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The Health and Economic Consequences of Moderate Alcohol Consumption in Germany 2002

Alexander Konnopka, MD, Hans-Helmut König, MPH

University of Leipzig, Leipzig, Germany

ABSTRACT

Objective: Moderate alcohol consumption is associated with both positive and negative health effects. This study aims to estimate the positive and negative consequences on mortality, years of potential life (YPL), quality-adjusted life-years (QALYs), resource utilization, and societal costs attributable to moderate alcohol consumption in Germany in 2002.
Methods: The concept of attributable risks and a prevalence-based approach was used to calculate age- and sex-specific alcohol attributable mortality and resource utilization for a wide range of disorders, and avoided mortality and resource utilization for diabetes mellitus, coronary heart disease, stroke, and cholelithiasis. The literature provided prevalence of moderate alcohol consumption in Germany by age and sex and relative risks. Direct costs were calculated using routine utilization and expenditure statistics. Indirect costs were calculated using the human capital approach.

Results: Due to moderate alcohol consumption, 14,457 lives, 205,691 YPL, and 179,964 QALYs were lost, whereas 29,918 lives, 300,382 YPL, and 258,284 QALYs were gained. Up to an age of 55 to 60 (62.5–67.5) years, more lives were lost than gained among men (women), whereas in older age groups more lives were gained than lost. Moderate alcohol consumption caused €3049 million of direct and €2630 million of indirect costs, whereas €2094 million of direct and €2604 million of indirect costs were avoided.
Conclusion: Despite considerable uncertainty, moderate alcohol consumption seems to result in an overall net effect of gained lives, YPL, and QALYs, realized among the elderly, but overall increased societal costs. Thus, moderate alcohol consumption should still be seen critical, especially among youths.
Keywords: burden of illness, cost, economic, moderate alcohol, mortality.

Introduction

It is generally recognized that heavy alcohol consumption presents a significant risk factor for morbidity and mortality [1,2] creating considerable costs for society. This has been demonstrated for various countries, like the USA [3], Canada [4], France [5], New Zealand [6], and Germany [7]. Yet evidence suggests that moderate alcohol consumption can decrease the risk of illness in some cases, especially for the cardiovascular system [1,2,8–10] and consequently avoid mortality, morbidity-related resource utilization and costs. Nevertheless, even moderate alcohol consumption presents a risk factor for many diseases [1,2] and thus has positive and negative effects.

These effects can be quantified by various means. The most obvious is the determination of caused and avoided mortality, allowing calculation of lost or gained years of potential life (YPL) or quality-adjusted life-years (QALYs). Besides mortality, a further parameter is morbidity, resulting in resource utilization. In addition, costs for society are connected with morbidity and mortality, and these should also be considered in a comprehensive assessment of a risk factor. Costs can be divided into direct and indirect costs. Direct costs are those resulting directly from health care. Indirect costs are loss of productivity arising from morbidity and mortality of illness [11].

The goal of this study was the estimation of caused and avoided mortality, YPL, QALYs, morbidity-related resource utilization, and direct as well as indirect costs resulting from moderate alcohol consumption in Germany for the year 2002.

Address correspondence to: Alexander Konnopka, University of Leipzig, Health Economics Research Unit, Department of Psychiatry, Liebigstrasse 26, D-04103 Leipzig, Germany. E-mail: alexander.konnopka@medizin.uni-leipzig.de
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Methods

The concept of attributable fractions and a prevalence-based approach was used to determine alcohol attributable mortality and morbidity-related resource utilization, which then enabled the determination of societal costs via monetary valuation. These calculations were based on the prevalence of moderate alcohol consumption in Germany, relative risks for alcohol-associated diseases and official statistics for mortality and morbidity-related resource utilization in Germany.

Alcohol-Attributable Fractions

Age- and sex-specific alcohol attributable fractions (AAFs) were calculated to quantify the proportion of morbidity and mortality caused and avoided by moderate alcohol consumption in the overall morbidity and mortality. To calculate AAFs, data on drinking prevalence P_i by consumption class i ($i = 0, 1, 2, 3$) and relative risks on disease formation RR_i were combined as follows [12]:

$$AAF_1 = \frac{P_1(RR_1 - 1)}{\sum_{i=0}^{i=3} P_i(RR_i - 1) + 1} \quad (1)$$

Consumption classes were defined by grams of alcohol per day: 0 = abstinent (0 g/day), 1 = moderate (females: >0–20 g/day, males: >0–40 g/day), 2 = risky (females: >20–40 g/day, males: >40–60 g/day), 3 = dangerous (females: >40 g/day, males: >60 g/day) [1].

