Public Health England

Protecting and improving the nation's health

Alcohol-attributable fractions for England: An update

Appendix 2: Technical appendix

About Public Health England

Public Health England exists to protect and improve the nation's health and wellbeing and reduce health inequalities. We do this through world-leading science, research, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. We are an executive agency of the Department of Health and Social Care, and a distinct delivery organisation with operational autonomy. We provide government, local government, the NHS, Parliament, industry and the public with evidence-based professional, scientific and delivery expertise and support.

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Alcohol consumption in England

The most recent alcohol consumption data was estimated from the 2016 Health Survey for England (HSE2016) data. Individual level raw data from HSE2016 was extracted and used to estimate the alcohol attributable factions (AAF) in this study. The relevant variables extracted from the dataset along with the exclusion and inclusion criteria are summarised below:

- variable = Age16g5: This variable identifies the age group that an individual aged 16 years or above falls into. A 5-year band was used for individuals aged 20 years or above and a 2-year band was used for those aged between 16 to 19 years. Individuals aged 16 and over in England were used in the study, ie Age16g5>0
- variable = Sex: This variable is used to determine the gender of each individual in the sample. Both males and females were included in this study, ie, Sex>0
- variable = alcbase: This variable is used to categorise individuals as either a former drinker, a lifetime abstainer or a current drinker. We included all individuals with valid information for this variable, ie, alcbase>0
- variable = totalwu: The variable specifies the total units of alcohol consumed by an individual in units per week. All individuals with valid information were included in the analysis, ie, totalwu>0
- variable = d7unitwgrp: The variable is used to determine whether a current drinker is a binge drinker. A person who reports to have over 6 units on the heaviest drinking day in the last 7 days is categorised as a binge drinker. Among binge drinkers, a person that has up to 8 units on the heaviest drinking day is categorised as a type 1 binge drinker, over 8 units as a type 2 binge drinker
- note that the relative risk for the acute condition at a drinking level (x) was adjusted for the time at risk in order to calculate the risk ratio of binge drinkers (RR_{binge}). (1 drink [~10 grams of alcohol] = 30 minutes; 3 drinks = 2 hours; 5 drinks = 3 hours; 7 drinks = 4.8 hours)(Jones & Bellis, 2013)

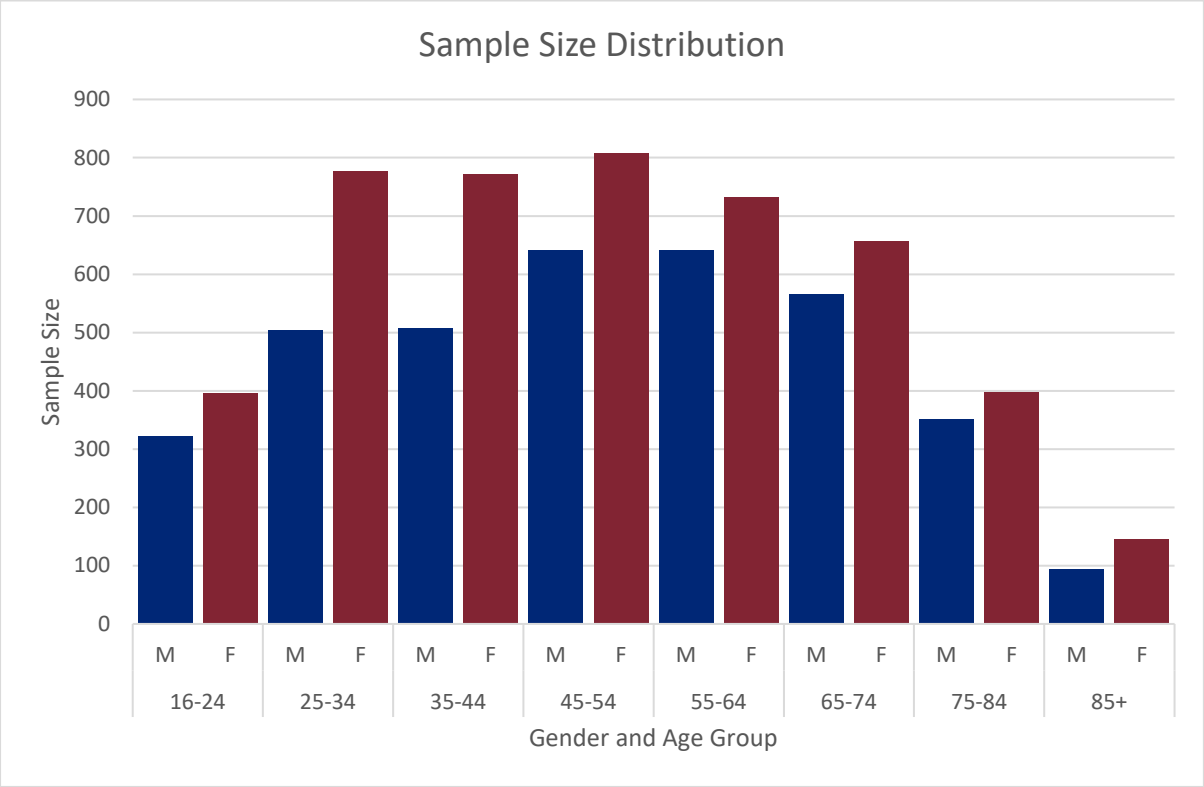
- variable = dnany: This variable is used to decide whether a person is a former drinker. A person who drinks “very occasionally”, ie dnany = 1, is categorised as a former drinker
- variable = dnoft: This variable is used to decide whether a person is a former drinker. A person who reports to “have not drunk alcohol at all in the last 12 months”, ie, dnoft = 8, is categorised as a former drinker
- variable = dnevr: This variable is used to decide whether a person is a former drinker. A person who reports to “used to drink, but stopped”, ie, dnevr = 2, is categorised as a former drinker

Age- and Gender-specific distribution of current and binge drinkers

The population was divided into three group, lifetime abstainers, former drinkers and current drinkers. In total, 778 lifetime abstainers, 1203 former drinkers and 6326 current drinkers were included. These results were used to estimate the distribution of alcohol consumption for the whole population.

