuries were based on direct estimates of alcohol involvement where available for Canada (traffic accidents; fire); and for other types of injury were based on results from the America A region derived by the comparative risk analysis of the Global Burden of Disease study (Rehm *et al.* 2004; for details of calculation see below).

For chronic disease conditions, the AAFs were calculated from alcohol exposure prevalence proportions in Canada and the pooled relative risks for the diseases from the update of comprehensive meta-analyses. We used the most comprehensive meta-analysis for each condition, as indicated in Table 2 (see Rehm *et al.* 2003a for an overview). 'Most comprehensive' was determined by the meta-analysis with the greatest number of unique studies included. Other selection criteria included whether the methodologies were comparable and fulfilled the following standards: clear and explicit criteria for selection of studies, outcome exactly defined as needed for our study, control for and reporting of heterogeneity, exposure defined in terms of average volume of drinking and exclusion of studies not based on general population. As many of the meta-analyses were based on prior meta-analyses for the same disease conditions and had merely added the newly published literature, this identification was often easy (e.g. Gutjahr *et al.* 2001 where most of the analyses were based on the previous works of English *et al.* 1995 and Single *et al.* 1996). Where meta-analyses used other drinking categories than the ones used here, we interpolated the respective regression coefficients

Table 2 Alcohol-related disease categories and sources for determining risk relations including alcohol-attributable fractions (AAFs).

Condition	*ICD-10 code*	*Source for meta-analysis or AAF*
Malignant neoplasms		
Mouth and oropharynx cancers	C00–C14	Gutjahr *et al.* (2001)
Oesophageal cancer	C15	Gutjahr *et al.* (2001)
Liver cancer	C22	Gutjahr *et al.* (2001)
Laryngeal cancer	C32	Gutjahr *et al.* (2001)
Breast cancer	C50	Ridolfo & Stevenson (2001)
Other neoplasms	D00-D48	Rehm *et al.* (2004)
Diabetes		
Diabetes mellitus	E10–E14	Gutjahr *et al.* (2001)
Neuro-psychiatric conditions		
Alcoholic psychoses	F10.0, F10.3–F10.9	100% AAF per definition
Alcohol abuse	F10.1	100% AAF per definition
Alcohol dependence syndrome	F10.2	100% AAF per definition
Unipolar major depression	F32–F33	Rehm *et al.* (2004)
Degeneration of nervous system due to alcohol	G31.2	100% AAF per definition
Epilepsy	G40–G41	Gutjahr *et al.* (2001)
Alcoholic polyneuropathy	G62.1	100% AAF per definition
Cardiovascular diseases		
Hypertensive disease	I10–I15	Corrao *et al.* (1999)
Ischaemic heart disease	I20–I25	Corrao *et al.* (2000); Rehm *et al.* (2004)
Alcoholic cardiomyopathy	I42.6	100% AAF per definition
Cardiac arrhythmias	I47–I49	Gutjahr *et al.* (2001)
Heart failure and ill-defined complications of heart disease	I50–I52, I23, I25.0, I97.0, I97.1, I98.1	This is an unspecific category with no identification of underlying pathology. Therefore, the relationship between average volume of consumption cannot be determined by usual meta-analysis
Cerebrovascular disease	I60–I69	
Ischaemic stroke	I60–I62	Reynolds *et al.* (2003)
Haemorrhagic stroke	I63–I66	Reynolds *et al.* (2003)
Oesophageal varices	I85	Gutjahr *et al.* (2001)
Digestive diseases		
Alcoholic gastritis	K29.2	100% AAF per definition
Cirrhosis of the liver	K70, K74	Rehm *et al.* (2004)
Cholelithiasis	K80	Gutjahr *et al.* (2001)
Acute and chronic pancreatitis	K85, K86.1	Corrao *et al.* (1999)
Chronic pancreatitis (alcohol-induced)	K86.0	100% AAF per definition
Skin diseases		
Psoriasis	L40	Gutjahr *et al.* (2001)
Conditions arising during the perinatal period		
Low birth weight: as defined by the global burden of disease study*	P05–P07	Gutjahr *et al.* (2001)
Fetal alcohol syndrome (dysmorphic)	Q86.0	100% AAF per definition
Excess alcohol blood level	R78.0	100% AAF per definition
Unintentional injuries		
Motor vehicle accidents	§ (see footnote)	Traffic Injury Research Foundation of Canada 2004; Transport Canada (2004)
Poisonings	X40–X49	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Falls	W00–W19	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Fires	X00–X09	Council of Canadian Fire Marshals and Fire Commissioners (2003)

