Alcohol and Global Health 1

Global burden of disease and injury and economic cost attributable to alcohol use and alcohol-use disorders

Jürgen Rehm, Colin Mathers, Svetlana Popova, Montarat Thavorncharoensap, Yot Teerawattananon, Jayadeep Patra

Alcohol consumption has been identified as an important risk factor for chronic disease and injury. In the first paper in this Series, we quantify the burden of mortality and disease attributable to alcohol, both globally and for ten large countries. We assess alcohol exposure and prevalence of alcohol-use disorders on the basis of reviews of published work. After identification of other major disease categories causally linked to alcohol, we estimate attributable fractions by sex, age, and WHO region. Additionally, we compare social costs of alcohol in selected countries. The net effect of alcohol consumption on health is detrimental, with an estimated 3·8% of all global deaths and 4·6% of global disability-adjusted life-years attributable to alcohol. Disease burden is closely related to average volume of alcohol consumption, and, for every unit of exposure, is strongest in poor people and in those who are marginalised from society. The costs associated with alcohol amount to more than 1% of the gross national product in high-income and middle-income countries, with the costs of social harm constituting a major proportion in addition to health costs. Overall, we conclude that alcohol consumption is one of the major avoidable risk factors, and actions to reduce burden and costs associated with alcohol should be urgently increased.

Alcohol as a risk factor for disease

Alcohol has been a part of human culture since the beginning of recorded history.[1] Almost all societies that consume alcohol show related health and social problems. The industrialisation of production and globalisation of marketing and promotion of alcohol have increased both the amount of worldwide consumption and the harms associated with it. These developments have led to several resolutions by the World Health Assembly and WHO Regional Committees, outlining the public health problems caused by alcohol[2] and possible strategies to reduce the harmful use of alcohol.[3] A global strategy needs to be developed to achieve these resolutions, and will be discussed in the second and third papers in this Series.[4,5]

This paper gives an overview of alcohol as a risk factor for the global burden of disease and injury, with a special emphasis on so-called alcohol-use disorders—ie, alcohol dependence and harmful use of alcohol as outlined in the International Statistical Classification of Disease tenth revision (ICD-10).[6] Alcohol-use disorders, especially for men, are among the most disabling disease categories for the global burden of disease.[7] However, this disease category is not the only one linked to alcohol: more than 30 ICD-10 three-digit or four-digit codes include alcohol in their name or definition,[6] indicating that alcohol consumption is a necessary cause. Furthermore, more than 200 ICD-10 three-digit disease codes exist in which alcohol is part of a component cause.[8] We present global, regional, and selected country overviews for disease and injury from alcohol consumption.

No overall assessment of the health effects of alcohol would be complete without a discussion of the beneficial effects of specific drinking patterns. Regular drinking at low amounts has been identified as contributing to a decreased incidence of several diseases, most notably ischaemic cardiovascular outcomes and diabetes.[9,10] Although these beneficial effects have been controversial[11] and are far outweighed by the detrimental effects of alcohol on disease and injury,[12] we will also estimate their effects in this paper, together with the net burden resulting from alcohol consumption. Finally, we will also estimate the economic costs of alcohol consumption in selected societies. This analysis will enable us to examine the full societal effect of alcohol, since economic studies are not restricted to health but usually include criminal outcomes and other social detriments.[13]

Key messages

- Even though most adults worldwide abstain from drinking alcohol, consumption is common in many parts of the world
- For low-income countries, there is a strong relation between economic wealth and alcohol consumption: the higher the gross domestic product, the higher the overall volume of consumption and the lower the proportions of abstainers
- Alcohol contributes substantially to the global burden of disease (4% of total mortality and between 4% and 5% of disability-adjusted life-years), and thus is one of the largest avoidable risk factors
- Poor populations and low-income countries have an even greater disease burden per unit of alcohol consumption than do high-income populations and countries
- The consequences attributable to alcohol account for large costs to societies; they are not limited to health-care costs, but also include costs related to social harm