Each drinking group was further stratified into 10-year age and gender groups, ie, 16-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65-74 years, 75-84 years, 85+ years. The sample size distribution over all age- and gender-specific groups is shown in Table 1 and Figure 1. The age groups between 45 and 64 years contained relatively large sample sizes compared with the other age groups. For this reason, the variance for these two age groups was relatively low and the results were more reliable. Age groups 25 to 34 years and 75 to 84 years had relatively smaller sample sizes and the results for these groups were therefore less reliable. The 85+ year old age group had the smallest sample size and therefore the highest variance. The distribution of different drinking groups within each age- and gender-specific groups is shown in Table 2.

Figure 1: Sample size distribution over age- and gender-specific groups



To analyse the AAFs related to acute conditions the current drinkers were divided into binge and non-binge drinkers. Binge drinking was defined as consuming more than 6 units on their heaviest drinking day for males and females, respectively (NHS Choices, 2016). The proportion of binge drinkers in current drinkers for each age and gender specific group is listed in Table 3.

Alcohol consumption level distribution

The average weekly alcohol consumption level in units of alcohol was extracted for each sampling unit that were classified as current drinker from HSE2016 and converted to average daily alcohol consumptions level in grams (where 1 unit was equal to 8 grams). The average daily consumption levels for each individual were aggregated to calculate the gender-specific mean consumption level and variance for each age group, shown in Table 4. However, it has been debated that national surveys underestimate population levels of alcohol consumption (Catto & Gibbs, 2008; Corrao, Bagnardi, Zambon, & Arico, 1999; Jones & Bellis, 2013; Meier et al., 2013; Parkin, 2011; J. Rehm et al., 2010). Mean levels of alcohol assumption summarised in Table 4 were upshifted by 40% based on the literature (Boniface, Kneale, & Shelton, 2013; Boniface & Shelton, 2013; Meier et al., 2013) The variation

was assumed to be shifted based on previous analysis (Jones & Bellis, 2013; J. Rehm et al., 2010).

The upshifted mean ($\mu_{shifted}$) and variance ($\sigma_{shifted}$) for each age and gender specific group are:

$$\mu_{shifted} = 1.4 * \mu \quad (1)$$

$$\sigma_{shifted} = 1.174 * \mu_{shifted} + 1.003 * sex \quad (2)$$

where μ was the original mean and sex was coded 0 for males and 1 for females. Original and upshift means and variances are listed in Table 4.

A gamma distribution was estimated from the mean and standard deviation alcohol consumption level for each age and gender specific group with the following steps:

- it was not possible to generate a gamma distribution in R directly from the mean and standard deviation, therefore upshifted means and standard deviation were converted to shape (α) and rate (β) parameters of the gamma distribution using $\alpha = \frac{\mu^2}{\sigma^2}$ and $\beta = \frac{\mu}{\sigma^2}$. The shape and rate parameters for each age and gender specific group are also listed in Table 4
- gamma distribution was estimated for each pair of shape and rate parameters with simulations in R, with the sampling size set to 100,000
- the gamma distribution was sampled at discrete intervals equal to 0.5g/day to ensure that the PAFs were as accurate as possible, as relative risks per 0.5g/day were reported for some diseases. The alcohol consumption probability was also estimated for each 0.5g/day. The maximum consumption level included in the analysis for both types of diseases was set to 150g/day (Gmel et al., 2011; Jones & Bellis, 2013). An example of the discrete probability distribution of the male group aged 35-44 years was shown in Figure 2

