Alcohol attributable fractions for England

February 2019

Laura Webster

Colin Angus

John Holmes

Alan Brennan

Duncan Gillespie

Address for correspondence:
Dr Duncan Gillespie
School of Health and Related Research
University of Sheffield
Regent Court
Regent Street
Sheffield
S1 4DA
UK
Mail: duncan.gillespie@sheffield.ac.uk

Introduction

Alcohol causes, or can contribute to, the development of many health conditions. Conditions such as alcoholic liver disease where alcohol is the sole cause are known as wholly alcohol attributable conditions. Conditions where alcohol may be one of a range of causative factors are called partially alcohol attributable conditions. Alcohol attributable fractions (AAFs) are the proportion of cases of a partially attributable disease or injury that would be prevented if exposure to alcohol was eliminated. AAFs are applied routinely to mortality and morbidity to estimate the impact that alcohol has on population health and health service use. Up-to-date AAFs are needed to help to understand the current burden that alcohol places upon health and healthcare services.

Although a recent study calculated AAFs for a range of alcohol-related cancers [1], the last comprehensive estimates of AAFs for all alcohol-related conditions in England were in 2014 [2]. These estimates have been used to quantify the burden of harm from alcohol in academic studies [3, 4], by Public Health England in their Local Alcohol Profiles for England [5], and by NHS Digital in their statistics on alcohol for England [6]. As detailed in a previous report [7], further evidence is now available on the association of alcohol consumption with the development of chronic conditions (specifically, cancers [8], hypertension [9], ischaemic stroke [10], pancreatitis [11], type II diabetes [12], tuberculosis [13]),and acute consequences estimated from emergency department data (falls, traffic accidents, violence, other [14]).

The Sheffield Alcohol Research Group have also developed new methods to estimate the annual risk that someone faces of experiencing the acute consequences of drinking (e.g. falls) [15, 16]. This is based on a study by Hill-McManus et al. [16], who analysed drinking occasions using data from detailed diaries in the National Diet and Nutrition Survey 2000/2001. Using the results, it possible to model each individual's expected number of drinking occasions across the year, the average amount they drunk on an occasion, the variability in the amount drunk among occasions, and how these vary socio-demographically. Based on the Widmark equation [17, 18], it is then possible to estimate the total time over one year that an individual spends with a blood alcohol concentration greater than zero, considering their height and weight, and the rate at which the liver clears alcohol from the blood. To estimate AAFs, these estimates of exposure to alcohol in the blood can be combined with estimates from emergency department data of how the risk of acute consequences varies with the amount drunk on a single occasion [14].

The 2014 AAF report stratified its estimates by age (0–15, 16–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75+ years) and sex [2]. However, the burden of harm from alcohol-related conditions tends to be borne most heavily by people who live in the most deprived socio-economic conditions, as has been demonstrated in a range of high-income countries, including England [19-21]. It is therefore important to also investigate the variation in AAFs by socio-economic conditions.

For our estimates of AAFs we used data on alcohol consumption from the Health Surveys for England 2015 and 2016 [22] and the latest epidemiological evidence on the health effects of alcohol consumption [7]. Our new estimates are stratified by sex, age, and socio-economic conditions as measured by the 2015 English Index of Multiple Deprivation (IMD) [23]. From our list of 45 alcohol-related health conditions [7], 16 conditions are wholly-attributable to alcohol consumption i.e. AAF = 1. We estimated AAFs for the remaining 29 conditions that are partially-attributable to alcohol consumption.

Methods

All analyses were undertaken in the R environment (version 3.5.2) [24], using code developed as part of the new Sheffield Tobacco and Alcohol Policy Model.

Survey data

We analysed data from the Health Survey for England (HSE), a nationally representative annual cross-sectional survey of households in England [22]. We pooled two years of data (2015, 2016) to increase our sample size to 15,907 adults aged 16–89 years. We categorised survey respondents' ages into seven age-groups: 16–17, 18–24, 25–34, 35–49, 50–64, 65–74, and 75–89 years. All calculations were adjusted for the survey weights, which make the survey sample more representative of the general population.

Our measure of socio-economic conditions was the 2015 English IMD [23], which measures relative levels of deprivation in small areas or neighbourhoods with an average population of around 1,500 people, called Lower-layer Super Output Areas. The IMD is based on 37 separate indicators, organised into seven domains: Income Deprivation; Employment Deprivation; Health Deprivation and Disability; Education, Skills and Training Deprivation; Crime; Barriers to Housing and Services; and Living Environment Deprivation. These indicators are combined to give each area a multiple deprivation score. We investigated variation among quintiles of the IMD, quintile one being the least deprived, and quintile five the most deprived.

Our method for estimating AAFs for acute conditions is based on parameter estimates from Hill-McManus et al. [16] that require data on quintile of equivalised household income, ethnicity (white, non-white), age finished full-time education (15 years or under, 16–18 years, 19 years or over, never went to school), number of children in the household (0, 1, 2, 3+), and occupation (non-manual, manual and other). We multiply imputed missing values based on the relationships among these variables in the HSE 2001–2016 using the R package *mice* [25]; we integrated our AAF estimates over five alternative versions of the imputed data. The method also requires data

on individual height and weight; we replaced any missing values with the average height or weight within the corresponding sex, age-group and IMD quintile.

The HSE asks questions on frequency and typical quantity of alcohol consumed by beverage type and then combines this with assumptions regarding serving size and alcoholic strength to estimate individuals' average weekly consumption levels in UK units (one unit equals 8g or 10ml of ethanol). Whilst the HSE data includes its own derived estimates of average consumption for each individual, we used alternative assumptions around serving sizes and alcoholic strengths, which we detail in Table A1. For chronic health conditions, we defined the risk associated with alcohol to be a function of an individual's average daily consumption; we capped each individual at 150 g/day if they drank more than that as most published risk curves are unstable above that level [9, 26]. From our data sample, we excluded 149 individuals (0.9% of the sample) due to missing data on average daily consumption; missing data were concentrated in younger age-groups, with an approximately even distribution by sex and IMD quintile.

Figure 1 shows the IMD variation in the distribution of alcohol consumption.

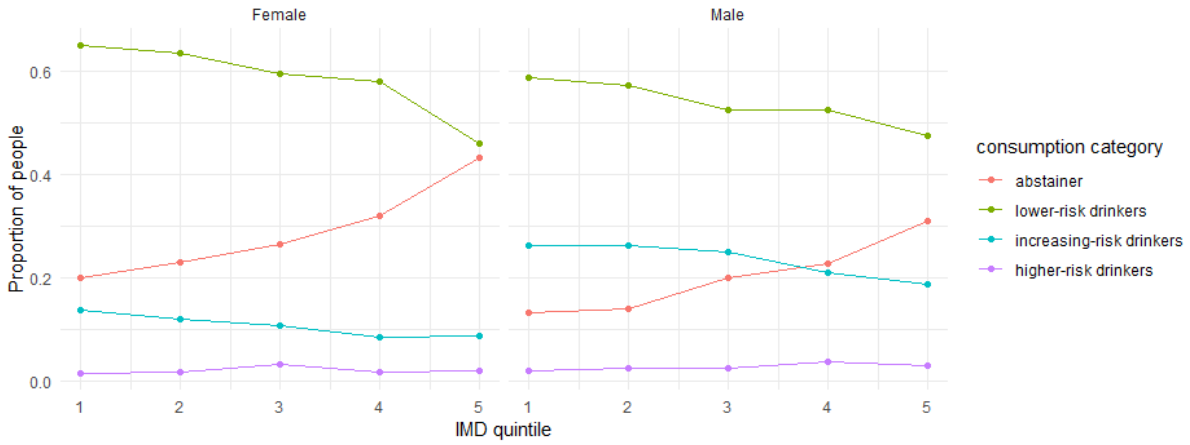


Figure 1. Variation in the distribution of alcohol consumption by socio-economic conditions. We define lower-risk drinkers as people who consume up to 14 units/week, increasing-risk drinkers as females who consume up to 35 units/week and males who consume up to 50 units/week, and higher-risk drinkers as people who consume more than these amounts. The proportion of people sums to 1 within each IMD quintile and sex subgroup. IMD quintile 1 is the least deprived and IMD quintile 5 is the most deprived.

Table 1. Alcohol-related conditions.

Condition type	Disease category	Condition	ICD10 code
Wholly–attributable chronic	Digestive	Alcoholic gastritis	K29.2
		Alcoholic liver disease	K70.0–K70.4, K70.9
		Acute pancreatitis (alcohol induced)	K85.2
		Chronic pancreatitis (alcohol induced)	K86.0
	Other	Maternal care for (suspected) damage to foetus from alcohol	O35.4
	Endocrine	Alcohol–induced pseudo–Cushing's syndrome	E24.4
	Nervous System	Degeneration of nervous system due to alcohol	G31.2
		Alcoholic polyneuropathy	G62.1
		Alcoholic myopathy	G72.1
	Cardiovascular	Alcoholic cardiomyopathy	I42.6
Wholly–attributable acute	Mental and behavioural disorders	Acute intoxication	F10.0
		Mental and behavioural disorders due to use of alcohol	F10.1–F10.9
	Other	Excessive Blood Level of Alcohol	R78.0
		Toxic effect of alcohol	T51.0, T51.1, T51.8, T51.9
		Alcohol poisoning	X45, X65, Y15
		Evidence of alcohol involvement determined by blood alcohol level	Y90
Partially–attributable chronic	Cancers	Oropharyngeal	C00–C06, C09, C10, C12–C14
		Oesophageal Squamous Cell Carcinoma (SCC)	C15*
		Colorectal	C18–C20
		Liver and intrahepatic bile ducts	C22
		Larynx	C32
		Breast (female only)	C50
		Pancreatic	C25
	Endocrine	Diabetes mellitus (type II)	E11
	Nervous System	Epilepsy and status epilepticus	G40–G41
	Cardiovascular	Hypertensive diseases	I10–I13
		Ischaemic heart disease	I20–I25
		Cardiac arrhythmias	I47–I48
		Haemorrhagic stroke	I60–I62
		Ischaemic stroke	I63–I67
	Respiratory	Pneumonia and influenza	J09, J10, J11, J12–J18
		Tuberculosis	A15–A19
	Digestive	Cirrhosis of the liver (excluding alcoholic liver disease)	K70 (excl. K70.0–K70.4, K70.9), K73–K74
		Acute pancreatitis	K85 (excl. K85.2, K85.3)
		Chronic pancreatitis	K86 (excl. K86.0)
Partially–attributable acute	Injuries	Transport injuries (including road traffic accidents)	V01–V98, Y85.0
		Fall injuries	W00–W19
		Fire injuries	X00–X09, Y26
		Assault	X85–Y09, Y87.1
		Other intentional injuries	Y35
		Drowning	W65–W74
		Other Unintentional Injuries	W75–W99, X10–X33, Y20, Y22–Y25, Y27–Y29, Y31–Y34
		Intentional self–harm	X60–X84 (excl. X65), Y87.0
		Exposure to mechanical forces (including machinery accidents)	W20–W52
		Accidental poisoning by exposure to noxious substances	X40–X49 (excl. X45), Y10–Y14, Y16–Y19, T36–T50, T52–T65

* Oesophageal cancer has two main histological types: Squamous Cell Carcinoma (SCC) and Adenocarcinoma (AC). Alcohol is only associated with SCC, not AC [8]. The relative prevalence of SCC and AC varies widely between countries and within population subgroups [27] and it may therefore be necessary to apportion overall oesophageal cancer prevalence between SCC and AC using external data such as that from cancer registries.

Risk curves and attributable fraction calculation

In a previous report [7], we presented the list of 45 health conditions related to alcohol (Table 1) that are included in the most recent version (4.0) of the Sheffield Alcohol Policy Model (SAPM). These conditions are defined in terms of the International Classification of Diseases, 10th revision (ICD10). We also presented the corresponding dose-response curves (the mathematical relationships between volume of alcohol consumed and risk of morbidity/mortality) for all included conditions which are not wholly-attributable to alcohol. In Appendix B we show the shape of these risk curves for ease of reference.

Chronic conditions

The risk curves for chronic conditions are based on recent reviews by Rehm et al. [9, 28] and Sherk et al. [26], as well as previous versions of SAPM [29]. Note that SAPM considers only conditions which affect the drinker and therefore several conditions related to alcohol, such as Foetal Alcohol Spectrum Disorders, are not included. For ischaemic heart disease, stroke and liver cirrhosis, evidence is available demonstrating a different risk curve for morbidity than for mortality [10, 30-33]. For these conditions, we present separate AAFs for morbidity and mortality. Where no separate morbidity evidence exists we assume the risk curves for both outcomes are the same.