Public Health and Regulatory Policies, Centre for Addiction and Mental Health, Toronto, Canada (J Rehm PhD, S Popova MD, J Patra PhD); Dalla Lana School of Public Health, University of Toronto, Toronto, Canada (J Rehm, S Popova); WHO Collaboration Centre for Substance Abuse, Zurich, Switzerland (J Rehm); Epidemiological Research Unit, Klinische Psychologie und Psychotherapie, Technische Universitä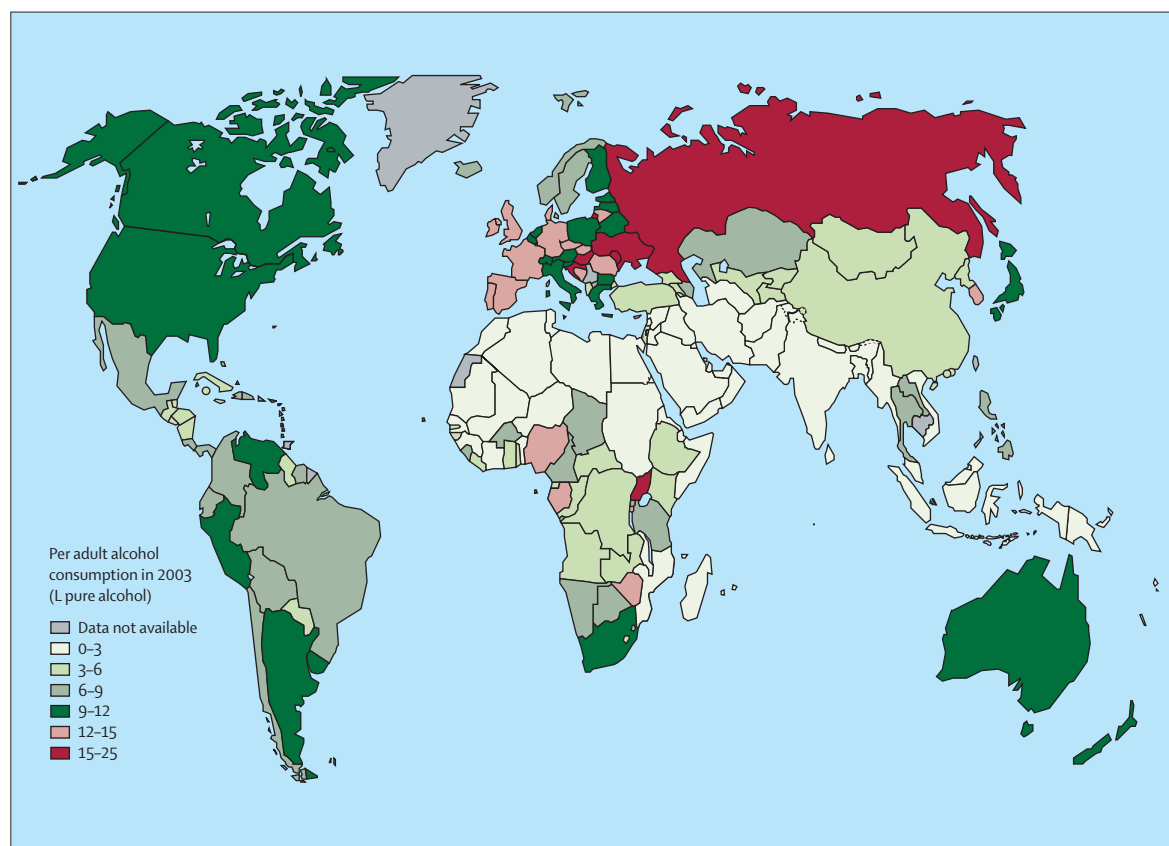t Dresden, Dresden, Germany (J Rehm); WHO, Department of Health Statistics, Geneva, Switzerland (C Mathers PhD); Factor-Inwentash Faculty of Social Work, University of Toronto, Toronto, Canada (S Popova); Health Intervention and Technology Assessment Program (HITAP); Ministry of Public Health, Nonthaburi, Thailand (M Thavorncharoensap PhD, Y Teerawattananon PhD); and Department of Pharmacy, Faculty of Pharmacy, Mahidol University, Bangkok, Thailand (M Thavorncharoensap)

Correspondence to:
Jürgen Rehm, Centre for Addiction and Mental Health, 33 Russell Street, Room 2035B, Toronto ON M5S 2S1, Canada
jtrehm@aol.com

Per adult alcohol consumption in 2003 (L pure alcohol)
- Data not available
- 0–3
- 3–6
- 6–9
- 9–12
- 12–15
- 15–25

Figure 1: **Exposure to alcohol—recorded and unrecorded adult consumption by country**

	Men (%)*	Women (%)*	Total
Diseases for which alcohol has a detrimental effect			
Maternal and perinatal disorders (low birthweight)	2 (0·1%)	1 (0·3%)	3
Cancer	377 (18·5%)	111 (25·0%)	487
Diabetes mellitus	0 (0·0%)	0 (0·1%)	0
Neuropsychiatric disorders	109 (5·4%)	25 (5·7%)	135
Cardiovascular diseases	466 (22·8%)	80 (18·0%)	545
Cirrhosis of the liver	297 (14·6%)	76 (17·1%)	373
Unintentional injuries	556 (27·3%)	110 (24·8%)	666
Intentional injuries	232 (11·4%)	40 (9·0%)	272
Total detrimental effects attributable to alcohol	2039 (100·0%)	443 (100·0%)	2482
Diseases for which alcohol has a beneficial effect			
Diabetes mellitus	–8 (8·3%)	–4 (3·2%)	–12
Cardiovascular diseases	–88 (91·7%)	–128 (96·8%)	–215
Total beneficial effects attributable to alcohol	–96 (100·0%)	–132 (100·0%)	–227
All alcohol-attributable net deaths	1944	311	2255
All deaths	31063	27674	58738
Percentage of all net deaths attributable to alcohol	6·3%	1·1%	3·8%
CRA 2000 (for comparison)	5·6%	0·6%	3·2%

CRA=comparative risk assessment. *Numbers are rounded to the nearest thousand. Zero indicates fewer than 500 alcohol-attributable deaths in the disease category. Percentages refer to all deaths either caused or prevented by alcohol.

Table 1: **Alcohol-attributable deaths (in thousands) by sex and cause of death in 2004**

Global alcohol exposure and associated health
Indicators of alcohol consumption, mortality, and burden of disease

The exposure data for recorded and unrecorded alcohol consumption per adult for 2003—the most recent year of available comprehensive data—were taken from the WHO Global Status Report on Alcohol 2004[14] and the WHO Global Information System on Alcohol and Health, which provides regular updates on these data. Recorded alcohol consumption per adult was based on government records (taxation) and industry publications for the production and sales of alcohol, and data from the Food and Agriculture Organization. By definition, unrecorded alcohol consumption is not recorded. Thus, different methods were used to estimate unrecorded consumption, mainly expert opinion and general population surveys.[15] The main sources of unrecorded alcohol are home production; alcohol intended for industrial, technical, and medical uses; and illegal industrial production or illegal import.

Prevalence of abstention, defined as abstention during the previous year, and average volume of drinking categories were taken from large representative surveys in the respective countries in the 2000s, and survey-derived volume of drinking was adjusted for total consumption per adult, with the assumption that the per adult

consumption was the most valid indicator for overall consumption and that surveys provide correct proportions of volume of alcohol consumed by groups defined by sex and age (a detailed description of the method has been reported previously[15]).