Table 2 *Cont.*

Condition	*ICD-10 code*	*Source for meta-analysis or AAF*
Accidental poisoning and exposure to alcohol	X45	100% AAF per definition
Drowning	W65-W74	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Other unintentional injuries	†Rest of V & W20–W64, W75–W99, X10–X39, X50–X59, Y40–Y86, Y88, Y89	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Intentional injuries		
Self-inflicted injuries	X60–X84, Y87.0	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Intentional self-poisoning by and exposure to alcohol	X65	100% AAF per definition
Homicide	X85–Y09, Y87.1	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Other intentional injuries	Y35	Rehm *et al.* (2004); adjusted to Canada by AAF for traffic accidents
Ethanol and methanol toxicity, undetermined intent	Y15	100% AAF per definition

*Relative risk refers to drinking of mothers. §V021–V029, V031–V039, V041–V049, V092, V093, V123–V129, V133–V139, V143–V149, V194–V196, V203–V209, V213–V219, V223–V229, V233–V239, V243–V249,V253–V259, V263–V269, V273–V279, V283–V289, V294–V299, V304–V309, V314–V319, V324–V329, V334–V339, V344–V349, V354–V359, V364–V369, V374–V379, V384–V389, V394–V399, V404–V409, V414–V419, V424–V429, V434–V439, V444–V449, V454–V459, V464–V469, V474–V479, V484–V489, V494–V499, V504–V509, V514–V519, V524–V529, V534–V539, V544–V549, V554–V559, V564–V569, V574–V579, V584–V589, V594–V599, V604–V609, V614–V619, V624–V629, V634–V639, V644–V649, V654–V659, V664–V669, V674–V679, V684–V689, V694–V699, V704–V709, V714–V719, V724–V729, V734–V739, V744–V749, V754–V759, V764–V769, V774–V779, V784–V789, V794–V799, V803–V805, V811, V821, V830–V833, V840–V843, V850–V853, V860–V863, V870–V878, V892. †Rest of V = V-series MINUS §.

to the midpoints of our drinking categories (for definition of drinking categories see Table 1).

The relative risk for each condition was combined with different levels of alcohol consumption for each sex and age group and an attributable fraction was obtained using the following formula (see Walter 1976, 1980), which uses no consumption at all as counterfactual scenario (see Rehm *et al.* 2001b; Murray *et al.* 2003; for a discussion of this choice).

$$AAF = [\Sigma^{k}_{i=1} P_i(RR_i - 1)]/[\Sigma^{k}_{i=0} P_i(RR_i - 1) + 1]$$

where *i*: exposure category with baseline exposure or no alcohol $i = 0$; RR_i: relative risk at exposure level *i* compared to no consumption; P_i: prevalence of the i*th* category of exposure.

The AAFs were then applied to the mortality data to estimate the number of alcohol attributed deaths by age and sex.

For injuries, a different approach had to be adopted because injuries are usually more determined by patterns of excessive per occasion drinking than by average volume of alcohol consumption (see Rehm *et al.* 2003a, 2004). Thus we looked for injury statistics that would include the blood alcohol level in the event. This was available for the traffic sector, where statistics exist in Canada to explicitly account for blood alcohol concentration (BAC; Traffic Injury Research Foundation of Canada 2004; Transport Canada 2004). To determine causality of alcohol, we used the criterion of BAC larger than 100 mg/dl (see also Smith *et al.* 1999). This does exclude all injury with involvement of alcohol at lower levels of BAC. As alcohol influences psychomotor ability at much lower levels (Eckardt *et al.* 1998), the criterion can be seen as conservative.

For injury categories, where we had no Canadian studies (e.g. falls), we based AAFs on the age and sex-specific values of the America A region of the Comparative Risk Analysis (CRA) of the Global Burden of Disease study (Rehm *et al.* 2004). The CRA America A region consisted of population weighted estimates for Canada, Cuba and the United States combined, which were heavily based on US studies (especially Smith *et al.* 1999). These estimates were scaled differences between CRA and Canadian data for motor vehicle accidents: if, for example, the Canadian prevalence rates were 8% lower for motor vehicle accidents in a sex–age category, this ratio (0.92) was transferred to decrease the AAF for other injury types without specific Canadian data; if they

were higher, the AAFs for other injury types were increased accordingly.