The AAF is defined as the proportion of cases of a particular condition in a population that are attributable to alcohol. It is the estimated proportion of cases that would not have occurred if there had been no exposure to alcohol. Our method for calculating AAFs for all chronic conditions that are partially attributable to alcohol is given by:

$$AAF = \frac{\sum_{i=1}^{k} P(i)[RR(i) - 1]}{\sum_{i=0}^{k} P(i)[RR(i) - 1] + 1}, \quad (1)$$

where the level of exposure to alcohol (in average grams of ethanol consumed per day) is i = 0, 1, 2, …, k = 150 g/day, *RR(i)* is the relative risk at a given exposure level, and *P(i)* is the proportion of people who drink alcohol to that level.

For ischaemic heart disease, stroke, acute pancreatitis, and type II diabetes, the risk curves indicate protective effects of alcohol. These protective effects occur in general at low levels of alcohol consumption, but for type II diabetes in women and ischaemic heart disease for men the risk curve indicates protective effects at all levels of alcohol consumption. Protective effects tend to result in small positive or negative AAFs. Negative AAFs indicate that there are currently fewer cases of a condition than would be the case if nobody drank alcohol, i.e. there

would be more cases if everyone stopped drinking. Negative AAFs can be used to estimate this hypothetical higher number of cases (*b*) according to:

$$b(no\ exposure) = \frac{b(observed\ exposure)}{1 + AAF}. \quad (2)$$

Our basecase analysis includes protective effects. Due to uncertainty around the existence of these protective effects [34], we also computed a set of alternative AAFs where all *RR(i)* < 1 = 1, i.e. removing the protective effects of alcohol from the risk curve.

Acute conditions

The relative risk for acute consequences for the drinker that are attributable partially to alcohol increases with increasing amounts of alcohol drunk on a single occasion. To calculate the AAFs of partially-attributable acute conditions, our first step was to model each individual's expected number of drinking occasions across the year, the average amount they drunk on an occasion, and the variability in the amount drunk among occasions. Our calculations used parameter estimates from Hill-McManus et al. [16], who analysed drinking occasions in the National Diet and Nutrition Survey 2000/2001. The estimated parameters describe how drinking occasions vary according to individual average weekly consumption, age, income, ethnicity, education, children, and occupation. We applied these estimates to the HSE data to give the probability that each individual drank each possible amount of ethanol on a drinking occasion.

Second, we approximated each individual's exposure to the risk of partially-attributable acute conditions using an estimate of the total time (*T*) that they spent with a blood alcohol concentration (BAC) greater than zero during one year [15]. To make this estimate, we used the Widmark equation [17, 18], which we re-arranged to give the time (*t*) in hours that each individual would spend with BAC > 0 for each of the possible amounts drunk on an occasion. Our calculation used individual height and weight from the HSE data, and the rate at which the liver clears BAC, set at 0.017 g%/hour. The total time (*T*) that an individual spent with BAC > 0 during one year is given by:

$$T = 52n \sum_{i=0}^{150} p(i)t(i), \quad (3)$$

where *n* is the estimated number of drinking occasions in a week (so 52*n* is the number in a year), *p(i)* is the probability that an individual drank each possible amount *i* on a drinking occasion, and *t(i)* is their estimated time spent with BAC > 0 for each amount drunk.

Third, we incorporated estimates of how the single-occasion relative risk (*r*) of four categories of acute condition varies with the amount drunk. Later we convert the single-occasion relative risk (*r*) to the relative risk averaged over the year (*RR*), which includes the times when people have BAC > 0 and BAC = 0. We took the single-occasion risk curves from Cherpitel et al. [14], who estimated them from emergency department data (see also our report on risks [7]). The categories are: transport injuries, fall injuries, violence (under which we included assault and other intentional injuries), and other (under which we included fire injuries, drowning, other unintentional injuries, intentional self-harm, exposure to mechanical forces, and accidental poisoning by exposure to noxious substances). We converted the 'standard drinks' measure of consumption used by Cherpitel to grams of ethanol assuming that one standard drink contained 12.8g ethanol. We then used (4) to calculate *A*, which is the sum of the single-occasion relative risks to which an individual was exposed during the times that their BAC > 0 i.e. $r > 1$ across the year:

$$A = 52n \sum_{i=0}^{150} t(i)p(i)r(i). \quad (4)$$

The amount of time during the year when BAC = 0 is 8760 – *T* (365 days × 24 hours = 8760 hours), for which we set the $r = 1$. We used (5) to calculate the relative risk of an acute consequence of drinking that each individual faced on average across all time in the year, i.e. considering all the time that they were drinking and had BAC > 0, and were not drinking and so had BAC = 0:

$$RR = \frac{A + (8760 - T)}{8760}, \quad (5)$$

where *A* is the sum of the relative risk when BAC > 1 and (8760 – *T*) is the sum of the relative risk when BAC = 0 ($r = 1$). We used this estimate of the average relative risk experienced throughout the year to calculate the AAFs based on (1).

AAF estimates

We provide our complete set of AAF estimates stratified by age-group, sex and IMD quintiles in a supplementary spreadsheet. Below we highlight the main findings. It is worth noting that only ischaemic heart disease, stroke and liver cirrhosis have separate risk functions for morbidity and mortality, and for these conditions we present separate morbidity and mortality AAFs (in the figures we focus presentation on the mortality AAFs and then show the morbidity AAFs using crosses).

Figure 2 presents AAFs by condition. Liver cirrhosis is the condition for which the highest proportion of cases are caused by alcohol, i.e. it has the highest AAF. We estimated that 47% (AAF = 0.47) of liver cirrhosis deaths were caused by alcohol, compared to 30% of liver cirrhosis morbidity, with the difference due to the shape of the risk curves for mortality and morbidity in Rehm et al. [33] (Figure B13). As Rehm et al. discuss, alcohol consumption can worsen existing liver disease, increasing the chance that it proves to be fatal. The two cancers with the highest AAF are oesophageal SCC, for which we estimated that 28% of cases were caused by alcohol, and oropharyngeal cancer, with 23% of cases caused by alcohol. These cancer sites, along with the larynx (13% of cases caused by alcohol), are at the 'front-line' of exposure to the potential carcinogenic factors, which include acetaldehyde increasing DNA damage, and ethanol acting as a solvent that increases the exposure of mucosa to other carcinogens e.g. in tobacco smoke and the diet [35]. At the opposite end of the AAF spectrum, our negative AAF estimates indicate that alcohol has a net protective effect for stroke (except for Haemorrhagic stroke mortality), type II diabetes, and ischaemic heart disease. These negative AAFs are created by the non-linear 'J' shape of the risk curves for these conditions (Figures B9, B11, B12, B16).

Figure 3 presents AAFs stratified by condition and sex (Table A2 shows the effect on our estimated AAFs of removing the protective effects by setting all $RR(i) < 1 = 1$ in the risk curves). For liver cirrhosis, the risk curves indicate that females tend to face a higher risk than males at all levels of alcohol consumption (Figure B13). Thus, it follows that females have higher AAFs than males, e.g. for liver cirrhosis mortality we estimated that 52% of female deaths were caused by alcohol, compared to 40% of male deaths. For most other conditions, males have higher AAFs than females because the risk functions do not differ by sex; and therefore, the higher AAF of males is driven by higher levels of consumption. Of note is the pattern for acute pancreatitis, for which our AAFs indicate that alcohol has a net protective effect for females (alcohol causes 4% fewer cases) but not males (alcohol causes 15% of cases). This is due to the J-shaped risk curve in females but not males in Samokhvalov et al. [11] (Figure B14), who discuss that the apparent protective effect of low levels of alcohol consumption in females might result from two effects: first, from the non-drinker group being a mixture of never and former drinkers, who have a higher risk of pancreatitis; second, from a genuine protective effect of low levels of alcohol consumption against acute pancreatitis caused by biliary problems, of which there tend to be more cases in females than males. For ischaemic heart disease, stroke and type II diabetes, the net protective effects also tend to be more apparent in females than males, with several potential explanations [10, 12, 30-32]. For example, for type II diabetes [12] four different possible causes of the deeper J-shaped risk curve for females (Figure B16) were discussed: female non-drinkers might have been less healthy than male non-drinkers; the potential benefits of low levels of alcohol consumption among men might be cancelled by a higher frequency of heavy episodic drinking; there might be sex differences in biological pathways; or there might have been issues with the primary studies around selection bias and insufficient statistical controls for individual differences.

Table A3 presents our AAFs stratified by sex and age-group. The main pattern is that AAFs are low at 16–17 years, high and roughly consistent at 18–24, 25–34, 35–49, 50–64 years, and then decline gradually at 65–74 and 75–89 years. Of note is the further age pattern in the AAFs for assaults and other intentional injuries: at 18–24 years, alcohol caused 13% of cases in females, and 15% in males; this rose to a peak at 50–64 years, at which alcohol caused 18% of cases in females, and 21% in males.

Figure 4 presents our AAFs stratified by condition and IMD quintiles (see supplementary spreadsheet for tables). It is important to note that none of our risk curves are stratified socio-economically, due to a lack of epidemiological studies that report stratified risks, and to the studies that do finding minimal evidence for socio-economic variation [36]. Therefore, the IMD variation in our AAFs is due only to IMD variation in levels of alcohol consumption. In general, people who live in more deprived socio-economic conditions have smaller AAFs. This is likely to be due to the higher frequency of abstention in more deprived socio-economic conditions (Figure 1), which has a greater influence on the AAF than the higher frequency of higher-risk drinking in more deprived socio-economic conditions (Figure 1). Assaults and other intentional injuries show a particularly high IMD variation in AAFs, with 15% of cases caused by alcohol in the most deprived quintile, rising to 23% of cases caused by alcohol in the least deprived quintile. The high IMD variation for these conditions is because the risk of violence increases more steeply than for other acute conditions with the amount consumed on a single occasion (Figures B20–B23), making the AAFs more sensitive to IMD variation in the amount drunk.

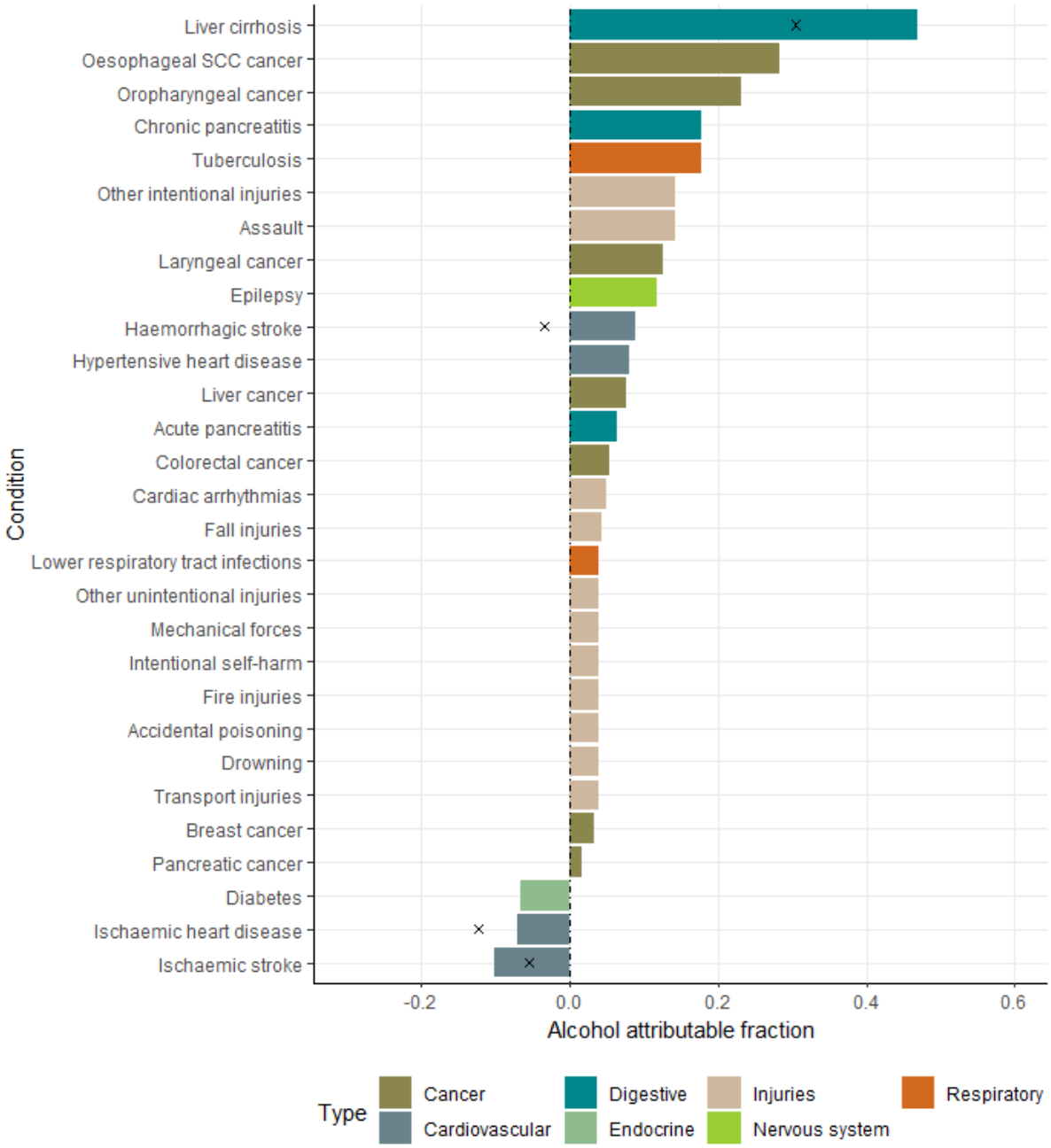


Figure 2. Alcohol attributable fractions by condition. Negative AAFs indicate that on average alcohol has a protective effect. Colours show type of condition. Each bar shows the overall or mortality-specific AAF for each condition; for conditions that have separate mortality- and morbidity-specific risk functions, crosses show the morbidity-specific AAFs. Note that our AAF estimates for partially-attributable acute conditions only differ among the four categories: transport injuries, fall injuries, violence (under which we included assault and other intentional injuries), and other (under which we included fire injuries, drowning, other unintentional injuries, intentional self-harm, exposure to mechanical forces, and accidental poisoning by exposure to noxious substances).