Two different dimensions of alcohol consumption affect health: average volume of alcohol consumption and patterns of drinking, especially occasions involving heavy drinking.[10,12] As in the Comparative Risk Assessment (CRA) of the Global Burden of Disease (GBD) 2000 study,[12] patterns of drinking were used in addition to average volume in the modelling of the effect on injury and ischaemic heart disease.

We used both event-based (mortality) and time-based (disability-adjusted life-years, DALYs) measures of population health. DALYs combine years of life lost due to premature death and years of life lived with disabilities into one indicator that assesses the total lost years of full health from different causes.[16,17] WHO provided a comprehensive revision of estimates for mortality and DALYs for 136 disease and injury causes for 2004 (most recent year available) as part of the ongoing GBD project.[18] Of particular relevance for the estimation of mortality and burden of disease attributable to alcohol use was the revision of data for cancer incidence and mortality, diabetes incidence and prevalence, incidence and prevalence of alcohol-use disorders, and disability attributable to cardiovascular diseases.[18] Methods and data to estimate mortality and DALYs in the GBD project are described elsewhere.[19,20] Population estimates for 2004 were based on the latest revisions by the United Nations Population Division.[21]

Alcohol-use disorders

Previous global estimates for alcohol-use disorders were based on a range of assessment instruments with varying quality. These methods included screening instruments such as the CAGE or the Alcohol Use Disorders Identification Test,[22] which by design overestimate the prevalence.[23] A new review was undertaken for the GBD 2004 update with use of studies that were done only after 1990 and that used ICD-10, Diagnostic and Statistical Manual of Mental Disorders (DSM)-IIIR, or DSM-IV criteria for alcohol dependence and one of the following diagnostic instruments: the Composite International Diagnostic Interview, the Schedules for Clinical Assessment in Neuropsychiatry, or the Alcohol-Use Disorder and Associated Disabilities Interview Schedule-alcohol/drug-Revised.[24]

We obtained population estimates of the point prevalence of alcohol dependence for people aged 18–64 years from 37 studies.[24] We then adjusted estimated regional prevalence for alcohol dependence by age and sex to account for the additional prevalence of harmful use of alcohol, and to correct for comorbidity. Incidence and average durations for alcohol-use disorders were estimated from prevalence, relative risk of mortality, and remission
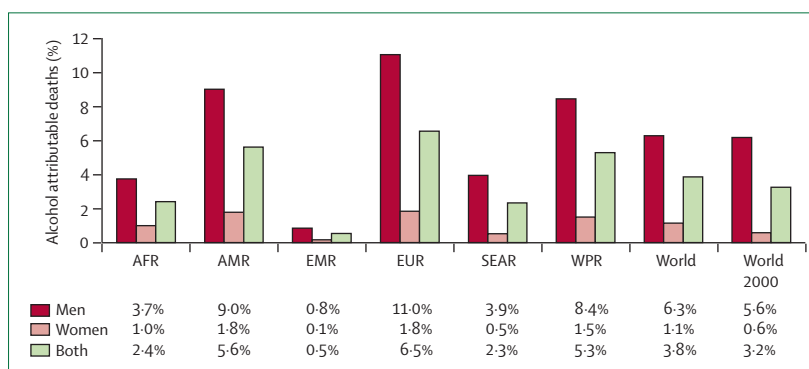
Figure 2: Alcohol-attributable deaths as proportion of all deaths by sex and WHO region in 2004
AFR=African region. AMR=American region. EMR=eastern Mediterranean region. EUR=European region. SEAR=southeast Asian region. WPR=western Pacific region.

	Men (%)*	Women (%)*	Total
Diseases for which alcohol has a detrimental effect			
Maternal and perinatal disorders (low birthweight)	64 (0·1%)	55 (0·5%)	119
Cancer	4732 (7·6%)	1536 (13·5%)	6268
Diabetes mellitus	0 (0·0%)	28 (0·3%)	28
Neuropsychiatric disorders	23 265 (37·6%)	3417 (30·1%)	26 682
Cardiovascular diseases	5985 (9·7%)	939 (8·3%)	6924
Cirrhosis of the liver	5502 (8·9%)	1443 (12·7%)	6945
Unintentional injuries	15 694 (25·4%)	2910 (25·6%)	18 604
Intentional injuries	6639 (10·7%)	1021 (9·0%)	7660
Total detrimental effects attributable to alcohol	61 881 (100·0%)	11 349 (100·0%)	73 231
Diseases for which alcohol has a beneficial effect			
Diabetes mellitus	–238 (22·2%)	–101 (8·1%)	–340
Cardiovascular diseases	–837 (77·8%)	–1145 (91·9%)	–1981
Total beneficial effects attributable to alcohol	–1075 (100·0%)	–1246 (100·0%)	–2321
All alcohol-attributable net DALYs	60 806	10 104	70 910
All DALYs	799 536	730 631	1 530 168
Percentage of all net DALYs attributable to alcohol	7·6%	1·4%	4·6%
CRA 2000 (for comparison)	6·5%	1·3%	4·0%

CRA=comparative risk assessment. DALY=disability-adjusted life-year. *Numbers are rounded to the nearest thousand. Zero indicates fewer than 500 alcohol-attributable disability-adjusted life-years in the disease category. Percentages refer to all disability-adjusted life-years either caused or prevented by alcohol.