Figure 2: The probability distribution for levels of alcohol consumption in 2016

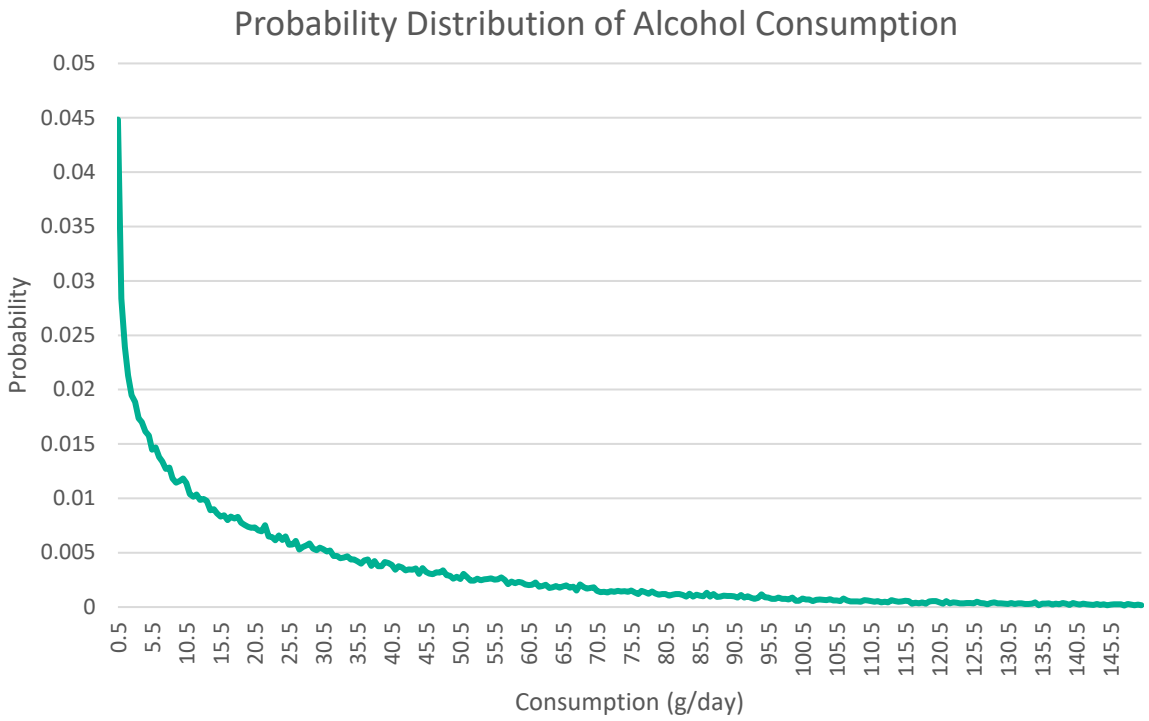


Table 1: Age- and Gender-specific sample size distribution

Population Distribution	Age/Gender Group															
	16-24		25-34		35-44		45-54		55-64		65-74		75-84		85+	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Current drinker	220	259	408	554	411	573	530	644	540	581	474	464	271	253	70	74
Former drinker	39	70	42	122	48	110	68	106	77	113	68	133	61	91	20	35
Lifetime abstainer	63	67	53	101	48	88	43	58	24	38	23	60	19	53	4	36
Total	322	396	503	777	507	771	641	808	641	732	565	657	351	397	94	145

Table 2: Distribution of different drinking groups within each age- and gender-specific group

Population Distribution	Age/Gender Group															
	16-24		25-34		35-44		45-54		55-64		65-74		75-84		85+	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Current drinker	0.68	0.65	0.81	0.71	0.81	0.74	0.83	0.80	0.84	0.79	0.84	0.71	0.77	0.64	0.74	0.51
Former drinker	0.12	0.18	0.08	0.16	0.09	0.14	0.11	0.13	0.12	0.15	0.12	0.20	0.17	0.23	0.21	0.24
Lifetime abstainer	0.20	0.17	0.11	0.13	0.09	0.11	0.07	0.07	0.04	0.05	0.04	0.09	0.05	0.13	0.04	0.25

Table 3: Proportion of binge drinkers in current drinkers of each age- and gender-specific group

Population Distribution	Age/Gender Group															
	16-24		25-34		35-44		45-54		55-64		65-74		75-84		85+	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Current drinker	220	259	408	554	411	573	530	644	540	581	474	464	271	253	70	74
Binge drinker	74	65	132	124	135	109	166	110	154	81	99	24	35	7	1	2
Proportion	0.34	0.25	0.32	0.22	0.33	0.19	0.31	0.17	0.29	0.14	0.21	0.05	0.13	0.03	0.01	0.03

Table 4: Original and upshifted alcohol consumption distribution over age- and gender-specific groups

	Age Group (Years)							
	16-24	**25-34**	**35-44**	**45-54**	**55-64**	**65-74**	**75-84**	**85+**
Mean (std. dev.) alcohol consumption in g/day								
Male	13.4 (18.5)	16.2 (25.6)	19.4 (28.7)	20.0 (32.7)	22.7 (32.2)	19.8 (23.8)	15.9 (19.5)	11.3 (10.3)
Female	8.0 (11.8)	8.8 (13.0)	10.6 (21.0)	13.7 (34.5)	12.2 (22.1)	9.6 (13.6)	7.9 (12.7)	5.4 (8.1)
Upshifted mean (std. dev.) alcohol consumption in g/day								
Male	18.8 (22.0)	22.7 (26.6)	27.1 (31.8)	28.0 (32.9)	31.8 (37.3)	27.8 (32.6)	22.2 (26.1)	15.8 (18.5)
Female	11.2 (14.2)	12.3 (15.4)	14.8 (18.4)	19.1 (23.5)	17.1 (21.1)	13.5 (16.8)	11.1 (14.0)	7.5 (9.8)
Shape (rate) parameters of the gamma distribution								
Male	0.726 (0.039)	0.726 (0.032)	0.726 (0.027)	0.726 (0.026)	0.726 (0.023)	0.726 (0.026)	0.726 (0.033)	0.726 (0.046)
Female	0.627 (0.056)	0.634 (0.052)	0.648 (0.044)	0.665 (0.035)	0.658 (0.038)	0.642 (0.048)	0.625 (0.056)	0.585 (0.078)

Dose-response functions for alcohol-related conditions

Four different types of dose-response functions were used to estimate the relative risk of a disease for each alcohol consumption level (ie, between 0g/day to 150g/day with incremental interval of 0.5g/day for chronic conditions and 1g/day for acute conditions). Detailed information about these functions can be found in the 2013 report (Jones & Bellis, 2013) and XXX. These dose-response functions included linear, J-shaped, non-linear and categorical relationships and were sourced from the literature. An explicit dose-to-response function was preferred, if available. When explicit functions were not provided, a function was fitted to the relative risk data. Raw categorical data was used in cases where the dose-response functions were not given, and it was not possible to fit a function. Gender-specific functions were preferred over general functions for both genders.

Type 2 diabetes was reported to have a quadratic J-shaped dose-response function, although neither the explicit function or the training data (which could be used to estimate a function) were reported (Knott, Bell, & Britton, 2015). We still managed to recover the dose-to-response function based on the limited information provided: decreased risks were observed for any alcohol consumption level below 60g with the minimum risk observed between 10-14g.

For diseases reported to have a non-linear dose-response relationship, log-linear functions were fitted to the data applying the same assumptions that were used in (Jones & Bellis, 2013).