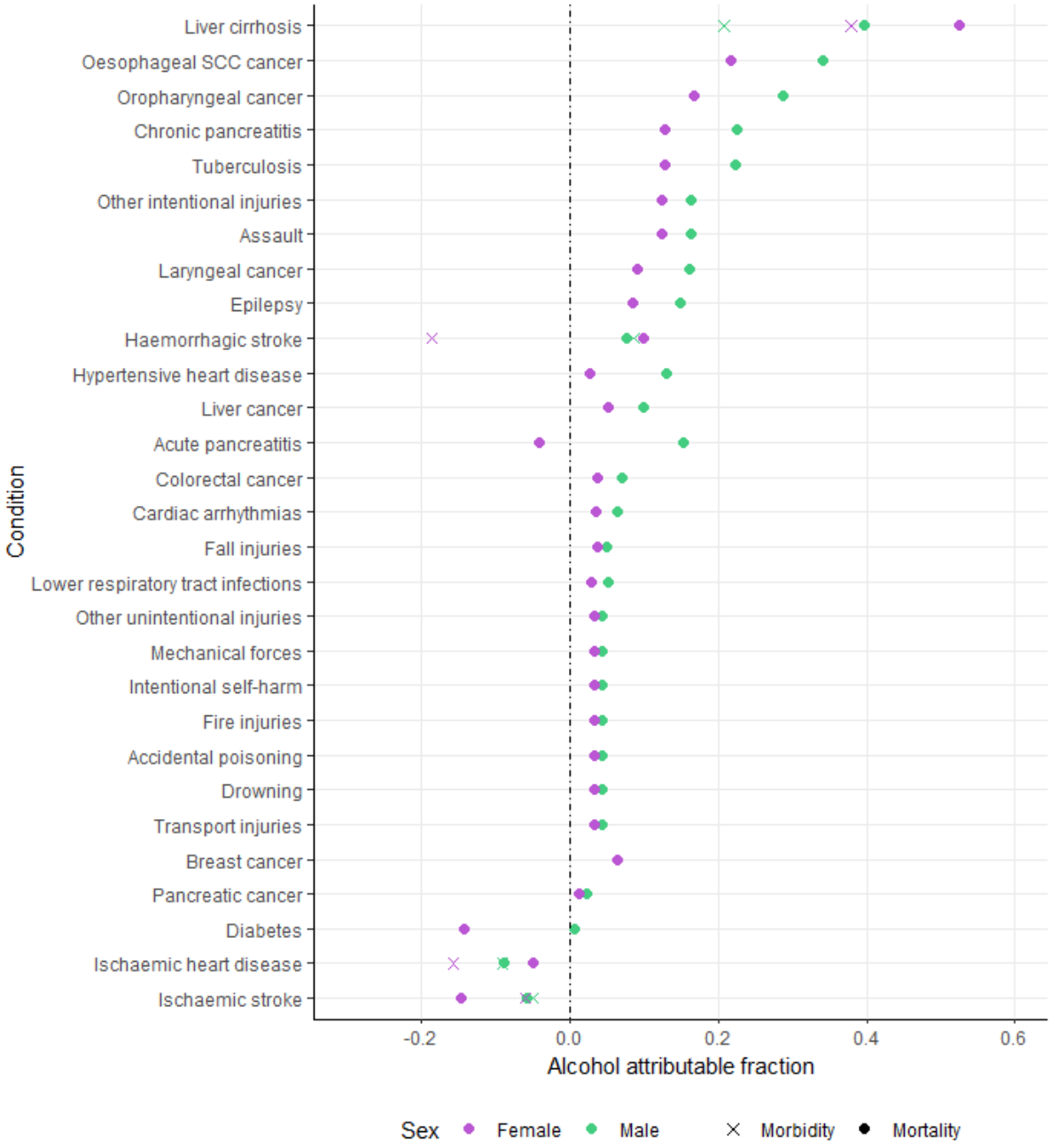


Figure 3. Alcohol attributable fractions by condition and sex. Each point shows the overall or mortality-specific AAF for each condition; for conditions that have separate mortality- and morbidity-specific risk functions, crosses show the morbidity-specific AAFs. Each colour represents a different sex.

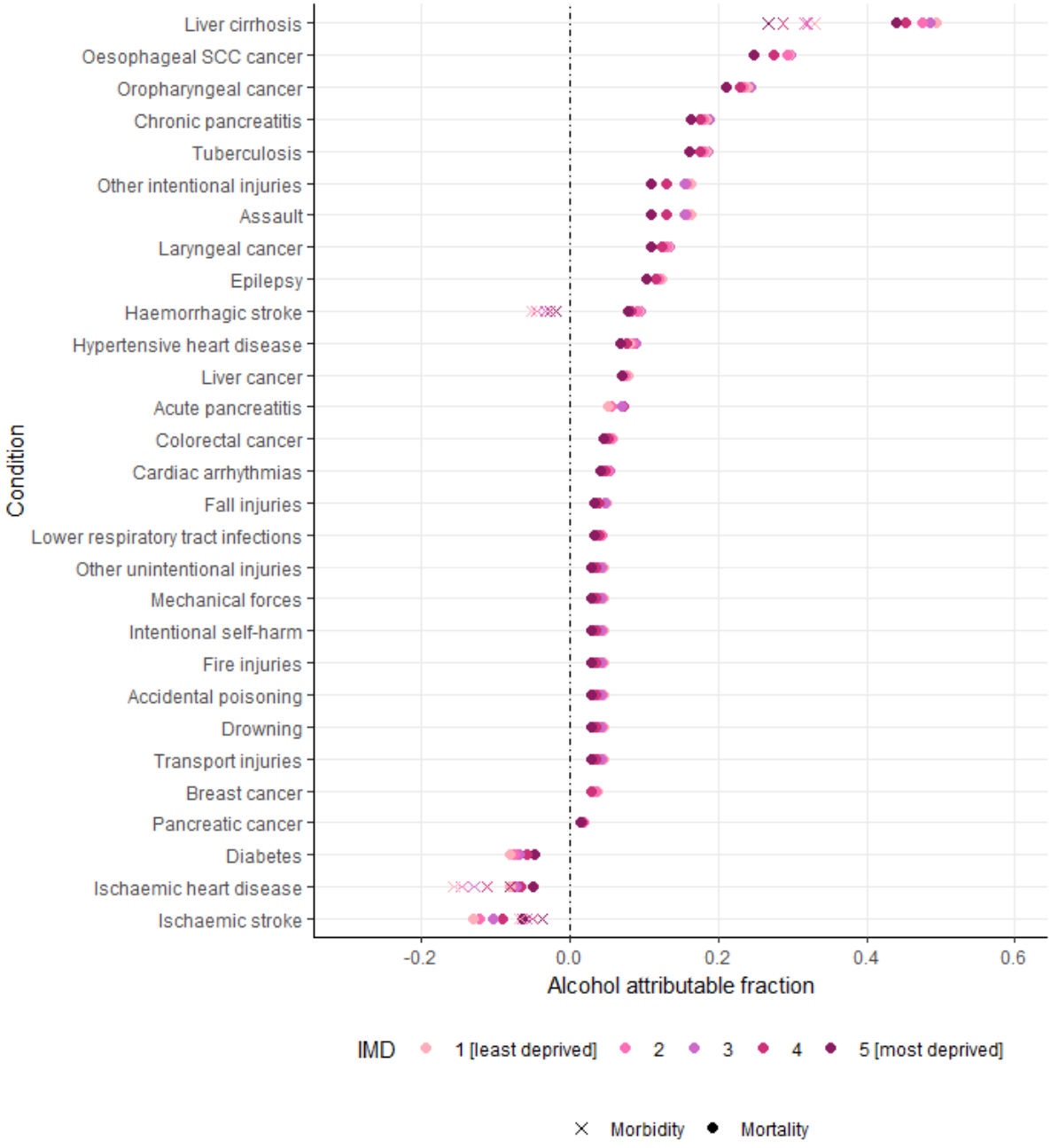


Figure 4. Alcohol attributable fractions by condition and quintiles of the Index of Multiple Deprivation. Each point shows the overall or mortality-specific AAF for each condition; for conditions that have separate mortality- and morbidity-specific risk functions, crosses show the morbidity-specific AAFs. Each colour represents a different level of deprivation.

Appendix A. Supplementary Tables

Table A1. Assumptions of serving sizes and the percentage of alcohol by volume (ABV) i.e. alcoholic strength.

	Item	Assumed value
Serving size	Half pint of beer	284ml
	Can of beer	330ml
	Large can of beer	440ml
	Bottle of beer	330ml
	Single measure of spirits	25ml
	Single measure of sherry	50ml
	Small wine glass	125ml
	Standard wine glass	175ml
	Large wine glass	250ml
	Bottle of wine	750ml
	Small can of alcopops	250ml
	Small bottle of alcopops	275ml
	Large bottle of alcopops	700ml
Alcoholic strength (ABV)	Normal beer or cider	4.4%
	Strong beer or cider	8.4%
	Spirits	38%
	Sherry	17%
	Wine	12.5%
	Alcopops	4.5%

Table A2. Alcohol attributable fractions by condition and sex, with and without protective effects of alcohol.

		Female		Male	
Type	Condition	With protective effects	Without protective effects	With protective effects	Without protective effects
Cancer	Breast	0.06		0.00	
	Colorectal	0.04		0.07	
	Laryngeal	0.09		0.16	
	Liver	0.05		0.10	
	Oesophageal SCC	0.22		0.34	
	Oropharyngeal	0.17		0.29	
	Pancreatic	0.01		0.02	
Endocrine	Diabetes	−0.14	0.00	0.01	0.01
Nervous system	Epilepsy	0.08		0.15	
Cardiovascular	Cardiac arrhythmias	0.03		0.06	
	Haemorrhagic stroke – morbidity	−0.19	0.01	0.09	0.09
	Haemorrhagic stroke—mortality	0.10	0.10	0.08	0.08
	Hypertensive heart disease	0.03		0.13	
	Ischaemic heart disease—morbidity	−0.16	0.01	−0.09	0.00
	Ischaemic heart disease—mortality	−0.05	0.01	−0.09	0.00
	Ischaemic stroke—morbidity	−0.06	0.00	−0.05	0.01
	Ischaemic stroke—mortality	−0.15	0.02	−0.06	0.01
Respiratory	Lower urinary tract infections	0.03		0.05	
	Tuberculosis	0.13		0.22	
Digestive	Acute pancreatitis	−0.04	0.03	0.15	0.15
	Chronic pancreatitis	0.13		0.22	
	Liver Cirrhosis – morbidity	0.38		0.21	
	Liver Cirrhosis – mortality	0.52		0.40	
Injuries	Accidental poisoning	0.03		0.04	
	Assault	0.12		0.16	
	Drowning	0.03		0.04	
	Fall injuries	0.04		0.05	
	Fire injuries	0.03		0.04	
	Intentional self-harm	0.03		0.04	
	Mechanical forces	0.03		0.04	
	Other intentional injuries	0.12		0.16	
	Other unintentional injuries	0.03		0.04	
	Transport injuries	0.03		0.04	

Table A3. Alcohol attributable fractions by condition, age-group, and sex.