*Table 2:* Alcohol-attributable burden of disease (in 1000 disability-adjusted life-years) by sex and cause in 2004

rates with DisMod II (Disease Modelling II) software.[25] We assumed an instantaneous average remission rate of 0·175 for people aged 15 years and older;[22] the relative risk of mortality averaged 1·80 (95% CI 1·76–1·84) for men and 3·84 (3·54–4·15) for women.[26]

The original GBD 1990 disability weight of 0·18 for alcohol dependence was applied to both alcohol dependence and harmful use in the GBD 2000–02 study. In ICD 10, harmful use is the second category of alcohol-use disorders that is similar to "alcohol abuse" in DSM IV, but defined as a pattern of substance use that is causing harm to physical or mental health.[6] Recent analyses of disability associated with harmful use of alcohol from the Australian burden of disease study[27] and
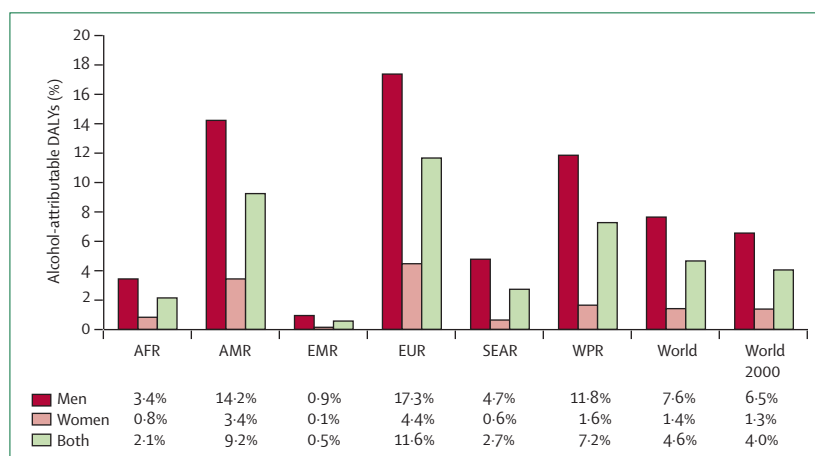
Figure 3: Alcohol-attributable burden of disease in disability-adjusted life-years (DALYs) as proportion of all DALYs by sex and WHO region in 2004

AFR=African region. AMR=American region. EMR=eastern Mediterranean region. EUR=European region. SEAR=southeast Asian region. WPR=western Pacific region.
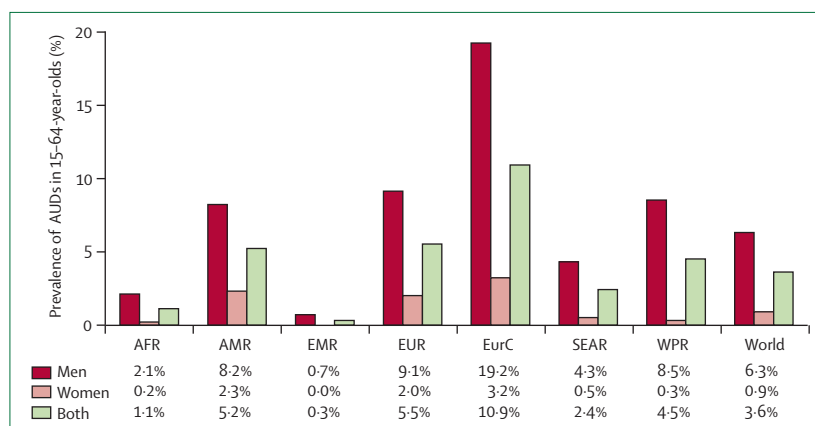
Figure 4: 1-year prevalence of alcohol-use disorders (AUDs) in people aged 15–64 years by sex and WHO region in 2004

AFR=African region. AMR=American region. EMR=eastern Mediterranean region. EUR=European region. EurC=eastern European region with proportionally higher adult mortality than other European parts (most populous country: Russia). SEAR=southeast Asian region. WPR=western Pacific region.

of estimations of health state collected in the WHO multicountry survey study[28] suggested that the actual average disability weights for alcohol-use disorders were lower than were those from the GBD, and weights were adjusted downwards to 0·122–0·137 (depending on age and sex). Adjustment was achieved by keeping the original disability weight for alcohol dependence from GBD 1990, but combining it with a lower weight for harmful use.

Identification of disease categories causally linked to alcohol

Several diseases and injuries are caused by alcohol by definition (eg, alcohol-use disorders, alcoholic liver disease, and alcohol-induced pancreatitis). These disorders are wholly attributable to alcohol, meaning that they would not exist without it. Furthermore, alcohol is a contributory cause of some diseases and injuries.[8] For

many of these diseases, such as specific types of cancer, alcohol is a contributory cause in only a fairly small number.

To identify disease categories for which alcohol is a contributory cause, we applied the standard epidemiological criteria. The establishment of causality required sufficient evidence of: a consistent association (positive or negative) between alcohol consumption and the disease or injury; chance, confounding variables, and other bias being ruled out with reasonable confidence as factors for association;[29] and evidence of a plausible mediating process.[30] These assessments were made with the standard criteria to establish causality in epidemiology,[12] in which the most weight was placed on temporality, consistency across studies, established experimental biological evidence of mediating processes or at least physiological plausibility (biological mechanisms), and strength of the association (effect size).

In terms of wider codes from the GBD study,[20] the following categories were related to alcohol: disorders arising during the perinatal period; mouth and oropharynx cancers (ICD-10: C00–C14); oesophageal cancer (C15); colon and rectal cancers (C18–C21); liver cancer (C22); breast cancer (C50); other neoplasms (D00-D48); diabetes mellitus (E10–E14); alcohol-use disorders (F10); unipolar depressive disorders (F32–F33); epilepsy (G40, G41); hypertensive heart disease (I10–I14); ischaemic heart disease (I20-I25); haemorrhagic stroke (I60–I62); ischaemic stroke (I63); cirrhosis of the liver (K74); low birthweight (P05–P07); road traffic accidents (many V codes[12]); falls (W00–W19); drownings (W65–W74); poisonings (X40–X49); other unintentional injuries (rest of V codes plus some W, X, Y codes[12]); self-inflicted injuries (X60–X84, Y87.0); violence (X85–Y09, Y87.1); and other intentional injuries (Y35). The identified alcohol-attributable diseases and injuries are the same as those in the CRA GBD 2000, except that colorectal cancer has been added on the basis of the 2007 assessment of the International Agency for Research on Cancer on the carcinogenicity of alcohol beverages.[31]

For alcohol, the usual epidemiological model has to be widened, since drinking can harm the health of non-drinkers in some cases (ie, maternal drinking can affect the health of the newborn baby, or driving while under the influence of alcohol can affect bystanders or other drivers).