This report differs from the earlier report where lifetime abstainers were used as the reference group and relative risks for former drinkers were included, we used lifetime abstainers and former drinkers as the reference group. In other words, the relative risk of these two drinking groups was 1. This was because the evidence base for the relative risk for former drinkers was not reliable. Very few publications had disaggregated the non-drinking group into lifetime abstainers and former drinkers. For certain diseases where new relative risk estimates were not available, we used the old estimates from (Jones & Bellis, 2013). In these cases, relative risk estimates

for former drinkers were included in the calculation, if available. Detailed information about the data collection and updated dose-response functions for the diseases which were updated from the literature review are summarised in the main report. For diseases where these was no update the dose response functions provided in the 2013 report were used (Jones & Bellis, 2013).

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Infectious and parasitic diseases			
Tuberculosis	(Imtiaz et al., 2017)	RR 1.35 (1.09–1.68) for 'alcohol use' RR 1.57 (1.10–2.23) at 25 g/day RR 2.46 (1.21–4.98) at 50 g/day RR 3.85 (1.33–11.11) at 75 g/day RR 6.03 (1.47–24.81) at 100 g/day <u>Male</u> RR 1.50 (0.70–3.20) for former drinkers <u>Female</u> RR 5.30 (1.40–19.80) for former drinkers	Linear[3]
Malignant neoplasm of:			
Lip, oral cavity and pharynx	(Bagnardi et al., 2015)	RR 1.13 (1.00–1.26) for light drinking[4] RR 1.83 (1.62–2.07) for moderate drinking[5] RR 5.13 (4.31–6.10) for heavy drinking[6]	$y = \exp(0.02474x - 0.00004x^2)$

[1] Values are given as combined male and female where available. RRs compared to baseline (no alcohol consumption, unless otherwise stated). Includes values for relative risk (RR), hazard ratio (HR) and odds ratio (OR). Parentheses indicate 95% confidence intervals. Values for former drinkers given where appropriate – if not explicitly stated, these are assumed to be equal to those for non-drinkers.
[2] When formulae are explicitly given, x refers to the consumption (in g/day) and y refers to the value for the RR, HR or OR (as appropriate).
[3] Of the form $y = a_1x + a_2$
[4] Defined as ≤12.5 g/day
[5] Defined as between 12.5 and 50 g/day
[6] Defined as >50 g/day

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Oesophagus	(Bagnardi et al., 2015)[7]	RR 1.26 (1.06–1.50) for light drinking[4] RR 2.23 (1.87–2.65) for moderate drinking[5] RR 4.95 (3.86–6.34) for heavy drinking[6]	$y = \exp(0.05593x - 0.00789x \ln x)$
Colon	(Bagnardi et al., 2015)[8]	RR 0.99 (0.95−1.04) for light drinking[4] RR 1.17 (1.11–1.24) for moderate drinking[5] RR 1.44 (1.25–1.65) for heavy drinking[6]	$y = \exp(0.006279x)$
Rectum			
Liver and intrahepatic bile ducts	(Bagnardi et al., 2015)	RR 1.00 (0.85−1.18) for light drinking[4] RR 1.08 (0.97−1.20) for moderate drinking[5] RR 2.07 (1.66–2.58) for heavy drinking[6]	$y = \exp\left(0.00017x^2 - 0.00069\sqrt{x}\right)$
Larynx	(Bagnardi et al., 2015)	RR 0.87 (0.68−1.11) for light drinking[4] RR 1.44 (1.25–1.66) for moderate drinking[5] RR 2.65 (2.19–3.19) for heavy drinking[6]	$y = \exp(0.01462x - 0.00002x^2)$
Breast	(Bagnardi et al., 2015)	RR 1.04 (1.01–1.07) for light drinking[4] RR 1.23 (1.19–1.28) for moderate drinking[5] RR 1.61 (1.33–1.94) for heavy drinking[6]	$y = \exp(0.01018x)$
Diabetes mellitus			
Diabetes mellitus (type II)	(Knott et al., 2015)	RR <1 for consumption level of <63 g/day RR 1 for consumption level of 63 g/day RR >1 for consumption level of >63 g/day	$y = 0.0000640797\ x^2 - 0.00128159\ x + 0.826408$
Diseases of the nervous system			

[7] Oesophagus squamous cell carcinoma only.
[8] Results are given for malignant neoplasm of colorectum.

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Epilepsy and Status epilepticus	No update	RR 1.37 (1.28–1.47) at 25 g/day RR 1.86 (1.62–2.13) at 50 g/day RR 3.44 (2.61–4.52) at 100 g/day	Non-linear[9]
Cardiovascular diseases			
Hypertensive diseases	(Briasoulis, Agarwal, & Messerli, 2012)[10]	<u>Male</u> RR 1.03 (0.94–1.13) at <10 g/day RR 1.15 (0.99–1.33) at 11 to 20 g/day RR 1.07 (0.86–1.34) at 21 to 30 g/day RR 1.77 (1.39–2.26) at 31 to 40/day RR 1.17 (0.84–1.65) at 41 to 50/day RR 1.61 (1.31–1.87) at >50/day <u>Female</u> RR 0.87 (0.82–0.92) at <10 g/day RR 0.9 (0.87–1.04) at 11 to 20 g/day RR 1.16 (0.91–1.46) at 21 to 30 g/day RR 1.19 (1.07–1.32) at >30 g/day	<u>Male</u> Stepwise function[11] <u>Female</u> J-shaped (version 2)[12]

[9] Of the form $y = \exp(a_1 \ln x + a_2)$
[10] Results are given for hypertension.
[11] Stepwise linear functions consist of several constant sections, connected linearly.
[12] Of the form $y = \exp(a_1 x + a_2 \, log_{10} \, x)$