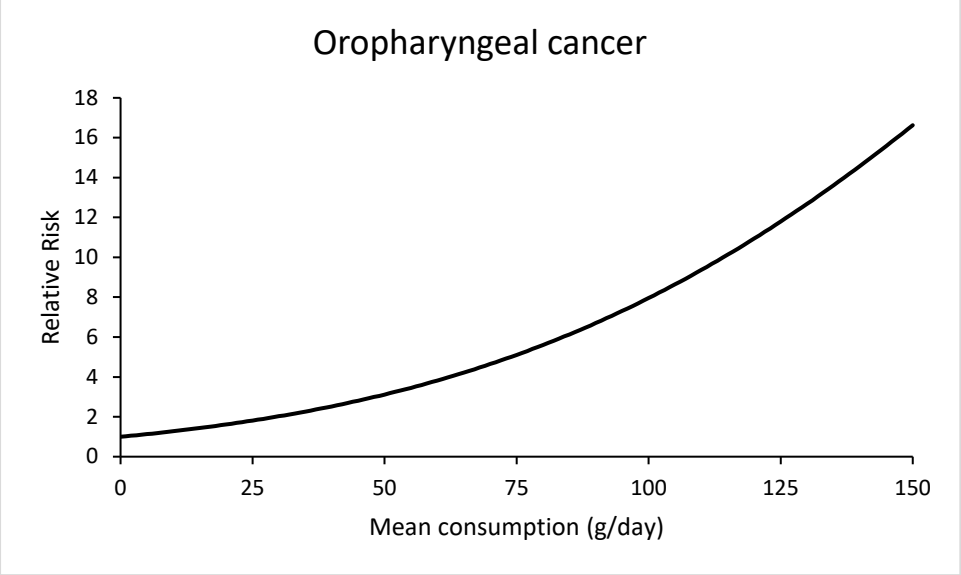
Type	Condition	Female							Male						
		16–17	18–24	25–34	35–49	50–64	65–74	75–89	16–17	18–24	25–34	35–49	50–64	65–74	75–89
Cancer	Breast	0.03	0.09	0.07	0.09	0.08	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Colorectal	0.02	0.05	0.04	0.05	0.05	0.03	0.01	0.02	0.08	0.08	0.09	0.08	0.07	0.04
	Laryngeal	0.04	0.12	0.10	0.12	0.12	0.07	0.03	0.04	0.19	0.18	0.19	0.19	0.17	0.10
	Liver	0.02	0.07	0.05	0.07	0.07	0.04	0.01	0.02	0.12	0.11	0.13	0.12	0.09	0.05
	Oesophageal SCC	0.11	0.27	0.23	0.27	0.27	0.18	0.10	0.11	0.38	0.38	0.39	0.38	0.36	0.23
	Oropharyngeal	0.08	0.22	0.18	0.22	0.21	0.13	0.06	0.07	0.34	0.32	0.34	0.33	0.29	0.17
	Pancreatic	0.01	0.02	0.01	0.02	0.02	0.01	0.00	0.01	0.03	0.03	0.03	0.03	0.02	0.01
Cardiovascular	Cardiac arrhythmias	0.02	0.05	0.04	0.05	0.05	0.03	0.01	0.02	0.08	0.07	0.08	0.08	0.07	0.04
	Haemorrhagic stroke—morbidity	−0.10	−0.20	−0.22	−0.22	−0.23	−0.21	−0.18	0.02	0.10	0.10	0.11	0.10	0.09	0.05
	Haemorrhagic stroke—mortality	0.05	0.13	0.10	0.13	0.13	0.08	0.04	0.02	0.09	0.09	0.09	0.09	0.08	0.05
	Hypertensive heart disease	0.01	0.04	0.03	0.04	0.03	0.02	0.00	0.04	0.15	0.15	0.15	0.15	0.14	0.09
	Ischaemic heart disease—morbidity	−0.09	−0.14	−0.18	−0.18	−0.20	−0.21	−0.16	−0.05	−0.08	−0.10	−0.10	−0.11	−0.12	−0.11
	Ischaemic heart disease—mortality	−0.03	−0.06	−0.07	−0.06	−0.06	−0.04	−0.03	−0.04	−0.11	−0.12	−0.11	−0.11	−0.08	−0.06
	Ischaemic stroke—morbidity	−0.04	−0.05	−0.07	−0.07	−0.07	−0.08	−0.06	−0.04	−0.04	−0.06	−0.05	−0.06	−0.07	−0.08
	Ischaemic stroke—mortality	−0.09	−0.17	−0.20	−0.18	−0.19	−0.13	−0.10	−0.03	−0.06	−0.08	−0.06	−0.07	−0.05	−0.06
Respiratory	Lower respiratory tract infections	0.01	0.04	0.03	0.04	0.04	0.02	0.01	0.01	0.06	0.06	0.06	0.06	0.06	0.03
	Tuberculosis	0.06	0.17	0.13	0.17	0.16	0.10	0.04	0.05	0.27	0.25	0.27	0.26	0.22	0.13
Digestive	Acute pancreatitis	−0.01	−0.04	−0.05	−0.03	−0.06	−0.06	−0.05	0.04	0.18	0.17	0.19	0.18	0.16	0.09
	Chronic pancreatitis	0.06	0.17	0.13	0.17	0.16	0.10	0.04	0.05	0.27	0.25	0.27	0.26	0.22	0.13
	Liver cirrhosis—morbidity	0.22	0.44	0.40	0.45	0.44	0.35	0.23	0.05	0.25	0.23	0.25	0.24	0.21	0.12
	Liver cirrhosis—mortality	0.34	0.59	0.55	0.60	0.59	0.48	0.32	0.09	0.46	0.44	0.48	0.44	0.37	0.22
Endocrine	Diabetes	−0.07	−0.18	−0.17	−0.18	−0.19	−0.14	−0.09	0.00	0.01	0.01	0.01	0.01	0.01	0.00
Nervous system	Epilepsy	0.04	0.11	0.09	0.11	0.11	0.07	0.04	0.04	0.18	0.17	0.18	0.17	0.15	0.09
Injuries	Accidental poisoning	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03
	Assault	0.05	0.13	0.13	0.16	0.18	0.11	0.05	0.04	0.15	0.17	0.19	0.21	0.20	0.11
	Drowning	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03
	Fall injuries	0.01	0.04	0.04	0.05	0.05	0.03	0.01	0.01	0.05	0.05	0.06	0.07	0.06	0.03
	Fire injuries	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03
	Intentional self-harm	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03
	Mechanical forces	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03
	Other intentional injuries	0.05	0.13	0.13	0.16	0.18	0.11	0.05	0.04	0.15	0.17	0.19	0.21	0.20	0.11
	Other unintentional injuries	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03
	Transport injuries	0.01	0.04	0.03	0.04	0.05	0.03	0.01	0.01	0.04	0.05	0.05	0.06	0.05	0.03

Appendix B. Risk functions

This appendix presents the mathematical relationships between volume of alcohol consumed and risk of morbidity/mortality. It is a duplicate of the information presented in our previous report [7], presented again here to aid the reader.

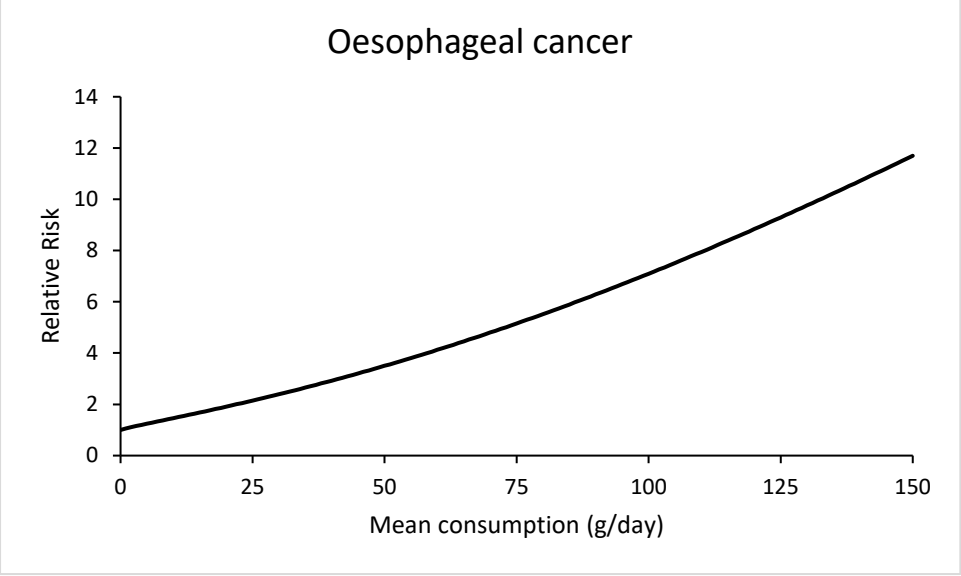
CANCERS

Figure B1. Oropharyngeal cancer (C00–06, C09–10, C12–14)



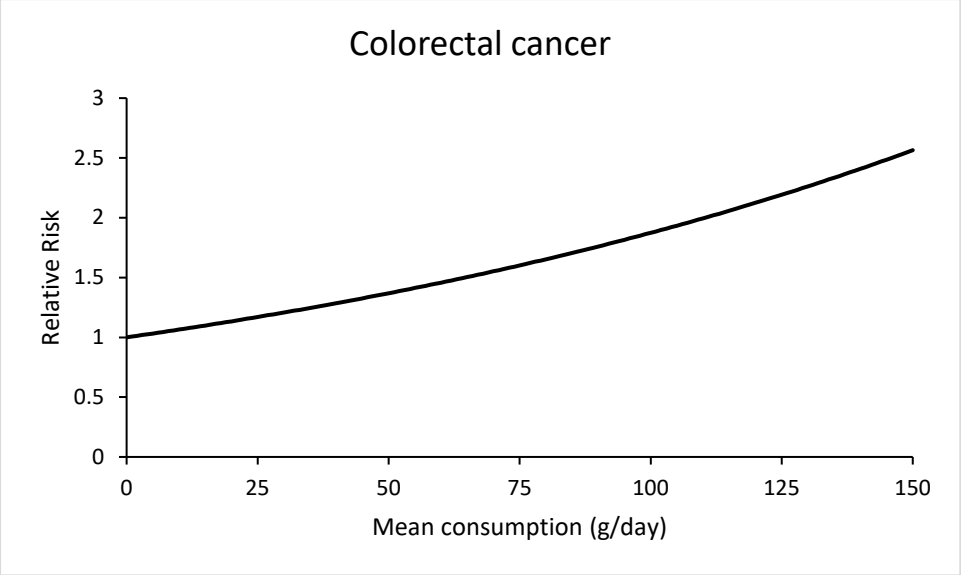
Source: Bagnardi et al. [8]

Figure B2. Oesophageal cancer (C15)



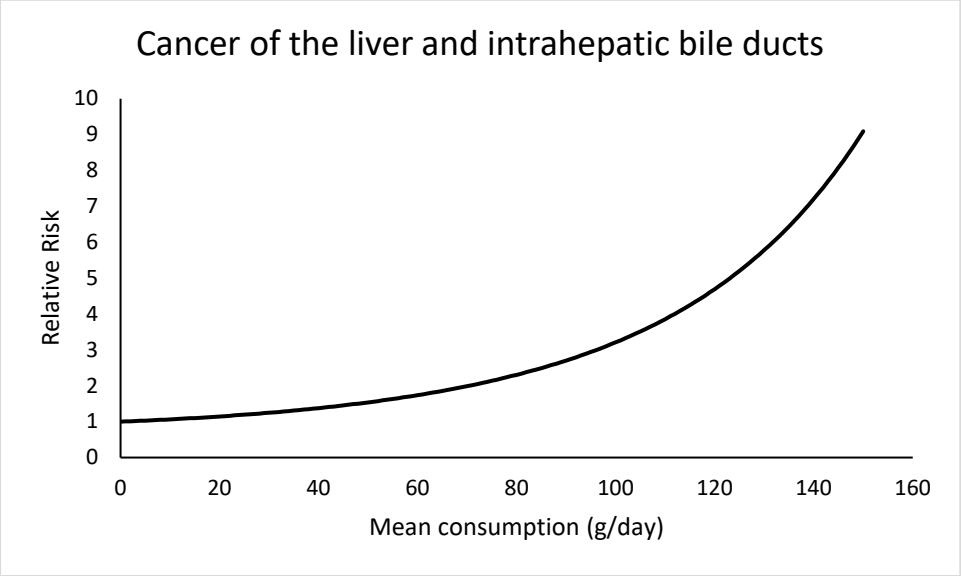
Source: Bagnardi et al. [8]

Figure B3. Colorectal cancer (C18–C20)