Mortality data

Mortality data in Canada for the year 2001, with the underlying cause coded according to the International Classification of Diseases version 10 (ICD-10), were obtained from Statistics Canada. Table 2 gives an overview of the disease conditions extracted by sex and age groups; 2001 was selected because it was the last year available.

Potential years of life lost

Potential years of life lost (PYLL) is an indicator of premature mortality. People dying due to alcohol consumption would have lived longer if they had not drunk alcohol. The average extra time such individuals would have lived is known as the residual life expectancy. For example, if a male died of alcoholic liver cirrhosis at age 50, in Canada he would have a residual life expectancy of 28.4 years (WHO Statistical Information System 2000). The sum of these extra times for all people dying from alcohol consumption is known as PYLL due to alcohol. PYLL for each sex–age group category can be estimated from the observed mean age at death in the age interval and the standard life expectancies tables at the exact ages defining the age interval through interpolation. The standard life expectancies table for Canada mortality in 2000 is available from the World Health Organization (WHO) website (http://www.who.int/evidence). In calculating the mean ages within the intervals, the rules specified by the Global Burden of Disease study have been followed (Mathers *et al.* 2001). PYLL due to death in Canada has been calculated for each age group (0–14, 15–29, 30–44, 45–59, 60–69, 70–79 and 80 + years) by multiplying the number of deaths by the interpolated life expectancy for the observed mean age at death in the interval. Mean age for the 80 + age groups for men (84 years) and women (85 years) were calculated from the life expectancy table. The upper age limit of 76.0 years for males and 81.5 years for females was used to approximate the life expectancy of Canadians for both sexes at birth. PYLL were calculated per population of 100 000.

Sensitivity analyses

Different measures of alcohol exposure were used as a basis to estimate alcohol-attributable mortality and PYLL:

- the 7-day-consumption protocol;
- the usual QF measure, as indicated by the respondents;
- a smoothed QF, where abrupt changes in prevalence of different drinking level categories between adjacent age groups were smoothed on the basis of the overall linear age distribution of volume of drinking; and
- a smoothed QF adjusted in a way that the overall volume in Canada corresponded to the per capita consumption, including unrecorded consumption.

As the last measure corresponded to the best estimate of overall consumption in Canada, it was considered the main measure of alcohol exposure.

RESULTS

Table 1 gives an overview of the estimated volume of alcohol exposure in Canada by sex and age group. As expected, men consumed on average more than women, and alcohol consumption decreased with age.

Table 3 provides the estimates of alcohol-attributable deaths and deaths prevented by alcohol consumption. Overall, in Canada for 2001, 3892 alcohol-attributable deaths were estimated accounting for 3313 deaths among men and 579 among women. Please note that these numbers were derived by multiplying AAFs with number of deaths for each category, thereby producing numbers with decimals. As a result, there may be rounding errors after collapsing numbers over different categories.

The 3892 alcohol-attributable deaths constituted 1.8% of all Canadian deaths. These were net figures, i.e. they included estimates of deaths prevented by alcohol. Overall, there were 7597 deaths attributable to alcohol and 3705 deaths prevented by alcohol, calculated using the same epidemiological procedure described above. Most of the estimated deaths prevented by alcohol were from IHD (3010 deaths). Overall, most of these statistically calculated 'prevented' deaths occur after age 70 (78.7% of all prevented deaths). There is some doubt as to whether the meta-analytically derived AAFs both for deaths caused and for preventive deaths really apply to this age group, as relative risks tend to converge to 1 with age. Thus, we additionally present the figures of alcohol-attributable mortality for the age-group under 70 years. In this age group, 4010 of all deaths in Canada 2001 were attributed to alcohol, accounting for 3132 men and 877 women. This represented 6.0% of all Canadian deaths in this age-group.

Among deaths caused by alcohol, the three biggest contributors were unintentional injuries, malignant neoplasms and digestive diseases (see Table 3). With respect to single disease categories, cirrhosis of the liver (1203 deaths, 854 males; 349 females), motor vehicle accidents (801 deaths, 662 males; 138 females), suicides/self-inflicted injuries (619 deaths, 507 males; 113 females), oesophageal cancer (467 deaths, 383 males; 84 females) and cardiac arrhythmias (412 deaths, 218 males; 194

Table 3 Alcohol-attributable fractions, mean age at death and alcohol related mortality based on smoothed quantity frequency measure adjusted for per capita consumption for major disease categories in Canada 2001.