Establishing risk relations

For most chronic disease categories, we estimated the quantification of the risk of disease attributable to alcohol by combining the prevalence of exposure and the relative risk estimates based on meta-analytical studies with the following formula to derive alcohol-attributable fractions (AAFs):[32,33]

$$AF = \left[\sum_{i=0}^{k} P_i (RR_i - 1) \right] \div \left[\sum_{i=0}^{k} P_i (RR_i - 1) + 1 \right]$$

	Brazil	China	Germany	India	Japan	Nigeria	Russia	South Africa	Thailand	USA
Men										
Diseases for which alcohol has a detrimental effect										
Cancer	93 (9%)	2180 (18%)	83 (9%)	325 (7%)	164 (11%)	85 (14%)	143 (9%)	34 (13%)	100 (22%)	168 (7%)
Neuropsychiatric disorders	1091 (29%)	6752 (34%)	365 (30%)	2947 (17%)	42 (4%)	255 (12%)	1664 (51%)	150 (23%)	420 (37%)	1410 (26%)
Cardiovascular diseases	290 (13%)	1148 (9%)	35 (3%)	993 (6%)	43 (4%)	95 (7%)	841 (12%)	47 (8%)	39 (10%)	122 (4%)
Cirrhosis of the liver	281 (75%)	913 (70%)	141 (85%)	826 (47%)	83 (70%)	61 (81%)	507 (88%)	22 (64%)	88 (84%)	225 (81%)
Unintentional and intentional injuries	1632 (35%)	2414 (14%)	113 (26%)	2244 (10%)	154 (18%)	390 (11%)	3579 (48%)	554 (31%)	175 (17%)	676 (23%)
All other DALYs caused by alcohol	4 (1%)	0 (0%)	0 (0%)	8 (0%)	0 (0%)	4 (0%)	1 (1%)	1 (0%)	0 (0%)	1 (0%)
Total detrimental effects attributable to alcohol	3392	13406	738	7343	487	891	6734	809	822	2601
Total beneficial effects attributable to alcohol	0	0	–144	0	–94	0	0	0	0	–270
All alcohol-attributable net DALYs	3392	13406	594	7343	393	891	6734	809	822	2331
Percentage of all DALYs attributable to alcohol	17·7	12·9	12·8	4·9	6·7	2·4	28·1	7·8	12·1	12·1
Women										
Diseases for which alcohol has a detrimental effect										
Cancer	51 (5%)	403 (5%)	63 (8%)	19 (0%)	60 (6%)	57 (8%)	109 (7%)	13 (5%)	22 (5%)	122 (5%)
Neuropsychiatric disorders	237 (6%)	271 (2%)	88 (7%)	310 (2%)	25 (2%)	58 (3%)	332 (13%)	43 (7%)	48 (5%)	527 (8%)
Cardiovascular diseases	52 (3%)	54 (0%)	16 (2%)	6 (0%)	2 (0%)	80 (5%)	253 (5%)	18 (3%)	7 (2%)	31 (1%)
Cirrhosis of the liver	37 (48%)	93 (17%)	57 (78%)	46 (4%)	26 (68%)	23 (74%)	299 (82%)	5 (47%)	27 (45%)	107 (74%)
Unintentional and intentional injuries	118 (14%)	710 (7%)	30 (17%)	401 (2%)	47 (13%)	125 (7%)	529 (28%)	65 (12%)	28 (5%)	173 (14%)
All other DALYs caused by alcohol	5 (1%)	1 (0%)	0 (0%)	9 (0%)	0 (0%)	9 (1%)	4 (1%)	2 (1%)	1 (0%)	1 (0%)
Total detrimental effects attributable to alcohol	499	1532	254	791	160	353	1526	147	133	962
Total beneficial effects attributable to alcohol	0	0	–271	0	–99	0	0	0	0	–180
All alcohol-attributable net DALYs	499	1532	–17	791	61	353	1526	147	133	782
Percentage of all DALYs attributable to alcohol	3·4	1·8	–0·4	0·5	1·3	0·8	10·7	1·4	2·5	4·5

Data are alcohol-attributable fraction (%), unless otherwise indicated. DALY=disability-adjusted life-year. M=men. W=women. *Numbers are rounded to the nearest thousand. Zero indicates fewer than 500 alcohol-attributable DALYs in the disease category.

Table 3: Alcohol-attributable burden of disease (in 1000 disability-adjusted life-years) by sex and cause in ten selected countries in 2004*

where i is the exposure category with baseline exposure or no exposure (i=0), $RR_{(i)}$ is the relative risk at exposure level i compared with no consumption, and $P_{(i)}$ is the prevalence of the ith category of exposure. The derived AAFs were taken from the CRA for 2002 for chronic disease categories.[34] For injury, AAFs were taken from the CRA 2000 study.[12] These AAFs take into account patterns of consumption for ischaemic heart disease and all injuries.

AAFs represent the proportion of each outcome (ie, number of deaths or burden of disease and injury in DALYs) that is attributable to alcohol, on the basis of a counterfactual scenario of no alcohol consumption.[35] The counterfactual scenario is, of course, the same for both beneficial and detrimental effects of alcohol.