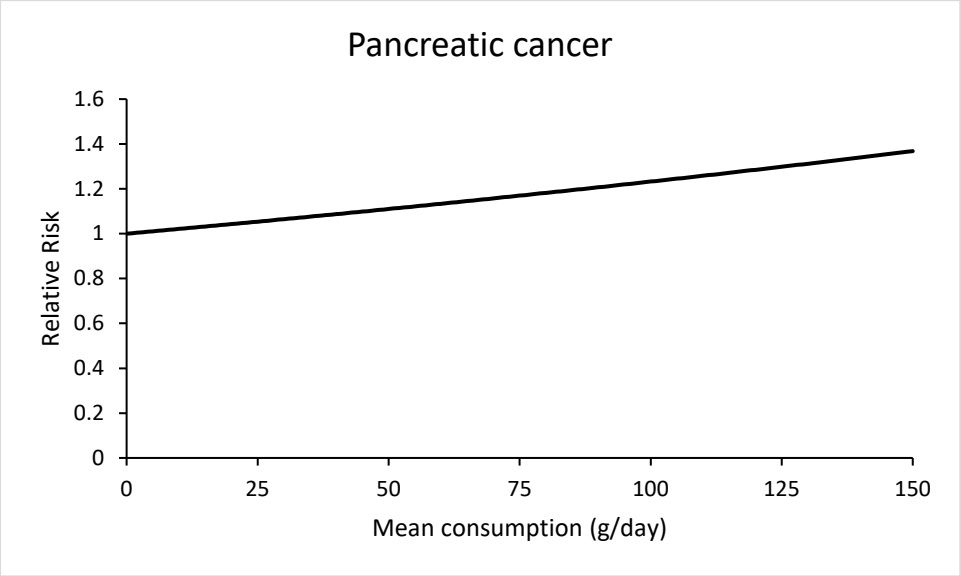
Source: Bagnardi et al. [8]

Figure B4. Liver and intrahepatic bile ducts (C22)



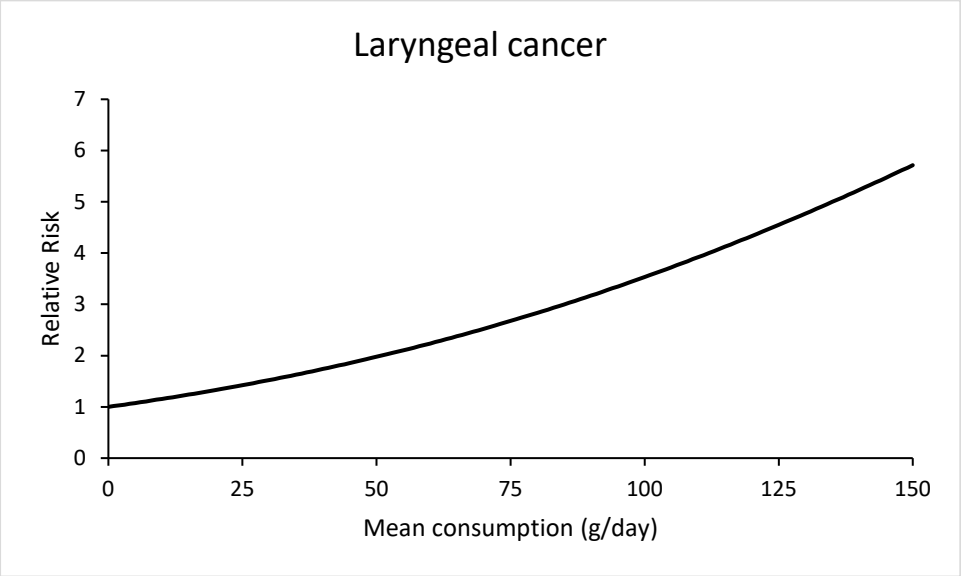
Source: Chuang et al. [37]

Figure B5. Pancreatic cancer (C25)



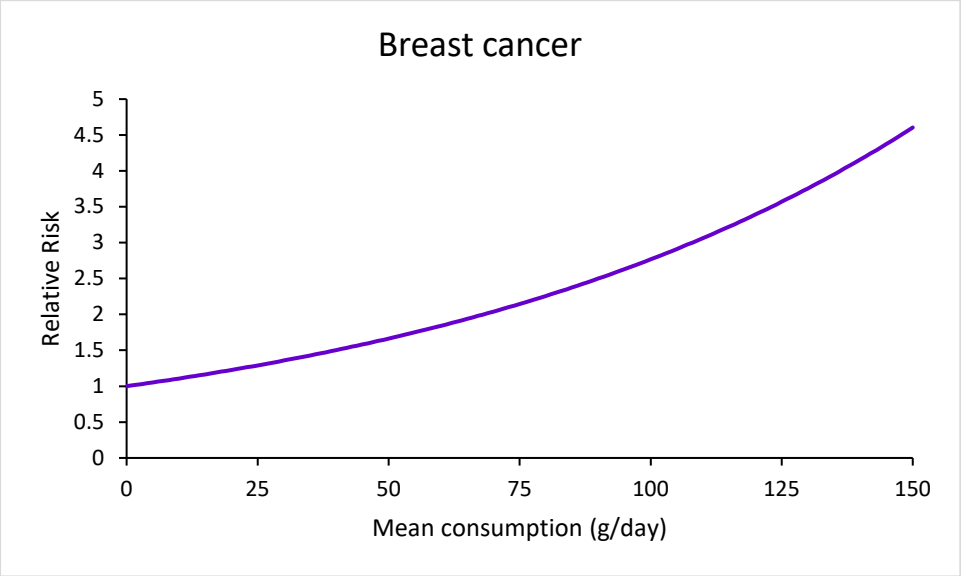
Source: Bagnardi et al. [8]

Figure B6. Laryngeal cancer (C32)



Source: Bagnardi et al. [8]

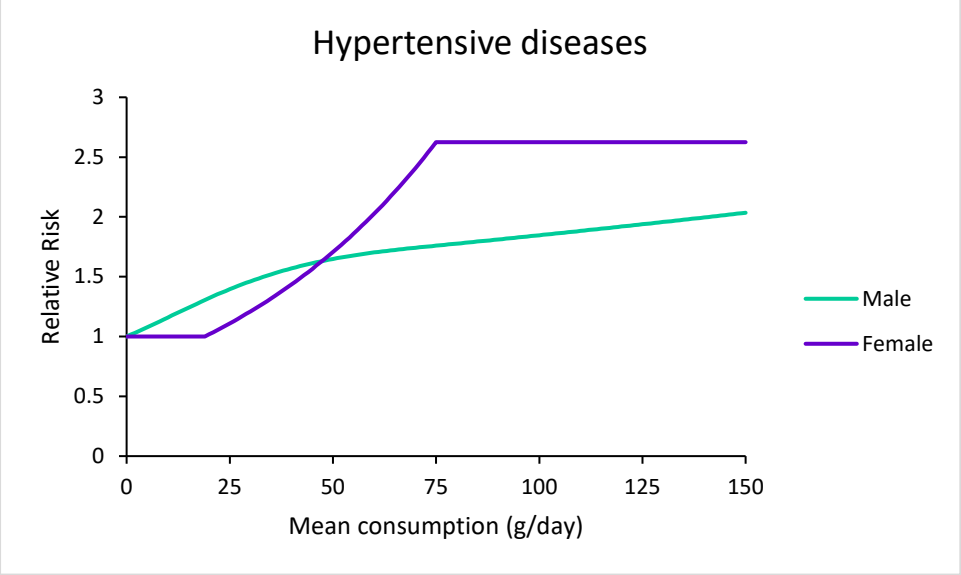
Figure B7. Breast cancer—females (C50)



Source: Bagnardi et al. [8]

CARDIOVASCULAR DISEASES

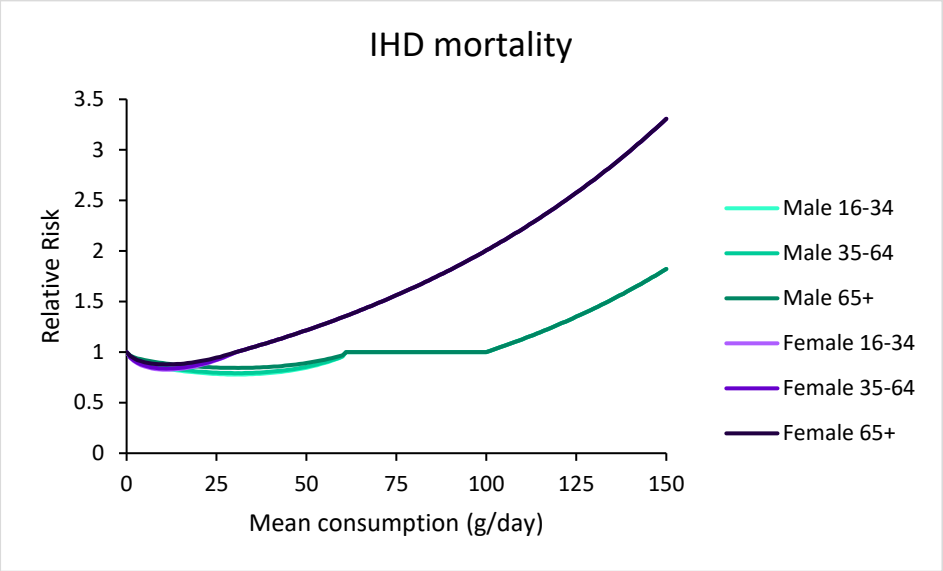
Figure B8. Hypertensive diseases (I10–I14)



Source: Rehm et al. [28]

Figure B9. Ischaemic heart disease (I20–I25)

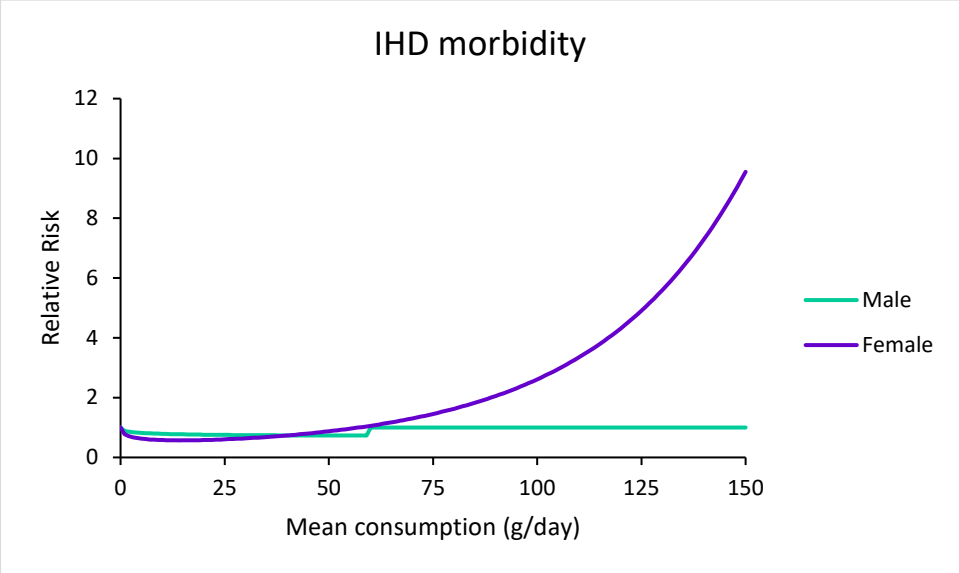
(a) Mortality



Source: Rehm et al. [10]

Notes: All protective effects are removed for drinkers who consume more than 60g in a single drinking occasion at least once per month, as per Roerecke & Rehm [32].

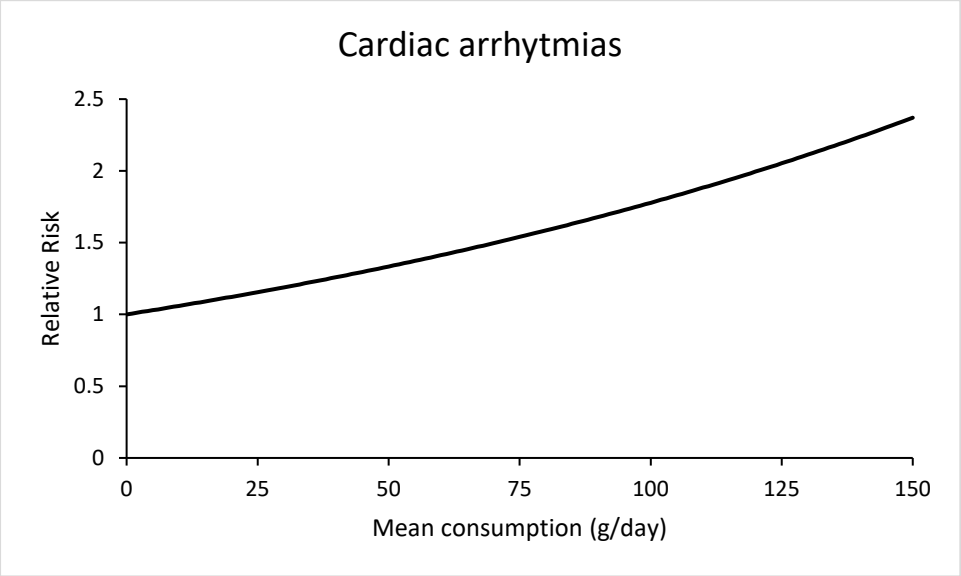
(b) Morbidity



Source: Roerecke & Rehm [31]

Notes: All protective effects are removed for drinkers who consume more than 60g in a single drinking occasion at least once per month, as per Roerecke & Rehm [32].