	AAF% (all ages)		*Mean age at death*		*Number of deaths*															
					0–14 years		*15–29 years*		*30–44 years*		*45–59 years*		*60–69 years*		*70–79 years*		*80+ years*		*Total*		
Condition	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*Overall*
Malignant neoplasms																					
Mouth and oropharynx cancers	32.7	18.5	64.8	70.5			1	0	12	3	67	8	66	11	58	15	32	18	237	56	293
Oesophageal cancers	37.7	24.2	67.3	73.8			0	0	12	2	90	10	104	17	117	23	60	32	383	84	467
Liver cancer	31.7	22.0	67.1	73.0			1	0	13	2	56	14	85	22	89	39	41	36	285	111	397
Laryngeal cancer	42.8	31.0	68.4	70.5			0	0	4	0	32	4	58	7	60	7	28	5	181	23	204
Breast cancer	–	6.4	–	67.0			–	0	–	25	–	80	–	61	–	71	–	80	–	318	318
Other neoplasms	8.7	5.1	70.6	75.4			2	0	3	1	9	3	9	4	17	11	22	16	62	36	98
Total	30.5	9.1	67.1	69.9			4	2	44	33	255	119	322	121	341	166	183	187	1148	628	1776
Diabetes																					
Total (diabetes mellitus)	−4.9	−2.5	71.2	77.5			−1	0	−6	−2	−25	−6	−31	−11	−55	−26	−49	−46	−167	−90	−258
Neuropsychiatric conditions																					
Alcoholic psychoses	100.0	100.0	61.3	62.8			3	2	25	9	39	8	22	2	36	9	21	12	146	42	188
Alcohol dependence syndrome	100.0	100.0	61.2	61.2			4	1	18	11	94	20	75	13	60	18	16	8	267	71	338
Alcohol abuse	100.0	100.0	58.5	57.7			0	0	18	6	49	13	22	10	32	6	2	1	123	36	159
Unipolar major depression	8.5	2.8	78.3	84.7			0	0	0	0	0	0	0	0	0	0	3	2	5	2	7
Degeneration of nervous system due to alcohol	100.0	100.0	69.0	75.3			0	0	0	0	3	1	4	0	6	0	2	2	15	3	18
Epilepsy	49.6	36.9	50.2	58.4			8	6	18	8	20	10	4	3	5	8	7	10	62	45	107
Alcoholic polyneuropathy	100.0	100.0	75.3	–			0	0	0	0	1	0	0	0	0	0	2	0	3	0	3
Total	84.7	56.6	60.0	60.7			15	9	79	34	207	52	127	28	139	41	53	35	620	199	819
Cardiovascular disease																					
Hypertensive disease	22.5	7.9	75.7	81.7			0	0	3	1	14	2	18	5	39	17	62	59	135	84	219
Ischaemic heart disease	−9.3	−4.9	73.5	80.6			−1	0	−43	−6	−273	−35	−371	−76	−652	−214	−755	−585	−2095	−915	−3010
Alcoholic cardiomyopathy	100.0	100.0	61.0	62.5	0	0	0	0	4	1	21	2	16	5	13	1	2	1	56	10	66
Cardiac arrhythmias	25.7	17.3	74.8	81.1			3	1	8	2	19	7	27	10	61	39	99	135	218	194	412
Cerebrovascular disease	2.7	−6.6	75.3	80.9			1	−1	4	−9	15	−25	24	−33	53	−119	72	−408	169	−595	−426
Ischaemic stroke	*−0.6*	*−8.3*	*73.6*	*71.2*			*0*	*−1*	*0*	*−9*	*−1*	*−21*	*−2*	*−18*	*−3*	*−36*	*−3*	*−50*	*−9*	*−136*	*−144*
Haemorrhagic stroke	*8.9*	*−3.6*	*78.9*	*82.7*			*0*	*0*	*2*	*−1*	*15*	*−4*	*36*	*−9*	*112*	*−42*	*184*	*−158*	*349*	*−215*	*134*
Oesophageal varices	54.1	43.7	64.8	68.0			0	0	0	0	2	0	2	1	3	0	0	1	7	4	11
Total	−5.0	−4.1	73.4	80.7	0	0	2	0	−24	−11	−201	−48	−284	−88	−483	−276	−520	−796	−1510	−1218	−2728