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Ischaemic heart disease	(Angus, Henney, Webster, & Gillespie, 2019; Roerecke & Rehm, 2012)	<u>Male</u> RR 0.82 (0.65–1.02) at <2.5 g/day RR 0.77 (0.65–0.92) at 2.5 to 12 g/day RR 0.75 (0.64–0.88) at 12 to 24 g/day RR 0.74 (0.53–1.02) at 24 to 36 g/day RR 0.99 (0.90–1.08) for former drinkers[13] <u>Female</u> RR 0.91 (0.78–1.07) at <2.5 g/day RR 0.54 (0.45–0.65) at 2.5 to 12 g/day RR 0.61 (0.38–0.99) at 12 to 24 g/day RR 0.40 (0.14–1.13) at 24 to 36 g/day RR 1.11 (0.94–1.32) for former drinkers[14]	<u>Male</u> $y = \ln x - 0.0989113\sqrt{x}$ <u>Female</u> $y = -0.296842\sqrt{x} + 0.0392805x$
Cardiac arrhythmias	(Wood et al., 2018)	HR 1.17 (0.86-1.60) per 100 g/week higher consumption	$y = 0.0119x + 1$
Heart failure	(Wood et al., 2018)	HR 1.09 (1.03–1.15) per 100 g/week higher consumption	<u>Male</u> $y = 0.007x + 1$ <u>Female</u> $y = -0.0042x + 1$

[13] (Jones & Bellis, 2013)
[14] (Jones & Bellis, 2013)

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Haemorrhagic stroke	(Wood et al., 2018)	HR 1.17 (1.12–1.23) per 100 g/week higher consumption	Mortality - Male Linear Mortality – Female J-shaped (version 2) Morbidity $y = 0.0119x + 1$
Ischaemic stroke	(Wood et al., 2018; Zheng et al., 2015)[15]	HR 1.13 (1.09–1.18) per 100 g/week higher consumption	Mortality $y = 0.0013x + 1$ Morbidity $y = 0.0119x + 1$
Oesophageal varices	No update	See *unspecified liver disease*	See *unspecified liver disease*
Respiratory infections			
Pneumonia	No update	RR 1.12 (1.02–1.23) for 24 g/day RR 1.33 (1.06–1.67) for 60 g/day RR 1.76 (1.13–2.77) for 120 g/day	Linear
Digestive diseases			

[15] In (Zheng et al., 2015), results are given by gender.

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Gastro-oesophageal laceration haemorrhage syndrome	No update	N/A	N/A
Unspecified liver disease	No update	<u>Male</u> RR 1.0 (0.6–1.6) for 0 to 12 g/day RR 1.6 (1.4–2.0) for 12 to 24 g/day RR 2.8 (2.3–3.4) for 24 to 36 g/day RR 5.6 (4.5–7.0) for 36 to 48 g/day RR 7.0 (5.8–8.5) for 48 to 60 g/day RR 14.0 (11.7–16.7) for >60 g/day <u>Female</u> RR 1.9 (1.1–3.1) for 0 to 12 g/day RR 5.6 (4.5–6.9) for 12 to 24 g/day RR 7.7 (6.3–9.5) for 24 to 36 g/day RR 10.1 (7.5–13.5) for 36 to 48 g/day RR 14.7 (11.0–19.6) for 48 to 60 g/day RR 22.7 (17.2–30.1) for >60 g/day	Stepwise linear
Cholelithiasis (gall stones)	(Shabanzadeh, Sorensen, & Jorgensen, 2016)	OR 0.99 (0.98; 1.00)	Constant
Acute and chronic pancreatitis	(Shabanzadeh et al., 2016)	RR 0.91 (0.70, 1.18) for 0.1 to 40 g/day	Non-linear

Condition	New Sources	Value(s) in New Sources[1]	Dose-Response Relationship[2]
Skin diseases			
Psoriasis	No update	N/A	N/A
Pregnancy and childbirth			
Spontaneous abortion	No update	RR 1.20 for <16 g/day RR 1.76 for >16 g/day	Stepwise linear
Low birth weight	No update	RR 1.03 (0.96-1.11) at 12 g/day RR 1.23 (1.10–1.36) at 24 g/day RR 1.50 (1.30–1.73) at 36 g/day RR 1.86 (1.54–2.24) at 48 g/day RR 2.32 (1.83–2.93) at 60 g/day RR 2.91 (2.18-3.88) at 72 g/day RR 3.67 (2.60-5.17) at 84 g/day	J-shaped (version 1)[16]

[16] Of the form $y = \exp(a_1 x + a_2 \sqrt{x})$

Population attributable fraction methodology

Alcohol attributable fractions (AAFs) related to alcohol consumption for chronic diseases were calculated using the following equation for each age and gender group (Kelly, Pashayan, Munisamy, & Powles, 2009; Jürgen Rehm et al., 2004; B. Taylor et al., 2009; B. Taylor et al., 2010):

$$AAF = \frac{P_{abs} + P_{former}RR_{former} + P_{current}\int_{>0}^{150} p(x)rr(x)dx - 1}{P_{abs} + P_{former}RR_{former} + P_{current}\int_{>0}^{150} p(x)rr(x)dx} \quad \textbf{(3)}$$

where

$$1 = P_{abs} + P_{former} + P_{current} \quad \textbf{(4)}$$

and

P_{abs} = proportion of lifetime abstainers in the age- and gender-specific group

P_{former} = proportion of former drinkers in the age- and gender-specific group

$P_{current}$ = proportion of current drinkers in the age- and gender-specific group

$p(x)$ = probability distribution function of drinkers

RR_{former} = relative risk (RR) for former drinkers

$rr(x)$ = relative risk function for a given alcohol consumption in grams/day

The definite integral in the above equation can be approximated with a sum by use the discrete form the alcohol consumption level distribution. It is assumed that the alcohol consumption levels are discrete ($x \in (x_1, x_2, x_3, \dots, x_n)$). The discrete distribution is then sampled at each 0.5 g/day interval. Additionally, it is assumed that the relative risk for former drinkers is equal to 1. The equation can therefore be approximated by:

$$AAF = \frac{P_{abs} + P_{former} + P_{current}\left(\sum_{i=1}^{300}\left(p(0.5i) - p\left((i-1)*0.5\right)\right)rr(0.5i)\right) - 1}{P_{abs} + P_{former} + P_{current}\left(\sum_{i=1}^{300}\left(p(0.5i) - p\left(0.5(i-1)\right)\right)rr(0.5i)\right)} \quad \textbf{(5)}$$

where $p(x_i)$ was the probability mass function (discrete probability distribution) of the alcohol consumption level distribution $p(x)$ for each age- and gender-specific current drinker group, which was approximated with simulations with 100,000 trials.