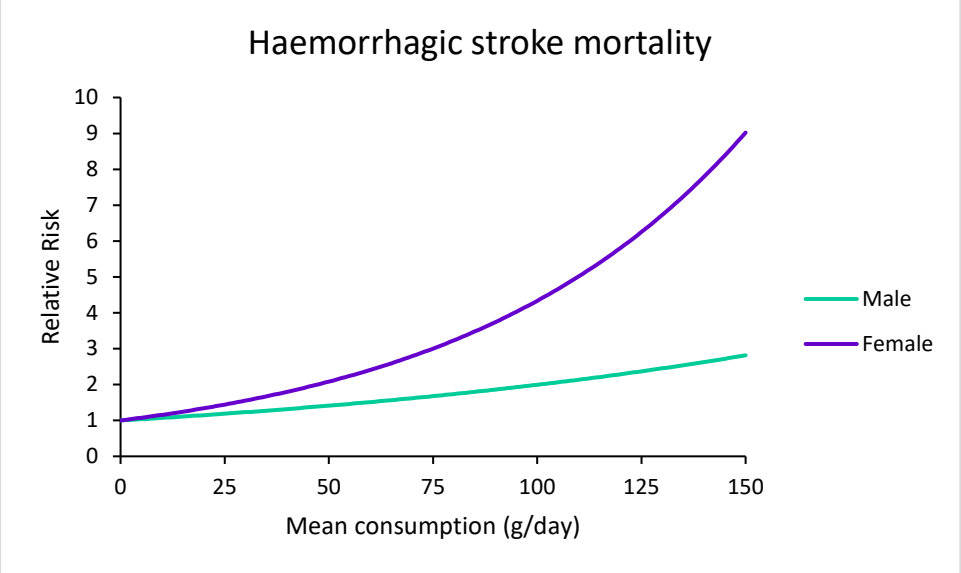
Figure B10. Cardiac arrhythmias (I47–I49)



Source: Samokhvalov et al. [38]

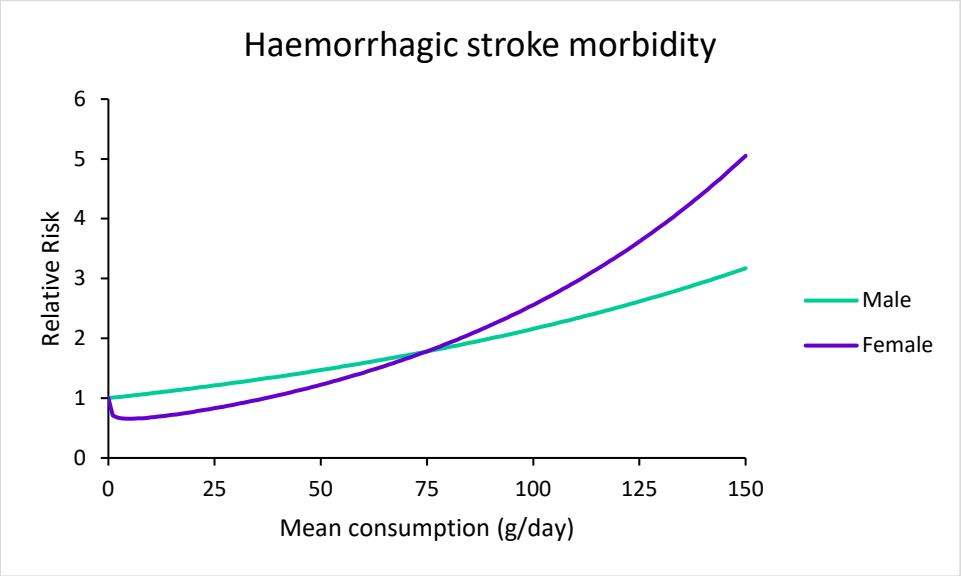
Figure B11. Haemorrhagic and other non-ischaemic stroke (I60–I62)

(a) Mortality



Source: Patra et al. [30]

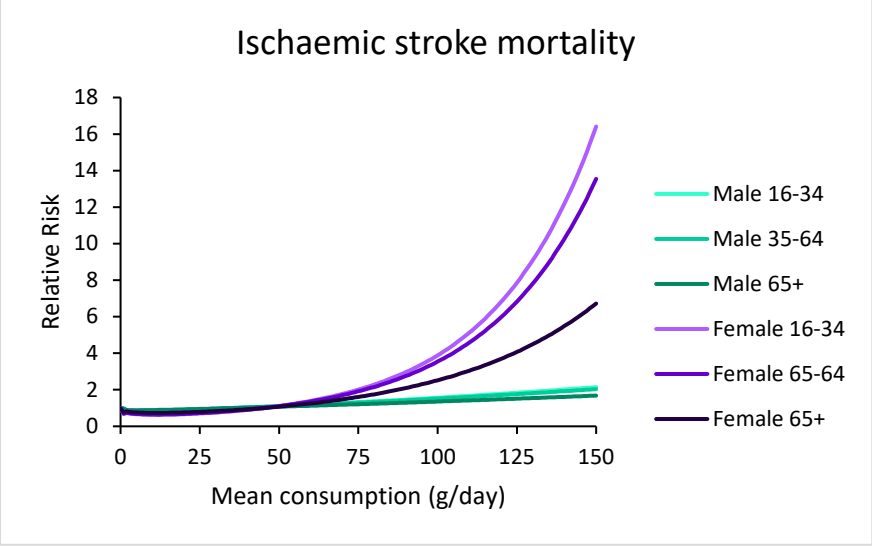
(b) Morbidity



Source: Patra et al. [30]

Figure B12. Ischaemic stroke (I63–I67)

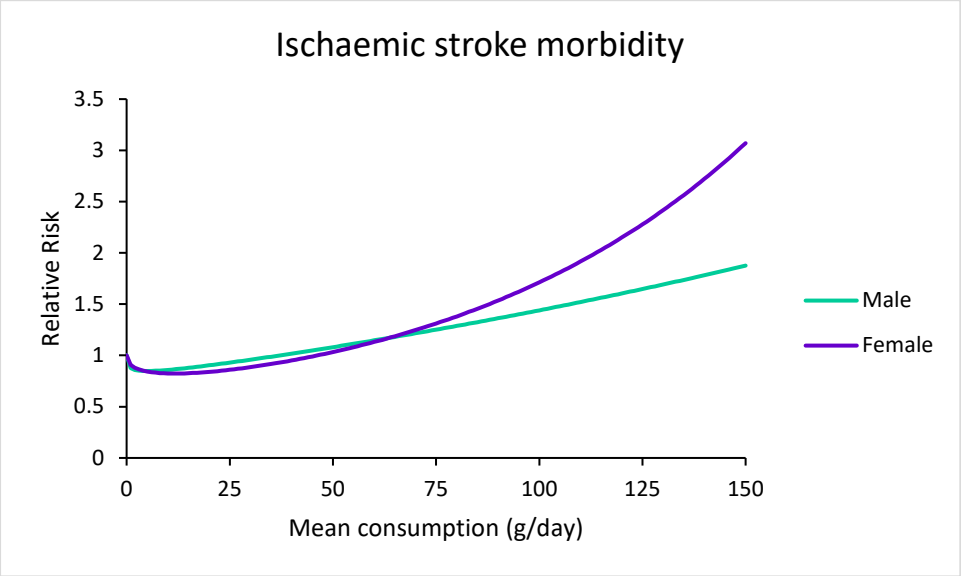
(a) Mortality



Source: Rehm et al. [10]

Notes: All protective effects are removed for drinkers who consume more than 60g in a single drinking occasion at least once per month, as per Roerecke & Rehm [32].

(b) Morbidity



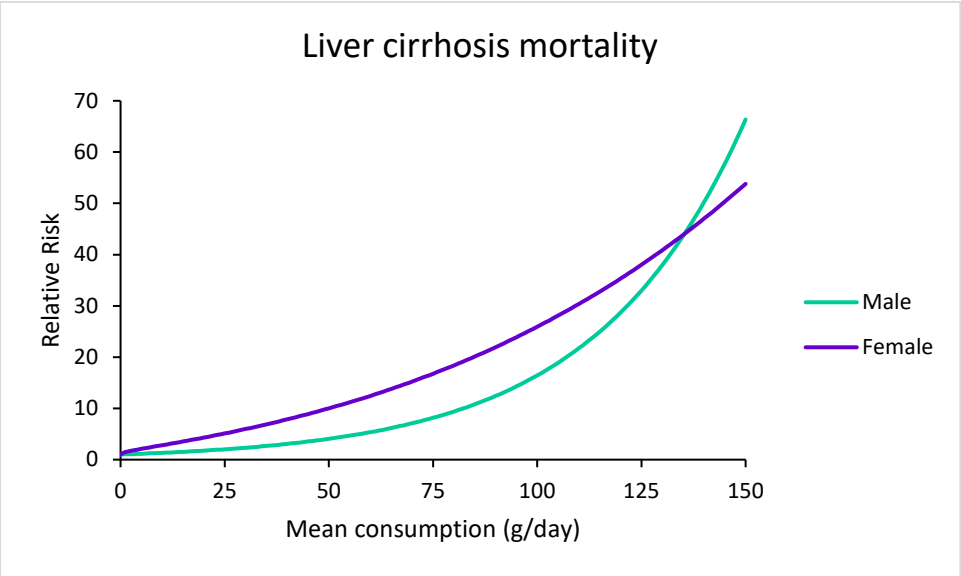
Source: Patra et al. [30]

Notes: All protective effects are removed for drinkers who consume more than 60g in a single drinking occasion at least once per month, as per Roerecke & Rehm [32].

DIGESTIVE DISEASES

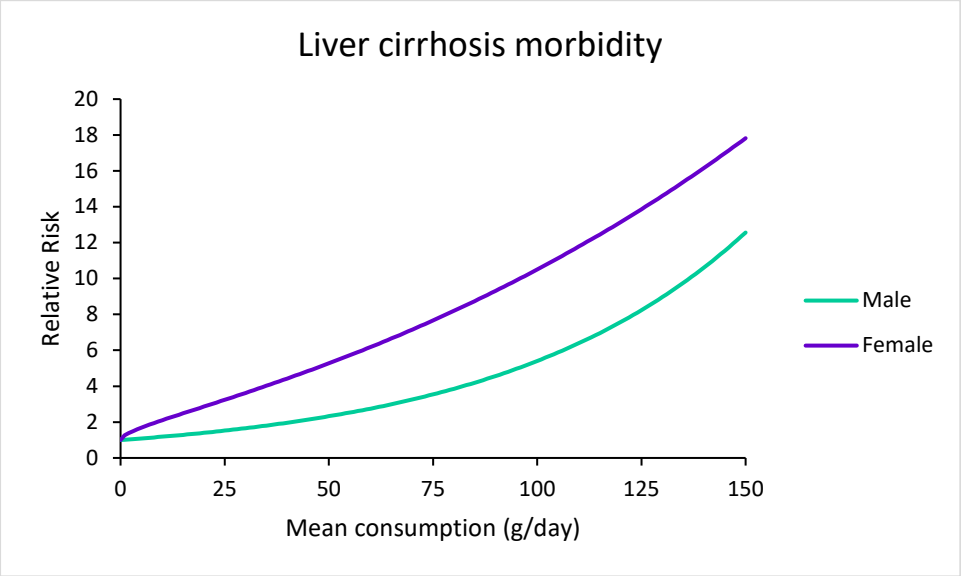
Figure B13. Cirrhosis of the liver (K70 (excl. K70.0–K70.4, K70.9), K73–K74)

(a) Mortality



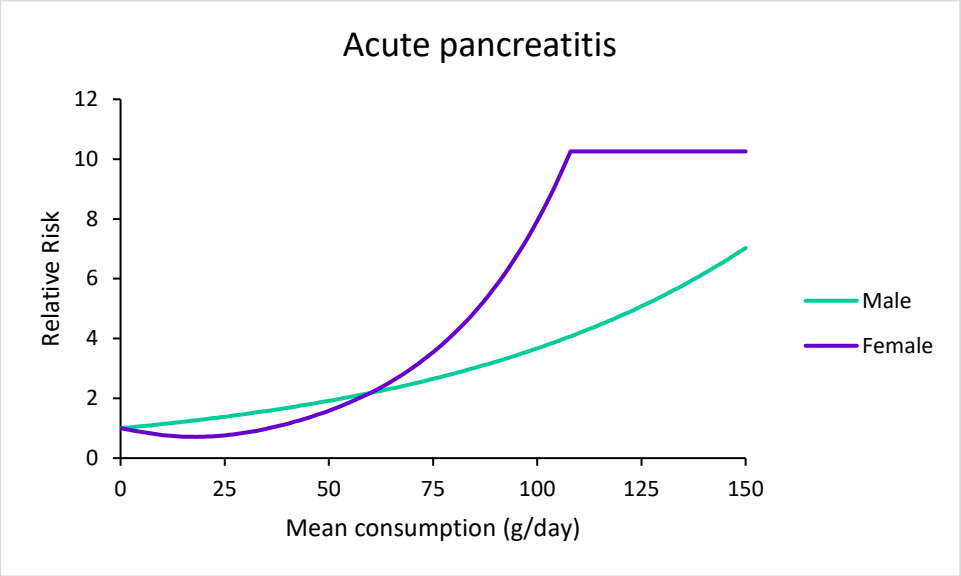
Source: Rehm et al. [33]