Table 3 *Cont.*

Condition	AAF% (all ages)		Mean age at death		Number of deaths: 0–14 years		15–29 years		30–44 years		45–59 years		60–69 years		70–79 years		80+ years		Total		Overall
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	
Digestive diseases																					
Alcoholic gastritis	100.0	100.0	57.0	–			0	0	1	0	1	0	1	0	1	0	0	0	4	0	4
Cirrhosis of the liver	58.1	45.7	61.7	65.2			1	0	63	29	300	86	246	79	190	107	55	47	854	349	1203
Cholelithiasis	−13.0	−7.2	77.6	78.6			0	0	0	0	0	0	−1	0	−3	−1	−3	−3	−7	−5	−11
Acute and chronic pancreatitis	22.8	11.7	67.5	75.1			0	0	2	1	9	1	6	2	10	4	8	9	35	17	52
Chronic pancreatitis (alcohol-induced)	100.0	100.0	57.9	54.5			1	0	1	1	9	1	4	0	5	1	0	0	20	3	23
Total	53.3	37.4	61.7	65.4			2	1	68	31	318	88	256	81	203	111	60	53	906	364	1271
Skin diseases																					
Total (psoriasis)	25.6	–	68.7	–			0	0	0	0	0	0	0	0	1	0	0	0	2	0	2
Conditions arising during the perinatal period																					
Low birth weight	6.8	6.8	0.0	0.0	8	5													8	5	14
Fetal alcohol syndrome	100.0	100.0	0.0	–	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Excess blood alcohol level	100.0	100.0	–	–	0	0													0	0	0
Total	100.0	100.0	0.0	0.0	9	5	0	0	0	0	0	0	0	0	0	0	0	0	9	5	15
Unintentional injuries																					
Motor vehicle accidents	40.0	18.2	33.9	41.3	16	8	308	37	202	37	83	29	22	9	18	11	13	7	662	138	801
Poisonings	24.4	21.6	38.7	41.0	0	0	43	15	68	23	46	18	4	4	2	1	1	1	164	62	225
Accidental poisoning and exposure to alcohol	*100.0*	*100.0*	*46.7*	*41.9*	*0*	*1*	*3*	*5*	*23*	*10*	*24*	*10*	*5*	*4*	*3*	*0*	*0*	*0*	*58*	*30*	*88*
Falls	17.4	5.4	64.5	73.0	0	0	11	1	17	2	34	10	18	3	22	6	51	24	154	46	199
Fires	37.5	19.7	41.3	35.3	7	6	10	3	14	3	10	3	5	1	6	2	3	2	54	20	74
Drowning	33.4	27.0	41.1	50.6	0	0	25	3	21	2	21	4	4	1	5	1	1	2	77	13	90
Other unintentional injuries	32.0	20.9	51.4	74.4	14	2	116	14	120	15	99	22	35	9	58	32	113	159	555	252	808
Total	31.0	16.2	43.6	59.7	37	16	512	73	442	82	292	86	88	27	111	53	182	194	1666	530	2196
Intentional injuries																					
Self-inflicted injuries	17.7	13.7	39.1	42.6	0	0	139	23	195	35	139	45	22	6	8	2	3	1	507	113	619
Intentional self-poisoning by and exposure to alcohol	*100.0*	*100.0*	*45.3*	*56.2*			*1*	*0*	*2*	*0*	*6*	*4*	*0*	*2*	*0*	*0*	*0*	*0*	*9*	*6*	*15*
Homicide	36.9	34.4	34.2	36.9	3	3	52	11	41	16	22	11	4	1	2	2	0	0	124	44	168
Other intentional injuries	28.4	–	32.5	–	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	2
Total	19.6	16.4	38.1	41.0	3	3	191	34	238	51	161	56	26	7	11	5	3	1	633	156	789
Ethanol and methanol toxicity, undetermined intent	100.0	100.0	44.5	57.6	0	0	0	0	3	1	3	0	0	3	0	0	0	0	6	4	10
Overall			45.9	58.8	50	24	724	117	844	219	1011	348	504	169	268	74	−88	−372	3313	579	3892

Categories in italic type are subcategories of immediate prior category. – = Not computed either due to absence of RR or death.

females) constituted the largest alcohol-attributable categories.

Overall, alcohol affected more men than women: in men 3.0% of the deaths were alcohol-attributable and in women the figure was 0.5% (in the age group under 70: 7.6% in men; 3.5% in women).