The AAFs for acute diseases were calculated by combining the results from two different methods (B. J. Taylor, Shield, & Rehm, 2011). The first method uses the prevalence of binge drinkers and the AAF refers to the alcohol attributable faction of acute conditions if all binge drinkers are given the same RR:

$$AAF_{injury} = \frac{P_{abs} + P_{former} + P_{nonbinge} + P_{binge_1}RR_{binge_1} + P_{binge_2}RR_{binge_2} - 1}{P_{abs} + P_{former} + P_{nonbinge} + P_{binge_1}RR_{binge_1} + P_{binge_2}RR_{binge_2}} \quad \textbf{(6)}$$

where

$$RR_{binge_i} = P_{dayatrisk} * P_{daysatrisk} * \left(RR_{crude_i} - 1\right) + 1 \quad \textbf{(7)}$$

and

P_{abs} = proportion of lifetime abstainers in the age- and gender-specific group

P_{former} = proportion of former drinkers in the age- and gender-specific group

$P_{nonbinge}$ = proportion of current drinkers who do not engage in binge drinking in the age- and gender-specific group

P_{binge_1} = proportion of current drinkers who engage in binge drinking (level 1) in the age- and gender-specific group

P_{binge_2} = proportion of current drinkers who engage in binge drinking (level 2) in the age- and gender-specific group

RR_{binge_i} = risk ratio for binge drinkers (level i) given a binge amount of alcohol consumed, corrected for both time at risk and number of drinking occasions

$P_{dayatrisk}$ = proportion of a given day during which a person binge drinks and is at risk

$P_{daysatrisk}$ = percentage of days the person undertakes binge drinking

RR_{crude_i} = relative risk at binge drinking level i, not adjusted for the time at risk per occasion

The second method is based on the proportion of current drinks and the AAF refers to the attributable alcohol fraction when binge drinkers with difference alcohol consumption levels are given different RRs.

$$AAF_{injury} = \frac{P_{abs} + P_{former} + P_{current}\int_{>0}^{150} p_{binge}(x)rr_{binge}(x)dx - 1}{P_{abs} + P_{former} + P_{current}\int_{>0}^{150} p_{binge}(x)rr_{binge}(x)dx} \quad \textbf{(8)}$$

where

$$rr_{binge}(x) = P_{dayatrisk} * (rr_{crude}(x) - 1) + 1 \quad \textbf{(9)}$$

and

P_{abs} = proportion of lifetime abstainers in the age- and gender-specific group

P_{former} = proportion of former drinkers in the age- and gender-specific group

$P_{current}$ = proportion of current drinkers in the age- and gender-specific group including binge drinker and non-binge drinkers

$p_{binge}(x)$ = probability distribution function of binge drinkers

$rr_{binge}(x)$ = risk ratio for binge drinkers given a binge amount of alcohol consumed, corrected for time at risk

$rr_{crude}(x)$ = relative risk at drinking level x, not adjusted for the time at risk per occasion

In the above equation, it is assumed that non-binge drinkers have a risk ratio equal for binge drinking equal to 1. Additionally, we assume that the distribution of binge alcohol consumption is proportional to that of all alcohol consumption. For this reason, the equation is implemented in R in the following way:

$$AAF_{injury} = \frac{(1 - P_{binge}) + P_{binge}\left(\sum_{i=1}^{300}\left(p(0.5i) - p\big(0.5(i-1)\big)\right)rr_{binge}(0.5i)\right) - 1}{(1 - P_{binge}) + P_{binge}\left(\sum_{i=1}^{300}\left(p(0.5i) - p\big(0.5(i-1)\big)\right)rr_{binge}(0.5i)\right)} \quad \textbf{(10)}$$

where

$$1 = P_{abs} + P_{former} + P_{nonbinge} + P_{binge} \quad \textbf{(11)}$$

and

P_{abs} = proportion of lifetime abstainers in the age- and gender-specific group

P_{former} = proportion of former drinkers in the age- and gender-specific group

$P_{nonbinge}$ = proportion of current drinkers who do not engage in binge drinking in the age- and gender-specific group

P_{binge} = proportion of current drinkers who engage in binge drinking in the age- and gender-specific group

$rr_{binge}(x)$ = risk ratio for binge drinkers given a binge amount of alcohol consumed, corrected for time at risk

A comparison between the methods implemented in this study and the previous study

The AAF for some diseases were reproduced with the methods above and input data as suggested in (Jones & Bellis, 2013). These AAFs are compared against those in the original report in Table 5. Most AAFs are identical to the original results. Most of the rest AAFs are different from the original results by 0.01 and a few of them has discrepancy up to 0.03. Two possible reasons contribute to the difference. One is the variance caused by simulations in R. The other reason is dose-to-response functions for some diseases were not explicitly stated in (Jones & Bellis, 2013) and slightly different algorithms may have been used in this study to approximate to function. AAFs for age group 75+ years have bigger differences, some of which are equal to 0.06. In addition to the two reasons above, an upper age limit may have been used in (Jones & Bellis, 2013) and was not explicitly stated in the report.