Exposure data were collected nationally and then aggregated regionally. All analyses for mortality and morbidity were based on 2004, and were done separately by sex, age, and regions. We used age groups of 0–4 years, 5–14 years, 15–29 years, 30–44 years, 45–59 years, 60–69 years, and 70 years and older. 14 WHO regions, the same as in the CRA 2000, were used as bases for

To estimate the economic costs due to alcohol in selected societies, we undertook a literature search of existing studies of alcohol-attributable social cost from January, 1992, to September, 2007, in multiple electronic bibliographical databases, including Ovid Medline, PubMed, Embase, Web of Science, PsychINFO, Google Scholar, and the Cochrane Database of Systematic Reviews. Additionally, we manually reviewed the content pages of the major epidemiological journals and retrieved citations from all relevant articles. The contents of 247 abstracts and 45 full-text reports were reviewed to establish whether they contained data for cost drivers associated with alcohol consumption. Of these reports, 29 studies were identified from 18 different countries (webappendix) and the European Union.[40]

Predictably, we noted a large variation in the methods used for the estimation of the social cost of alcohol. For example, studies from Australia[41,42] and Sweden[43] presented the net cost, which took into account the possible positive effects—eg, reduction of the risks of cardiovascular illnesses generated from low to moderate regular alcohol consumption without heavy drinking occasions—whereas other studies adopted the gross cost estimation in which only the costs associated with the negative effects of alcohol consumption were counted. Additionally, although most studies used a discount rate of 6%, we noted that the rates actually ranged between 3% and 10%.[43,44] The discount rate used to quantify the present value of the future cost is essential because the opportunity costs lost from premature mortality attributed to alcohol always constitute a substantial proportion of the overall costs.

Because the method used varied greatly between studies, sensible conclusions or comparisons from all identified studies are difficult to make. Thus, we included only studies that were methodologically most comparable—ie, those estimating the gross cost and using the same discount rate of 6% (apart from the South Korean study in which a discount rate of 5% was applied[45]). Only the most recent and comprehensive study per country, detailing cost categories, was included for the analysis to avoid overlapping in our database. As a result, four studies from high-income countries—France, the USA, Scotland, and Canada—were included. Only two comparable alcohol-attributable social cost studies from middle-income countries—South Korea and Thailand—were identified and included in the analysis.

The data were tabulated according to potential direct and indirect cost components including: health-care costs; law-enforcement costs; other direct social costs—eg, property damage and loss, direct administrative costs, and social work services; and indirect costs. Costs for different countries were converted to a single currency unit, an international dollar (I$) with use of the purchasing power parity (PPP) index used by the International Monetary Fund.[46] All costs were also

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calculations,[12] apart from the country-specific analyses. These regions were established on the basis of levels of child and adult mortality.[36]

Findings
Exposure to alcohol
Overall, there is wide variation around the worldwide consumption average of 6·2 L of pure alcohol (defined as 100% ethanol) per adult per year (figure 1). The countries with the highest overall consumption are in eastern Europe around Russia, but other areas of Europe also have high overall consumption (WHO Europe region 11·9 L per adult). The Americas are the region with the next highest overall consumption (WHO Americas region 8·7 L per adult). Apart from a few countries, some of them in Africa, alcohol consumption is lower in other parts of the world than in the Americas. To set the African countries with highest consumption into context, we need to consider that unrecorded consumption constitutes a large part of the overall consumption, and the figures for unrecorded consumption in African countries have a high amount of uncertainty. The WHO eastern Mediterranean region is lowest with 0·7 L alcohol consumption per adult. Nationally, alcohol consumption is linked to wealth in terms of gross domestic product (GDP) per adult measured in international dollars—ie, purchasing power parity adjusted dollars. Up to about I$10 000, the higher the GDP the higher the adult per head consumption. Above this threshold, the relation flattens substantially. A strong inverse relation is also detected between per head GDP and abstention up to a threshold of $7000; however, above this threshold there is no relation between wealth and abstention.[37] Thus, the relation between wealth and adult per head consumption seems to be mainly based on the level of abstention.

In all regions worldwide, men consume more alcohol than do women, although the exact ratio varies, with women in high-income countries consuming a larger proportion than those in low-income countries. In the interpretation of these numbers, we should keep in mind that most of the adult population worldwide actually abstains from drinking alcohol (45% of men and 66% of women), most of them for their lifetime.

Mortality
In 2004, 3·8% of all global deaths were attributable to alcohol, 6·3% for men and 1·1% for women (table 1). The difference between the sexes in mortality is an indicator of the difference in drinking, with respect to both overall volume and heavy drinking occasions. Mortality proportions attributable to alcohol are net numbers that have taken into consideration the beneficial effects of alcohol. Most of the deaths caused by alcohol were in the broad categories of injury, cancer, cardiovascular disease, and liver cirrhosis. The deaths

prevented were almost entirely in the cardiovascular category. Overall, the proportion of alcohol-attributable deaths increased since 2000, mainly because of increases in the number of women drinking.

The net effect of alcohol was larger in younger age groups, again for both sexes. Whereas 3·8% of deaths in all age groups were attributable to alcohol, 5·3% of deaths in people younger than 60 years were attributable to this risk factor (7·9% in men, 1·9% in women). This effect was mainly due to injuries caused by alcohol, with most beneficial effects detected in older age groups.

The proportion of alcohol-attributable net deaths varied widely between regions (figure 2), further indicating the difference in drinking patterns. As expected, the European region had the highest proportion, with more than one in every ten deaths in European men attributed to alcohol. Within Europe, the highest proportion was for the countries of the former Soviet Union.

The rates of alcohol-attributable mortality per 10 000 population younger than 70 years varied between 1·1 in the eastern Mediterranean region and 15·0 in the European region for men, and between 0·2 and 3·5, respectively, for women. Global averages were 7·4 for men and 1·4 for women (other rates per 10 000 population were 9·5 for men and 2·1 for women in Africa; 8·8 for men and 1·6 for women in the Americas; 5·0 for men and 0·5 for women in southeast Asia; and 6·2 for men and 1·1 for women in the western Pacific). Relative to the volume of alcohol consumed per head, the rates of alcohol-attributable mortality were higher in developing than in developed countries, especially in southeast Asia.