(b) Morbidity



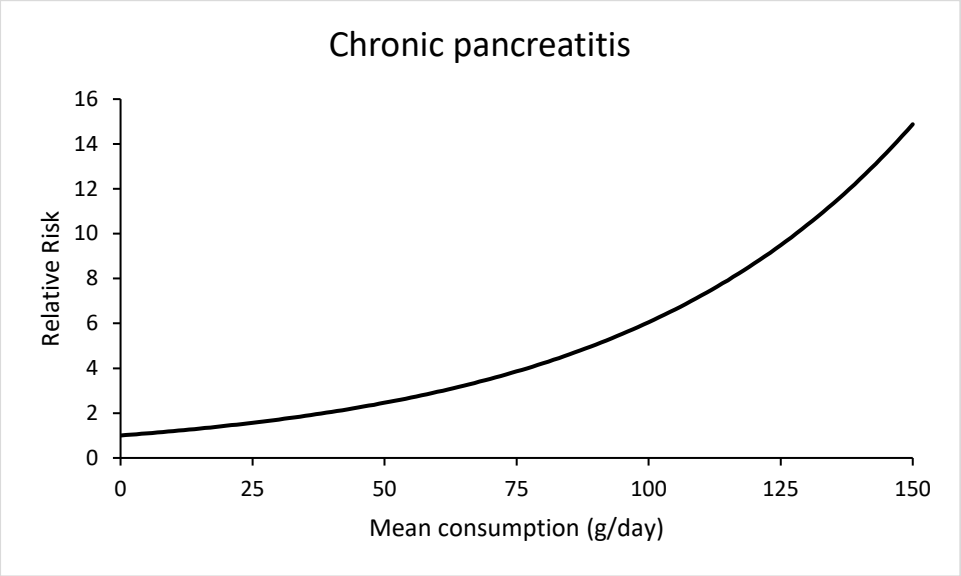
Source: Rehm et al. [33]

Figure B14. Acute pancreatitis (K85 (excl. K85.2, K85.3))



Source: Samokhvalov et al. [11]

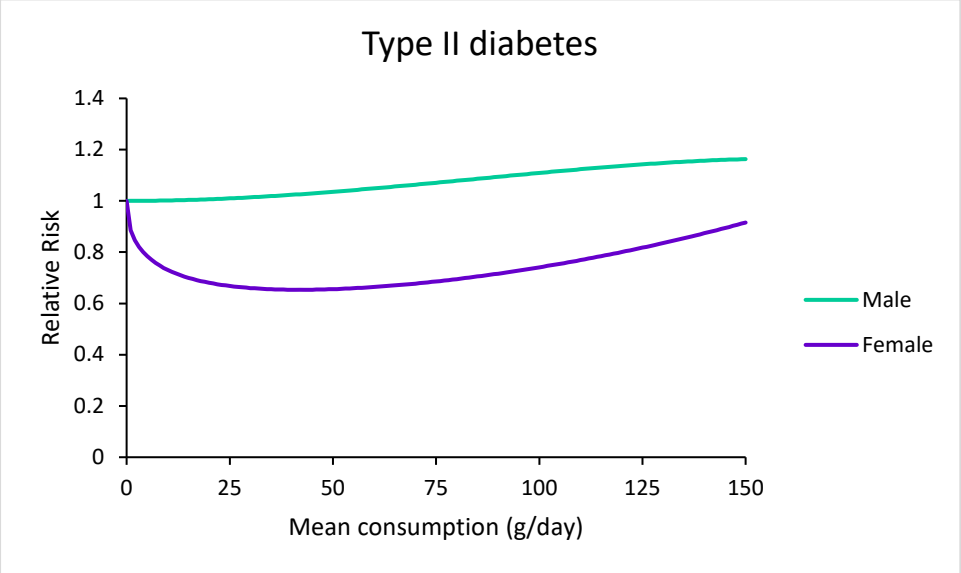
Figure B15. Chronic pancreatitis (K86 (excl. K86.0))



Source: Samokhvalov et al. [11]

ENDOCRINE DISEASES

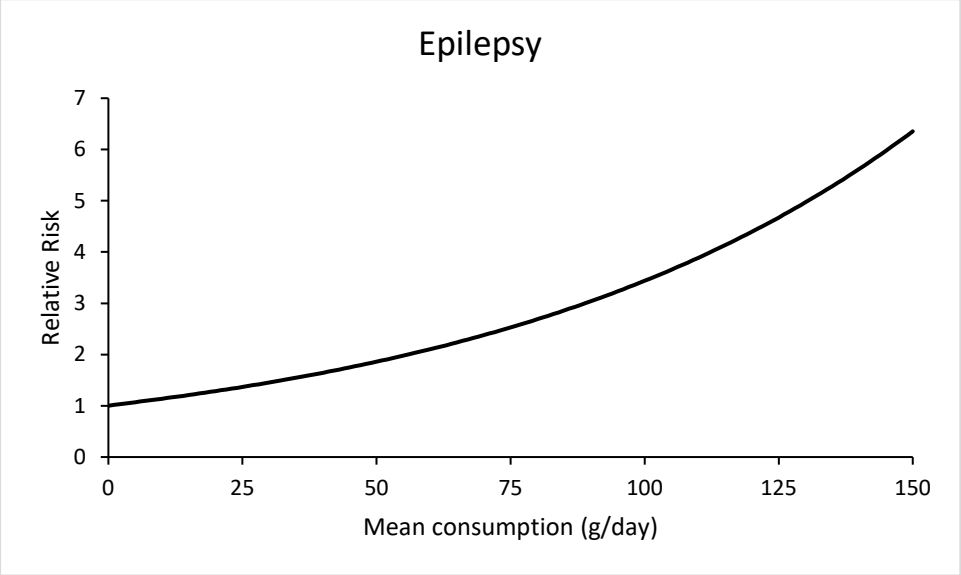
Figure B16. Diabetes mellitus (type II) (E11)



Source: Knott et al. [12]

DISEASES OF THE NERVOUS SYSTEM

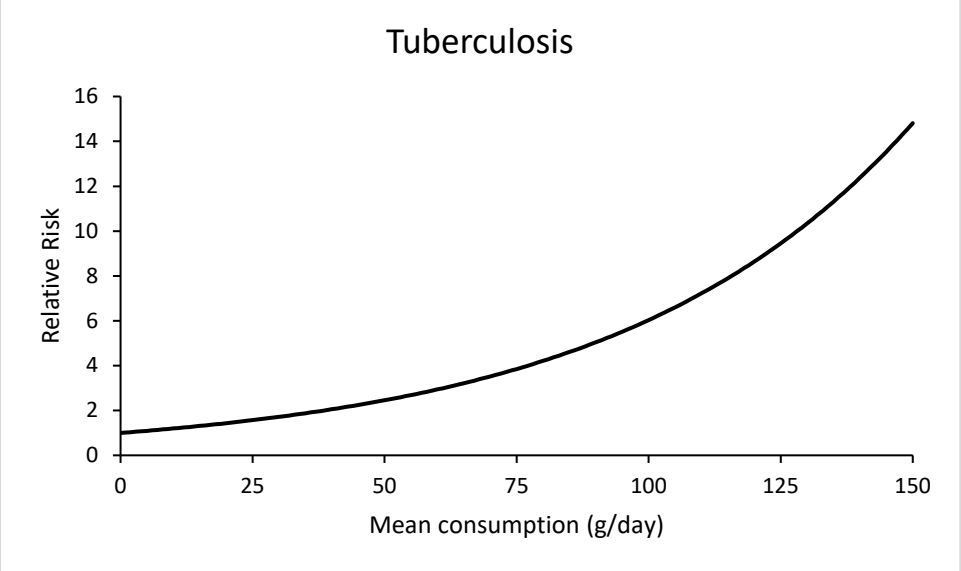
Figure B17. Epilepsy and status epilepticus (G40–G41)



Source: Samokhvalov et al. [39]

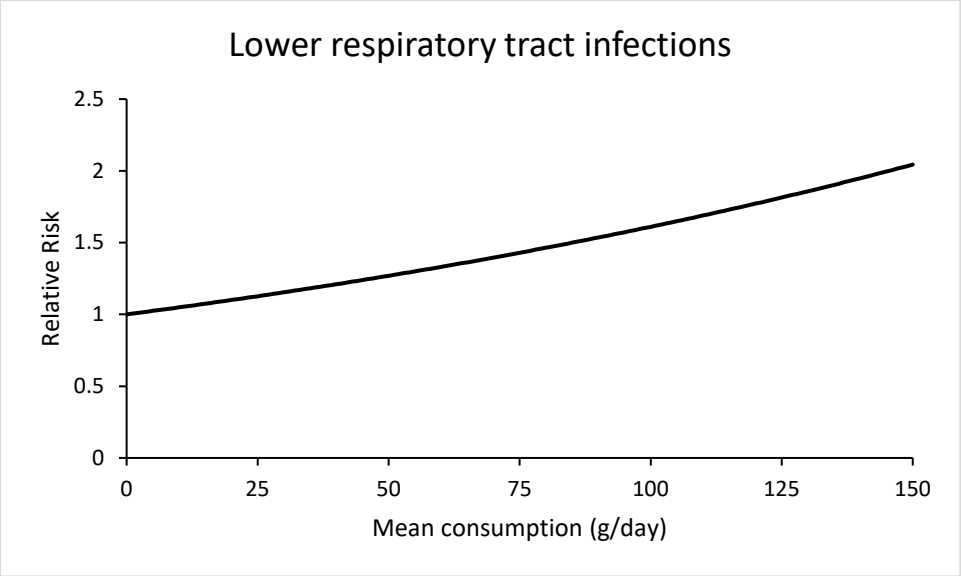
RESPIRATORY DISEASES

Figure B18. Tuberculosis (A15–A19)



Source: Imtiaz et al. [13]

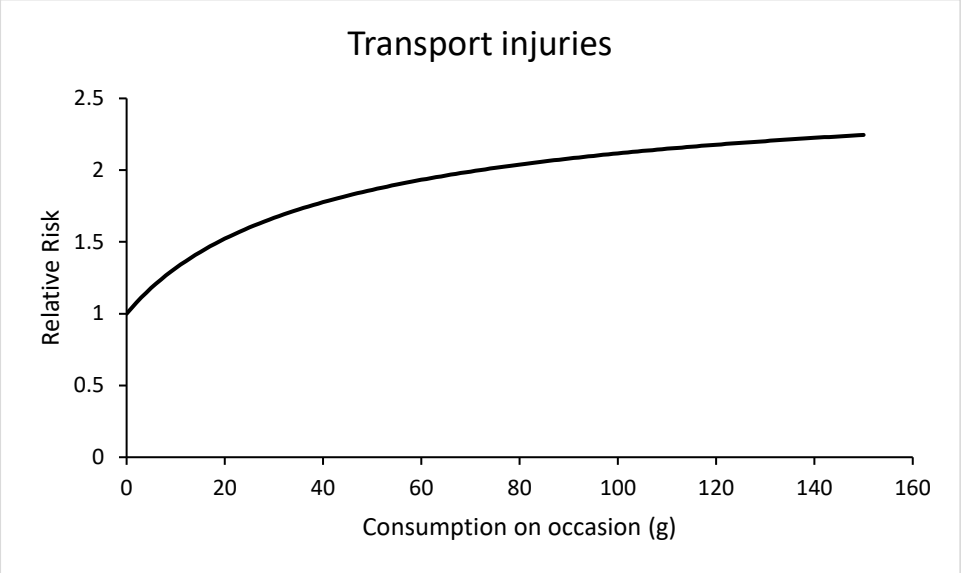
Figure B19. Lower respiratory tract infections (J09–J18)



Source: Samokhvalov et al. [40]

ACUTE CONSEQUENCES

Figure B20. Transport Injuries (V01–V98, Y85.0)