With respect to age, the overall average age for an alcohol-attributable death was 45.9 years for men and 58.8 years for women. There were notable differences between disease categories. For cardiac arrhythmias, the average age for an alcohol-attributable death was 74.8 years for men and 81.1 years for women. Alcohol-attributable deaths due to motor vehicle accidents occurred at the average age of 33.9 years for men and 41.3 years for women. For the category of alcohol-prevented deaths in general, the mean age was 74.4 years among men and 80.7 years among women.

In 2001, the PYLL rate for Canada for deaths due to alcohol was 769 per 100 000 for men and 203 per 100 000 for women aged 0–80 + (Table 4). That is, for every 100 000 people in the population, there was a potential loss of 769 years of life among men and 203 years of life among women as a result of premature death due to alcohol. A high PYLL rate for men was observed, indicating higher levels of premature mortality among men compared to women.

Although the estimates of alcohol exposure varied widely, i.e. by a factor of three between some survey measures and per capita consumption, the estimates for alcohol-attributable mortality did not vary by such a large degree (see Table 5): the lowest estimate was only 22.8% lower than the highest estimate.

Similarly, the PYLL rate per 100 000 population varied much less compared to the variation in exposure. For instance, between the main scenario (see Table 4) and a scenario based on usual quantity–frequency, the differences were as follows: the rate of alcohol-attributable years of life lost per 100 000 men decreased from 769 to 698 (–9.2%) and the respective rate for women decreased from 203 to 174 (–14.3%; details of the calculation available from the authors).

There are three main reasons for the relatively small variation in overall deaths or PYLL. First, only part of the alcohol-attributable mortality was based on survey estimates (see Methods above). The rest was derived using direct estimation from statistics. Secondly, as alcohol has protective as well as detrimental effects, and as the esti-

Table 4 Potential years of life lost (PYLL) attributable to alcohol in Canada 2001 by age and sex—main scenario.

Gender	*Age group (years)*	*Alcohol-attributable death all causes*	*PYLL*
Men	0–14	50	3418.1
	15–29	724	39 349.4
	30–44	844	33 760.0
	45–59	1011	26 437.7
	60–69	504	8038.8
	70–79	268	2559.4
	80+	–88	–484.0
			113 079.3
Alcohol-attributable years of life lost per 100 000 men = 769			
Women	0–14	24	1770.8
	15–29	117	6970.9
	30–44	219	9828.7
	45–59	348	10 669.7
	60–69	169	3337.8
	70–79	74	903.5
	80+	–372	–2418.0
			31 063.4
Alcohol-attributable years of life lost per 100 000 women = 203			
Total PYLL			144 143

Table 5 Sensitivity analysis on resulting burden under different exposure scenarios.

Exposure scenarios	*Gender*	*Malignant neoplasms*	*Diabetes*	*Neuro-psychiatric conditions*	*Cardiovascular diseases*	*Digestive diseases*	*Skin diseases*	*Conditions arising during perinatal period*	*Total net deaths*†
S1 usual QF	Male	828	–68	592	–1533	580	1	4	2709
	Female	389	–61	182	–860	209	0	2	551
S2 7-day-recall	Male	727	–47	583	–1293	469	1	4	2750
	Female	365	–56	181	–797	182	0	2	568
S3 smoothed usual QF	Male	865	–70	596	–1583	591	1	4	2710
	Female	426	–71	185	–1149	210	0	2	293
S4 smoothed adjusted QF	Male	1148	–167	620	–1510	906	2	9	3313
	Female	628	–90	199	–1218	364	0	5	579

†Note that the total of net deaths is not the sum of the chronic conditions only, but the sum of these conditions plus the deaths due to injury (see Table 3 for numbers). As the latter were estimated directly from statistics and independently of exposure, they remain constant for all scenarios. S1 = Alcohol-attributable fractions (AAF) based on usual quantity frequency (QF) measure. S2 = AAF based on 7-day-recall. S3 = AAF based on smoothed usual QF measure. S4 = AAF based on smoothed QF measure adjusted for per capita consumption.

mation of these effects depends on certain patterns of drinking (Rehm *et al.* 2003a), the effects of changes in volume of alcohol consumption on mortality are not linear, but depend on the distribution of drinking with respect to different volume categories, sex and age. Thirdly, a number of disease conditions are wholly attributable to alcohol (e.g. alcohol dependence), and thus their mortality is estimated independently of prevalence of alcohol consumption.