The reproduced AAFs for acute conditions have noticeable difference to the original results, with peak value equal to 0.09. The difference may be related to the following two reasons. First, the RRs for acute conditions were not reported in (Jones & Bellis, 2013) and only odds ratios were available in the paper referenced in this report. RRs can be approximated from odds ratios in cases where the disease/outcome is very rare. However, it is unclear how the odds ratios were converted to RRs in (Jones & Bellis, 2013) or if the odd ratios were used directly. A different variable could lead to different normalisation coefficients in the calculation.

Table 5: Reproduced results from (Jones & Bellis, 2013) for some conditions

Condition[17]		Age/Gender Group													
		16-24		25-34		35-44		45-54		55-64		65-74		75-84	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F
Infectious and parasitic diseases															
Tuberculosis	Original	0.30	0.19	0.33	0.17	0.34	0.21	0.35	0.22	0.35	0.20	0.31	0.14	0.22	0.11
	UKHF	0.30	0.19	0.33	0.17	0.33	0.21	0.35	0.22	0.35	0.20	0.30	0.14	0.21	0.11
Malignant neoplasm of:															
Oesophagus	Original	0.58	0.49	0.61	0.48	0.61	0.53	0.63	0.53	0.63	0.51	0.60	0.45	0.52	0.38
	UKHF	0.58	0.49	0.61	0.47	0.61	0.52	0.63	0.53	0.63	0.50	0.59	0.44	0.52	0.35
Colorectum	Original	0.16	0.11	0.18	0.12	0.18	0.13	0.19	0.14	0.19	0.13	0.17	0.11	0.13	0.11
	UKHF	0.16	0.10	0.17	0.09	0.18	0.11	0.19	0.12	0.18	0.11	0.16	0.08	0.11	0.05
Liver and intrahepatic bile ducts	Original	0.15	0.11	0.17	0.11	0.17	0.12	0.18	0.13	0.18	0.12	0.16	0.10	0.12	0.11
	UKHF	0.16	0.10	0.17	0.09	0.18	0.11	0.18	0.12	0.18	0.10	0.16	0.07	0.11	0.05
Larynx	Original	0.35	0.25	0.39	0.23	0.39	0.28	0.41	0.29	0.41	0.27	0.36	0.21	0.28	0.17
	UKHF	0.35	0.24	0.39	0.21	0.39	0.27	0.41	0.27	0.41	0.25	0.36	0.18	0.26	0.12
Breast	Original	N/A	0.12	N/A	0.13	N/A	0.14	N/A	0.15	N/A	0.14	N/A	0.12	N/A	0.11
	UKHF	N/A	0.12	N/A	0.11	N/A	0.14	N/A	0.14	N/A	0.13	N/A	0.10	N/A	0.07
Diseases of the nervous system															
Epilepsy and Status epilepticus	Original	0.32	0.22	0.35	0.20	0.35	0.24	0.37	0.25	0.37	0.23	0.33	0.18	0.24	0.15
	UKHF	0.32	0.21	0.35	0.18	0.35	0.23	0.37	0.24	0.37	0.21	0.32	0.15	0.23	0.10
Respiratory infections															

[17] See Table 1 in main report for ICD-10 code(s) used for each condition

Condition[17]		Age/Gender Group													
		16-24		25-34		35-44		45-54		55-64		65-74		75-84	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F
Pneumonia	Original	0.12	0.07	0.14	0.06	0.14	0.08	0.15	0.08	0.15	0.08	0.13	0.05	0.10	0.03
	UKHF	0.10	0.06	0.12	0.04	0.12	0.06	0.13	0.07	0.13	0.06	0.10	0.03	0.06	0.01
Digestive disease															
Acute and chronic pancreatitis	Original	0.35	0.17	0.39	0.14	0.40	0.20	0.43	0.21	0.43	0.18	0.35	0.12	0.20	0.10
	UKHF	0.36	0.18	0.39	0.13	0.40	0.20	0.42	0.21	0.42	0.18	0.35	0.09	0.21	0.02
Pregnancy and childbirth															
Low birth weight	Original	N/A	0.05	N/A	0.03	N/A	0.05	N/A	0.06	N/A	N/A	N/A	N/A	N/A	N/A
	UKHF	N/A	0.06	N/A	0.03	N/A	0.05	N/A	0.06	N/A	N/A	N/A	N/A	N/A	N/A
Unintentional injuries															
Road/pedestrian traffic accidents - Morbidity	Original	0.28	0.17	0.31	0.15	0.26	0.15	0.27	0.15	0.19	0.09	0.11	0.05	0.04	0.02
	UKHF	0.22	0.08	0.28	0.06	0.26	0.10	0.30	0.09	0.23	0.05	0.11	0.02	0.02	0.00

Bibliography

Angus, C., Henney, M., Webster, L., & Gillespie, D. (2019). *Alcohol-attributable diseases and dose-response curves for the Sheffield Alcohol Policy Model version 4.0*.