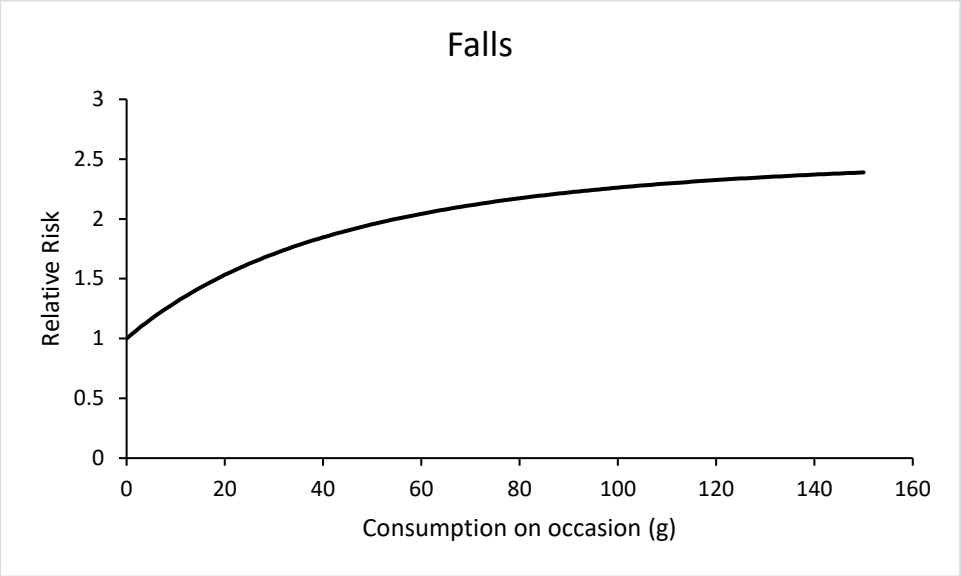


Source: Cherpitel et al. [14]

Figure B21. Violent injuries (X85–Y09, Y87.1 & Y35)

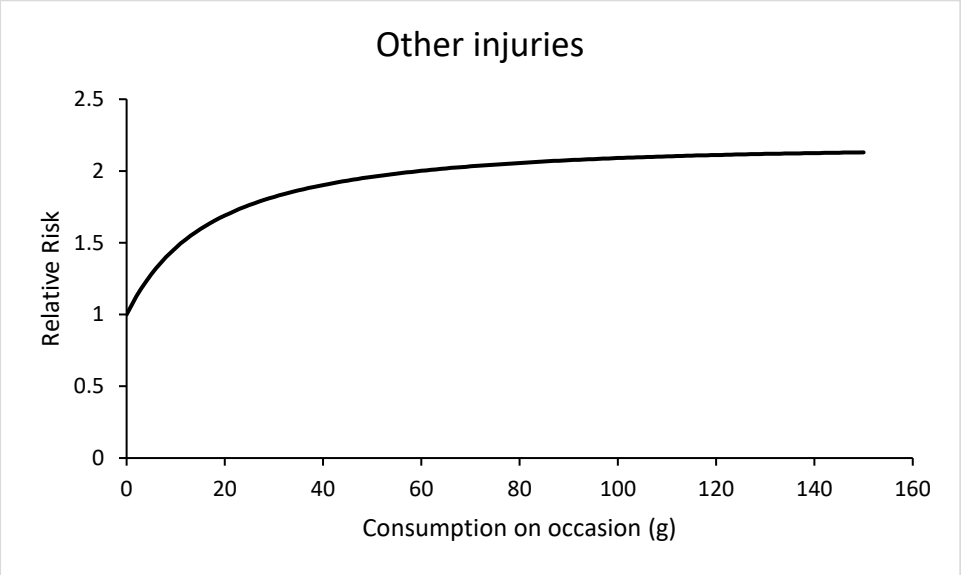
Source: Cherpitel et al. [14]

Figure B22. Falls (W00–W19)



Source: Cherpitel et al. [14]

Figure B23. Other injuries (W20–W52, W65–W74, Y21, X00–X09, Y26, W75–W99, X10–X33, Y20, Y22–Y25, Y27–Y29, Y31–Y34, X60–X84 (excl. X65), Y87.0)



Source: Cherpitel et al. [14]

References

1. Brown KF, Rumgay H, Dunlop C, Ryan M, Quartly F, Cox A, et al. The fraction of cancer attributable to modifiable risk factors in England, Wales, Scotland, Northern Ireland, and the United Kingdom in 2015. British Journal of Cancer. 2018;118(8):1130-41. doi: 10.1038/s41416-018-0029-6.
2. Jones L, Bellis MA. Updating England-specific alcohol-attributable fractions. Liverpool: Centre for Public Health, Liverpool John Moores University. 2014.
3. Green MA, Strong M, Conway L, Maheswaran R. Trends in alcohol-related admissions to hospital by age, sex and socioeconomic deprivation in England, 2002/03 to 2013/14. BMC public health. 2017;17(1):412.
4. Maheswaran R, Green MA, Strong M, Brindley P, Angus C, Holmes J. Alcohol outlet density and alcohol related hospital admissions in England: a national small‐area level ecological study. Addiction. 2018.
5. Public Health England. Local Alcohol Profiles for England https://fingertips.phe.org.uk/profile/local-alcohol-profiles2018.
6. NHS Digital. Statistics on Alcohol: England, 2018. https://digital.nhs.uk/data-and-information/publications/statistical/statistics-on-alcohol/2018: 2018.
7. Angus C, Henney M, Webster L, Gillespie D. Alcohol-attributable diseases and dose-response curves for the Sheffield Alcohol Policy Model version 4.0. https://figshare.com/articles/Alcohol-attributable_diseases_and_dose-response_curves_for_the_Sheffield_Alcohol_Policy_Model_version_4_0/68196892018.
8. Bagnardi V, Rota M, Botteri E, Tramacere I, Islami F, Fedirko V, et al. Alcohol consumption and site-specific cancer risk: a comprehensive dose-response meta-analysis. British Journal of Cancer. 2015;112(3):580-93. doi: 10.1038/bjc.2014.579. PubMed PMID: WOS:000349403200024.
9. Rehm J, Shield K, Gmel G. Risk relations between alcohol use and non-injury causes of death. . https://www.camh.ca/en/research/news_and_publications/reports_and_books/Documents/CAMH-Risk-relations-between-alcohol-use-and-non-injury-causes-of-death-Sept2017.pdf: 2017.
10. Rehm J, Shield KD, Roerecke M, Gmel G. Modelling the impact of alcohol consumption on cardiovascular disease mortality for comparative risk assessments: an overview. BMC Public Health. 2016;16(1):363.
11. Samokhvalov AV, Rehm J, Roerecke M. Alcohol consumption as a risk factor for acute and chronic pancreatitis: a systematic review and a series of meta-analyses. EBioMedicine. 2015;2(12):1996-2002.
12. Knott C, Bell S, Britton A. Alcohol consumption and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of more than 1.9 million individuals from 38 observational studies. Diabetes care. 2015;38(9):1804-12.
13. Imtiaz S, Shield KD, Roerecke M, Samokhvalov AV, Lönnroth K, Rehm J. Alcohol consumption as a risk factor for tuberculosis: meta-analyses and burden of disease. European Respiratory Journal. 2017;50(1):1700216.
14. Cherpitel CJ, Ye Y, Bond J, Borges G, Monteiro M, Chou P, et al. Alcohol Attributable Fraction for Injury Morbidity from the Dose‐Response Relationship of Acute Alcohol Consumption: Emergency Department Data from 18 Countries. Addiction. 2015;110(11):1724-32.
15. Hill-McManus D, Angus C, Meng Y, Holmes J, Brennan A, Meier P. Injury alcohol-attributable fractions: methodological issues and developments. http://eprints.whiterose.ac.uk/97968/: Health Economics and Decision Science, School of Health and Related Research (ScHARR), University of Sheffield , Sheffield., 2014.
16. Hill-McManus D, Angus C, Meng Y, Holmes J, Brennan A, Meier PS. Estimation of usual occasion-based individual drinking patterns using diary survey data. Drug and alcohol dependence. 2014;134:136-43.
17. Posey D, Mozayani A. The estimation of blood alcohol concentration. Forensic science, medicine, and pathology. 2007;3(1):33-9.
18. Watson PE, Watson ID, Batt RD. Prediction of blood alcohol concentrations in human subjects. Updating the Widmark Equation. Journal of studies on alcohol. 1981;42(7):547-56.
19. Sadler S, Angus C, Gavens L, Gillespie D, Holmes J, Hamilton J, et al. Understanding the alcohol harm paradox: an analysis of sex‐and condition‐specific hospital admissions by socio‐economic group for alcohol‐associated conditions in England. Addiction. 2017;112(5):808-17.
20. White C, Edgar G, Siegler V. Social inequalities in male mortality for selected causes of death by the National Statistics Socio-economic Classification, England and Wales, 2001-03. Health Statistics Quarterly. 2008;(38):19.
21. Mackenbach JP, Stirbu I, Roskam A-JR, Schaap MM, Menvielle G, Leinsalu M, et al. Socioeconomic inequalities in health in 22 European countries. New England Journal of Medicine. 2008;358(23):2468-81.

22. NatCen Social Research, University College London. Department of Epidemiology and Public Health. Health Survey for England, 2016. [data collection]. UK Data Service SN: 8334, http://doiorg/105255/UKDA-SN-8334-12018.
23. Department for Communities and Local Government. English indices of deprivation 2015 https://www.gov.uk/government/statistics/english-indices-of-deprivation-20152015.
24. R Core Team. R: A Language and Environment for Statistical Computing. Vienna, Austria. URL https://www.R-project.org/: R Foundation for Statistical Computing, 2018.
25. van Buuren S, Groothuis-Oudshoorn K. mice: Multivariate Imputation by Chained Equations in R. Journal of Statistical Software. 2011;45(3):1-67.
26. Sherk A, Stockwell T, Rehm J, Dorocicz J, Shield KD. The International Model of Alcohol Harms and Policies (InterMAHP): A comprehensive guide to the estimation of alcohol-attributable morbidity and mortality. Version 1.0:
December 2017. www.intermahp.cisur.ca: Canadian Institute for Substance Use Research, University of Victoria, British Columbia, Canada., 2017.
27. Arnold M, Soerjomataram I, Ferlay J, Forman D. Global incidence of oesophageal cancer by histological subtype in 2012. Gut. 2015;64(3):381-7.
28. Rehm J, Gmel GE, Gmel G, Hasan OS, Imtiaz S, Popova S, et al. The relationship between different dimensions of alcohol use and the burden of disease—an update. Addiction. 2017.
29. Meier PS, Holmes J, Angus C, Ally AK, Meng Y, Brennan A. Estimated Effects of Different Alcohol Taxation and Price Policies on Health Inequalities: A Mathematical Modelling Study. PLoS Med. 2016;13(2):e1001963. doi: 10.1371/journal.pmed.1001963.
30. Patra J, Taylor B, Irving H, Roerecke M, Baliunas D, Mohapatra S, et al. Alcohol consumption and the risk of morbidity and mortality for different stroke types-a systematic review and meta-analysis. BMC Public Health. 2010;10(1):258.
31. Roerecke M, Rehm J. The cardioprotective association of average alcohol consumption and ischaemic heart disease: a systematic review and meta‐analysis. Addiction. 2012;107(7):1246-60.
32. Roerecke M, Rehm J. Irregular heavy drinking occasions and risk of ischemic heart disease: a systematic review and meta-analysis. American journal of epidemiology. 2010;171(6):633-44.
33. Rehm J, Taylor B, Mohapatra S, Irving H, Baliunas D, Patra J, et al. Alcohol as a risk factor for liver cirrhosis: A systematic review and meta‐analysis. Drug and alcohol review. 2010;29(4):437-45.
34. Fekjaer HO. Alcohol—a universal preventive agent? A critical analysis. Addiction. 2013;108(12):2051-7.
35. Kawakita D, Matsuo K. Alcohol and head and neck cancer. Cancer and Metastasis Reviews. 2017;36(3):425-34.
36. Jones L, Bates G, McCoy E, Bellis MA. Relationship between alcohol-attributable disease and socioeconomic status, and the role of alcohol consumption in this relationship: a systematic review and meta-analysis. BMC public health. 2015;15(1):400.
37. Chuang S-C, Lee Y-CA, Wu G-J, Straif K, Hashibe M. Alcohol consumption and liver cancer risk: a meta-analysis. Cancer Causes & Control. 2015;26(9):1205-31.
38. Samokhvalov AV, Irving HM, Rehm J. Alcohol consumption as a risk factor for atrial fibrillation: a systematic review and meta-analysis. European Journal of Cardiovascular Prevention & Rehabilitation. 2010;17(6):706-12.
39. Samokhvalov AV, Irving H, Mohapatra S, Rehm J. Alcohol consumption, unprovoked seizures, and epilepsy: A systematic review and meta‐analysis. Epilepsia. 2010;51(7):1177-84.
40. Samokhvalov A, Irving H, Rehm J. Alcohol consumption as a risk factor for pneumonia: a systematic review and meta-analysis. Epidemiology & Infection. 2010;138(12):1789-95.