Alcohol-attributable mortality rates varied by sex between four-fold (European region) and almost ten-fold (southeast Asian region); globally, alcohol-attributable mortality rates for men were about 5·2 times those for women. The exact relation depended not only on the differential of the volume consumed by sex, but also on the pattern of drinking.

Burden of disease

In 2004, 4·6% of the global burden of disease and injury was attributable to alcohol: 7·6% for men and 1·4% for women (table 2). The relative effect of neuropsychiatric disorders on burden of disease was far more pronounced than was its effect on mortality, since 36·4% of all neuropsychiatric DALYs were caused by alcohol, compared with 5·4% of all neuropsychiatric deaths caused. This effect is mainly due to alcohol-use disorders, which cause disability but much less mortality than do the non-psychiatric chronic diseases.

As expected, there was substantial regional variability for the global burden of disease and injury similar to that for alcohol-attributable deaths (figure 3). Most of the alcohol-attributable burden of disease occurred in people aged 15–29 years (33·6% of all alcohol-attributable

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reported in the present value by inflating the original cost to the equivalent cost in 2007 with use of country-specific inflators.[46] Lastly, the population-weighted averages of all cost components, total costs, and costs as a percentage of gross domestic product (GDP) on PPP in the study year converted to the present value were calculated to help with comparison. These weightings determined the relative importance of each quantity on the population average.

Table 4 presents the economic costs attributable to alcohol for selected high-income and middle-income countries. The results show that the economic costs of alcohol were substantial in both groups. Alcohol-attributable cost per head in high-income countries ranged from I$358 in Scotland to I$837 in the USA; in middle-income countries, South Korea (I$524) had more than four times greater alcohol-attributable cost per head than did Thailand (I$122). All countries spent more than 1% of their GDP PPP, with the highest in the USA (2·7%) in the selected high-income countries, and in South Korea (3·3%) in the selected middle-income countries.

The indirect costs due to productivity losses were the predominant cost category of all alcohol-attributable social costs in all countries in both groups, ranging from 49% of the total cost in Canada to 95% in Thailand. In terms of direct costs in high-income countries, the category of other direct costs was the largest contributor for France and South Korea, whereas the direct health-care costs were the highest contributor to direct costs in Canada and the USA. In middle-income countries, direct health-care costs were the largest contributor among direct costs for Thailand. Direct law-enforcement costs were the lowest contributor among categories of direct costs for France, the USA, and Thailand.

In terms of a weighted average for high-income countries, the greatest contributor to total alcohol-attributable costs was the cost of productivity loss, which accounted for 72·1% of the overall cost, followed by direct health-care costs (12·8%), other direct costs (11·6%), and direct law-enforcement costs (3·5%). The hierarchy of costs was similar for middle-income countries except that the weighted average for other direct costs was the second largest share (15·5%), followed by health-care costs (5·6%).

Although many scholars frequently express these costs in reference to a renowned macroeconomic indicator—eg, GDP—this approach poses a serious methodological challenge because some components are often included in the social costs (health expenditure, research and prevention, and administration costs are parts of GDP), and thus cannot be appropriately interpreted as its deficit. We compared each cost component in a disaggregate form as well as the overall cost in relation to GDP to contrast these findings to previous published work that used the conventional approach, and so that individual cost components could be assessed.

	High-income countries					Middle-income countries		
	France[47]	USA[48]	Scotland[49]	Canada[50,51]	Weighted average	South Korea[52]	Thailand[45]	Weighted average
Study year	1997	1998	2001–02	2002	NA	2000	2006	NA
Population in study year (million)	58·6	280·6	5·1	31·9	NA	47·5	64·6	NA
GDP (PPP) in study year*	1 301 087	8 587 884	133 179	929 912	6 689 552	760 549	604 575	670 666
Direct health-care cost	3592	29 855	162	3045	23 090	1516	344	841
Direct laws	72	8049	454	2830	6262	..	15	9
Other direct cost	7619	26 244	145	966	20 848	5459	49	2341
Indirect cost	11 223	170 707	1052	6564	129 659	17 938	7496	11 921
Total economic costs of alcohol	22 506	234 854	1813	13 406	179 859	24 914	7903	15 111
Cost per head (2007 US$ PPP)	384	837	358	420	725	524	122	293
Health-care costs (% of total cost)	16·0%	12·7%	8·9%	22·7%	12·8%	6·1%	4·3%	5·6%
Law enforcement (% total cost)	0·3%	3·4%	25·0%	21·1%	3·5%	..	0·2%	0·1%
Other direct cost (% total cost)	33·9%	11·2%	8·0%	7·2%	11·6%	21·9%	0·6%	15·5%
Indirect cost (% total cost)	49·9%	72·7%	58·0%	49·0%	72·1%	72·0%	94·8%	78·9%
Total cost (% GDP [PPP])	1·7%	2·7%	1·4%	1·4%	2·5%	3·3%	1·3%	2·1%
Health-care costs (% GDP [PPP])	0·3%	0·4%	0·1%	0·3%	0·3%	0·2%	0·1%	0·1%
Law enforcement (% GDP [PPP])	0·0%	0·1%	0·3%	0·3%	0·1%	0·0%	0·0%	0·0%
Other direct cost (% GDP [PPP])	0·6%	0·3%	0·1%	0·1%	0·3%	0·7%	0·0%	0·3%
Indirect cost (% GDP [PPP])	0·9%	2·0%	0·8%	0·7%	1·7%	2·4%	1·2%	1·7%

GDP=gross domestic product. NA=not applicable because data unavailable. PPP=purchasing power parity. *Adjusted to 2007 US$million.