DISCUSSION

Alcohol consumption has substantial consequences for public health. Regardless of how alcohol intake is measured, it causes substantial mortality and years of life lost in Canada. Before we address potential ways to reduce alcohol-related harm, we would like to outline some of the limitations and potential problems of the present study. Exposure measurement is one of the biggest challenges in alcohol epidemiology. While we have relatively good per capita estimates (Rehm *et al.* 2003d), at least in countries such as Canada with relatively small proportions of unrecorded consumption, the distribution by sex and age, as derived from surveys, is problematic. The main problem is that surveys account for 50% or less of sales/production figures. That fact has been known for some time (e.g. Midanik 1988), but has not been addressed adequately with respect to epidemiology. The underlying measures of exposure also explain some of the variation between studies, where overall little or no net loss of mortality could be measured (e.g. Single *et al.* 1996; Britton *et al.* 2003; White *et al.* 2004) compared to studies where the net mortality is considerable (such as Rehm *et al.* 2004, or the present study). In the studies with little or no net loss of mortality, level of alcohol consumption was derived from surveys resulting in considerable underestimation of true consumption. There are other differences that explain the variations in study results, most importantly the number of disease categories included and the estimation of injury deaths (based on country-specific statistics or not). In comparison with the earlier Canadian study of Single and colleagues (Single *et al.* 1996), three other changes are important: the proportion of deaths in Canada due to IHD and cerebrovascular diseases decreased, and the relative risk estimates for the latter disease category changed considerably (compare the relative risks provided by English *et al.* 1995 to those from Reynolds *et al.* 2003). Thus, the estimated overall protective effect of alcohol consumption decreased.

A second problem concerns the estimation of risk relations for chronic disease, which still mainly do not take into account patterns of drinking. This may be less relevant for malignant neoplasm but certainly there is good evidence on alcohol and IHD to demonstrate that drinking pattern plays a crucial role (Puddey *et al.* 1999; Rehm *et al.* 2003c). There are also good examples of how this is relevant for public health. For example, in a representative follow-up study in the United States, a protective effect of average moderate consumption could be found in whites but not in African Americans (Sempos *et al.* 2002; for a Canadian example on the relevance of patterns see Murray *et al.* 2002). Thus, the burden estimates for all diseases where patterns are important can only be considered preliminary until we have a better understanding of the patterns of consumption in a population and the resulting disease outcomes. This point is especially important for the area of cardiovascular disease outcomes, where patterns of drinking may change the result from beneficial to detrimental effects of alcohol (Gmel *et al.* 2003b).

Thirdly, as already indicated above, the age specificity of relative risks between exposure and outcomes should be taken into consideration. For example, the relative risk of alcohol for IHD declines with age (Abrams *et al.* 1995), but in most estimations of alcohol-related harm, including this paper, the same relative risks have been used for all age groups. This leads to an overestimation of deaths caused and prevented by alcohol in older age groups, which is especially relevant for IHD deaths prevented, where we almost certainly obtain a significant overestimate using the current methodology. In fact, the majority of the beneficial effects of alcohol would disappear if age-specific relative risk estimates were used.

While such details are certainly important in improving future estimations of burden, they should not detract from the main result in this study. Under all assumptions, alcohol consumption in Canada resulted in a considerable burden of mortality and disease. In appraising this burden, it should be mentioned that disease burden is only part of the overall alcohol-related burden, and is actually considerably smaller than social harm in some regions (Room *et al.* 2003). Thus, in making policy decisions, consideration should be given to all consequences of alcohol, including social harm. In shaping policies, one must also look at the whole picture of the alcohol consumption culture and not concentrate only on excessive drinking (Centers for Disease Control & Prevention 2004), as excessive drinking and moderate drinking, with their different effects on health, are often intertwined, i.e. effects on one style may have unwanted effects on the other.

The burden related to alcohol in Canada is an unnecessary one. A large portion of this burden could be reduced considerably in a short period of time (WHO 2002; Chisholm *et al.* 2004) if known effective policies were implemented. In Canada, policies such as taxation, improvement of drinking driving countermeasures and

specific measures to reduce aggression and violence seem to be the most promising policies, given the epidemiological profile (Babor *et al.* 2003; Chisholm *et al.* 2004; Room *et al.* 2005). Such policies have proved their effectiveness in many jurisdictions and they could show effects almost immediately (Babor *et al.* 2003; Chisholm *et al.* 2004; Room *et al.* 2005).

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