Bagnardi, V., Rota, M., Botteri, E., Tramacere, I., Islami, F., Fedirko, V., . . . La Vecchia, C. (2015). Alcohol consumption and site-specific cancer risk: a comprehensive dose-response meta-analysis. *Br J Cancer, 112*(3), 580-593. doi:10.1038/bjc.2014.579

Boniface, S., Kneale, J., & Shelton, N. (2013). Actual and perceived units of alcohol in a self-defined "usual glass" of alcoholic drinks in England. *Alcohol Clin Exp Res, 37*(6), 978-983. doi:10.1111/acer.12046

Boniface, S., & Shelton, N. (2013). How is alcohol consumption affected if we account for under-reporting? A hypothetical scenario. *Eur J Public Health, 23*(6), 1076-1081. doi:10.1093/eurpub/ckt016

Briasoulis, A., Agarwal, V., & Messerli, F. H. (2012). Alcohol consumption and the risk of hypertension in men and women: a systematic review and meta-analysis. *J Clin Hypertens (Greenwich), 14*(11), 792-798. doi:10.1111/jch.12008

Catto, S., & Gibbs, D. (2008). *How much are people in Scotland really drinking? A review of data from Scotland's routine national surveys*. Retrieved from

Corrao, G., Bagnardi, V., Zambon, A., & Arico, S. (1999). Exploring the dose-response relationship between alcohol consumption and the risk of several alcohol-related conditions: a meta-analysis. *Addiction, 94*(10), 1551-1573. doi:10.1046/j.1360-0443.1999.9410155111.x

Gmel, G., Shield, K. D., Frick, H., Kehoe, T., Gmel, G., & Rehm, J. (2011). Estimating uncertainty of alcohol-attributable fractions for infectious and chronic diseases. *BMC Med Res Methodol, 11*, 48. doi:10.1186/1471-2288-11-48

Imtiaz, S., Shield, K. D., Roerecke, M., Samokhvalov, A. V., Lonnroth, K., & Rehm, J. (2017). Alcohol consumption as a risk factor for tuberculosis: meta-analyses and burden of disease. *Eur Respir J, 50*(1). doi:10.1183/13993003.00216-2017

Jones, L., & Bellis, M. A. (2013). Updating England-specific alcohol-attributable fractions.

Kelly, C., Pashayan, N., Munisamy, S., & Powles, J. W. (2009). Mortality attributable to excess adiposity in England and Wales in 2003 and 2015: explorations with a spreadsheet implementation of the Comparative Risk Assessment methodology. *Popul Health Metr, 7*, 11. doi:10.1186/1478-7954-7-11

Knott, C., Bell, S., & Britton, A. (2015). 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, 38*(9), 1804-1812. doi:10.2337/dc15-0710

Meier, P. S., Meng, Y., Holmes, J., Baumberg, B., Purshouse, R., Hill-McManus, D., & Brennan, A. (2013). Adjusting for unrecorded consumption in survey and per capita sales data: quantification of impact on gender- and age-specific alcohol-attributable fractions for oral and pharyngeal cancers in Great Britain. *Alcohol Alcohol, 48*(2), 241-249. doi:10.1093/alcalc/agt001

NHS Choices. (2016). Alcohol support: Binge drinking. Retrieved from https://www.nhs.uk/live-well/alcohol-support/binge-drinking-effects/

Parkin, D. M. (2011). 3. Cancers attributable to consumption of alcohol in the UK in 2010. *Br J Cancer, 105 Suppl 2*, S14-18. doi:10.1038/bjc.2011.476

Rehm, J., Kehoe, T., Gmel, G., Stinson, F., Grant, B., & Gmel, G. (2010). Statistical modeling of volume of alcohol exposure for epidemiological studies of population health: the US example. *Popul Health Metr, 8*, 3. doi:10.1186/1478-7954-8-3

Rehm, J., Room, R., Monteiro, M., Gmel, G., Graham, K., Rehn, N., . . . Jernigan, D. (2004). Addictive substances: Alcohol use. In M. Ezzati, A. D. Lopez, A. A. Rodgers, & C. J. L. Murray (Eds.), *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors* (Vol. 1, pp. 959-1108).

Roerecke, M., & Rehm, J. (2012). The cardioprotective association of average alcohol consumption and ischaemic heart disease: a systematic review and meta-analysis. *Addiction, 107*(7), 1246-1260. doi:10.1111/j.1360-0443.2012.03780.x

Shabanzadeh, D. M., Sorensen, L. T., & Jorgensen, T. (2016). Determinants for gallstone formation - a new data cohort study and a systematic review with meta-analysis. *Scand J Gastroenterol, 51*(10), 1239-1248. doi:10.1080/00365521.2016.1182583

Taylor, B., Irving, H. M., Baliunas, D., Roerecke, M., Patra, J., Mohapatra, S., & Rehm, J. (2009). Alcohol and hypertension: gender differences in dose-response relationships determined through systematic review and meta-analysis. *Addiction, 104*(12), 1981-1990. doi:10.1111/j.1360-0443.2009.02694.x

Taylor, B., Irving, H. M., Kanteres, F., Room, R., Borges, G., Cherpitel, C., . . . Rehm, J. (2010). The more you drink, the harder you fall: a systematic review and meta-analysis of how acute alcohol consumption and injury or collision risk increase together. *Drug Alcohol Depend, 110*(1-2), 108-116. doi:10.1016/j.drugalcdep.2010.02.011

Taylor, B. J., Shield, K. D., & Rehm, J. T. (2011). Combining best evidence: a novel method to calculate the alcohol-attributable fraction and its variance for injury mortality. *BMC Public Health, 11*, 265. doi:10.1186/1471-2458-11-265

Wood, A. M., Kaptoge, S., Butterworth, A. S., Willeit, P., Warnakula, S., Bolton, T., . . . Danesh, J. (2018). Risk thresholds for alcohol consumption: combined analysis of individual-participant data for 599 912 current drinkers in 83 prospective studies. *The Lancet, 391*(10129), 1513-1523. doi:10.1016/s0140-6736(18)30134-x

Zheng, Y. L., Lian, F., Shi, Q., Zhang, C., Chen, Y. W., Zhou, Y. H., & He, J. (2015). Alcohol intake and associated risk of major cardiovascular outcomes in women compared with men: a systematic review and meta-analysis of prospective observational studies. *BMC Public Health, 15*, 773. doi:10.1186/s12889-015-2081-y