Table 4: Overview of economic costs attributable to alcohol in selected high-income and middle-income countries (in 2007 million international $)

DALYs), followed by those aged 30–44 years (31·3%) and 45–59 years (22·0%). In all these age-groups, alcohol consumption was responsible for more than 10% of all burden of disease in men and for 2–3% in women. Although the effect of alcohol consumption was most pronounced in early and middle adulthood, it affected all phases of life—from newborn babies (0·3% in age-group 0–4 years) to elderly people (3·7% in age-group ≥70 years). Compared with many other traditional risk factors such as tobacco, cholesterol, or hypertension, the age profile of alcohol-attributable disease burden is shifted towards younger populations.

Alcohol-use disorders
Not surprisingly, alcohol-use disorders generally followed the same pattern as did alcohol-attributable harm: men had many more disorders than did women, and the regional patterns were similar (figure 4). Compared with the average volume of alcohol consumed per head, the highest prevalences of alcohol-use disorders were in southeast Asia (with India as the most populous country), the Americas, and the western Pacific region (with China as the most populous country). This pattern can be partly explained by the higher abstention rates in these regions, resulting in higher average volume consumed per drinker, and thus a higher risk for alcohol-use disorders. The tenet can be exemplified by the present situation in India of high, albeit falling, abstention rates with almost all women

still being lifetime abstainers, but a pattern of frequent and heavy drinking of spirits among drinkers, often to the point of intoxication, resulting in disproportional rates of alcohol-use disorders.[38,39]

The overall years of life lived with disabilities for alcohol-use disorders were 22·0 million in 2004 compared with 19·1 million in 2000, if the basic assumption and estimates of prevalence and incidence of these disorders remained constant between 2000 and 2004. The revised prevalence estimates have resulted in increases in the estimated burden for China, India, and countries of the former Soviet Union, and decreases for high-income countries, Latin America, and Africa.

Country profiles
Table 3 shows alcohol-attributable burden in the most populous countries. As noted previously, burden varied by sex and region. However, we also noted pronounced differences in the relative proportion of different disease categories. With respect to detrimental effects of alcohol, injury had a proportionally high effect in Brazilian, Nigerian, Russian, and South African men, and in Chinese and Indian women. Alcohol-use disorders were most important in Chinese, German, Thai, and US men, and in Brazilian and US women. In Japan, cancer was the most important alcohol-attributable burden of disease category for both sexes.

The panel outlines findings from a separate analysis, which we undertook to investigate the economic costs attributable to alcohol.

Conclusions

Our analysis does have some general limitations, such as the data quality of health outcomes relevant to all global studies—ie, mortality and burden of disease and specific limitations for a CRA for alcohol (Murray and Frenk[53] provide a general discussion of the limitations). Furthermore, we refer only to ongoing discussions on DALY assumptions[17] including the derivation of the DALY weights,[54] and on data quality for global mortality.[19]

Our approach also has some specific limitations. First, although we were able to collect data for alcohol exposure from most countries, the quality of data for unrecorded consumption in many countries was questionable. Because more than 25% of the global consumption is estimated to be unrecorded,[34,55] the harm estimates are uncertain since these data are mainly based on expert opinion owing to the very nature of unrecorded consumption, which is often illegal. Second, data for patterns of drinking had to be estimated from nearby countries or expert opinion because information from surveys was insufficient. Third, the risk relations between alcohol and chronic disease outcomes were taken from meta-analytical studies, which assumes transferability of relative risks between countries. Although this assumption is customary for most CRAs,[56] and certainly plausible in view of identical biological pathways, there could be interactions between alcohol and other risk factors such a poverty, malnutrition, or hopelessness, which introduce error.[57–60] Because the risk relations were mainly derived from meta-analyses predominantly based on middle-class cohorts from the developed world, bias introduced by poverty or malnutrition would lead to an underestimation of the real risk, but other biases could lead to the opposite. Finally, the study did not include any alcohol-attributable infectious disease. By 1785, Benjamin Rush[61] had already described pneumonia and tuberculosis as disease outcomes resulting from heavy consumption of alcohol, and modern research has confirmed a consistent relation with biological and social pathways.[62–64] These diseases will be included in the next iteration of the CRA of the GBD study. Overall, the uncertainty for estimates on the effect of alcohol on burden of disease has been quantified to be fairly low compared with other risk factors, being only worse than the category of risk factors with the best data available such as blood pressure, cholesterol, or smoking.[7]

Overall, our analysis shows that alcohol consumption is a major risk factor for burden of disease. The average volume of alcohol consumption and patterns of drinking, especially heavy drinking occasions, contribute to this disease burden. Alcohol is linked to many disease categories, but alcohol-use disorders, cancer, cardiovascular disease, liver cirrhosis, and injury are the most important disease categories causally affected by alcohol. The net effect of alcohol on cardiovascular disease might be beneficial in regions in which alcohol is regularly consumed lightly to moderately without heavy drinking occasions, but this benefit is restricted to older people only.[65] In other regions, where this is not the case, no net protective effect on ischaemic heart disease is expected, and the overall effect of alcohol on cardiovascular disease will be detrimental because of its harmful effect on haemorrhagic stroke and hypertensive disorders. Even in regions in which the net effect on cardiovascular disease is beneficial, the overall effect of alcohol on the burden of disease is detrimental. Globally, the effect of alcohol on burden of disease is about the same size as that of smoking in 2000, but it is greatest in developing countries.[12,56] Our analyses show that the alcohol-attributable burden has not fallen since then, but probably increased. This finding is not surprising since global consumption is increasing, especially in the most populous countries of India and China.[14] Furthermore, the relative effect of the disease categories related to alcohol has been increasing over the past few decades.[20] Finally, patterns of drinking have not improved in recent years.[66]

We face a large and increasing alcohol-attributable burden at a time when we know more than ever about which strategies can effectively and cost-effectively control alcohol-related harms.[66,67] The next papers of this Series will therefore discuss ways in which to decrease this burden.

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