Prevalence of alcohol consumption was provided by the Epidemiological Survey of Substance Abuse 2000 [13], a postal survey among 8139 persons from 18 to 59 years of age. For persons older than 59 years, the prevalence corresponded of the age group 50 to 59 was used.

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Table 1 Alcohol attributable fractions used for calculations in percent (listed by ICD-10-Code)

	Men						Women					
Age groups	15–20	21–25	26–30	31–40	41–50	>50	15–20	21–25	26–30	31–40	41–50	>50
Protective												
E10–E14[R]	0.0	0.0	0.0	0.0	0.0	0.0	–2.9	–7.3	–7.2	–7.3	–7.3	–6.7
I20–I25[R]	–6.4	–16.7	–17.9	–18.2	–17.6	–16.6	–7.1	–18.1	–18.0	–18.2	–18.0	–16.6
I63.0–5[R]	–1.8	–4.6	–4.9	–5.1	–4.8	4.5	–27.6	–70.8	–70.6	–71.9	–70.8	–63.4
I63.6[R]	0.0	0.0	0.0	0.0	0.0	0.0	–15.9	–44.0	–46.9	–45.1	–41.2	–36.6
K80[G]	–6.8	–17.9	–18.8	–19.1	–18.6	–17.7	–7.4	–18.6	–18.5	–18.8	–18.7	–17.3
Harmful												
C00–C14[R]	7.9	19.6	22.2	22.4	21.2	19.8	9.4	24.7	24.9	24.8	23.9	22.3
C15[R]	12.5	31.4	34	34.6	33.1	30.9	14.0	36.5	36.5	36.5	35.6	33.5
C22[R]	8.2	21.0	22.4	23.2	22.0	20.0	9.2	24.0	23.7	23.9	23.3	21.6
C32[G]	11.9	30.4	32.5	33.6	31.8	29.0	13.4	35.1	34.8	35.0	34.0	31.6
C50[R]	0.0	0.0	0.0	0.0	0.0	0.0	4.0	10.2	10.1	10.2	10.1	9.4
D00–D48[R]	2.6	6.8	7.3	7.4	7.1	6.7	2.9	7.5	7.5	7.6	7.4	6.9
G40–41[R]	3.4	9.0	9.6	10.4	9.4	7.9	5.6	15.3	14.9	15.1	14.3	12.8
I10–I13[R]	7.6	19.1	21.0	21.4	20.3	18.9	9.2	23.6	23.4	23.6	23.2	21.7
I47.1 & 0.9[G]	9.9	25.6	26.8	27.6	26.4	24.6	10.8	27.8	27.6	27.8	27.3	25.6
I48[G]	9.9	25.6	26.8	27.6	26.4	24.6	10.8	27.8	27.6	27.8	27.3	25.6
I63.6[R]	5.9	15.3	16.2	16.7	15.9	14.7	0.0	0.0	0.0	0.0	0.0	0.0
I85[G]	3.3	8.6	9.3	10.1	9.1	7.5	3.9	10.9	10.5	10.7	10.0	8.8
K 70 + 74[R]	3.4	8.7	9.9	10.5	9.4	8.0	4.2	11.9	11.7	11.7	10.9	9.6
L40 ex 0.5[G]	11.2	28.7	30.3	30.8	29.8	28.1	12.2	31.4	31.2	31.5	31.0	29.2
Morbidity												
Injuries[(R)]	1.0	1.0	1.0	1.0	1.0	0.8	0.5	0.5	0.5	0.5	0.5	0.5
Poisoning[(R)]	1.1	1.1	1.1	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5
Drowning[(R)]	1.1	1.1	1.1	1.3	1.3	1.3	0.8	0.8	0.8	1.0	1.0	1.1
Mortality												
V01–99[R]	3.2	3.2	3.2	3.6	3.6	1.9	0.9	0.9	0.9	1.4	1.4	1.2
W00–19[R]	2.0	2.0	2.0	2.1	2.1	2.1	1.0	1.0	1.0	1.0	1.0	1.1
W20–64[R]	2.6	2.6	2.6	2.7	2.7	2.3	1.6	1.6	1.6	1.7	1.7	1.5
W65–74[R]	2.4	2.4	2.4	2.9	2.9	2.9	1.8	1.8	1.8	2.3	2.3	2.4
X40–49[R]	2.6	2.6	2.6	1.5	1.5	1.6	1.6	1.6	1.6	1.1	1.1	1.2
X60–84[S]	1.4	1.4	1.4	1.5	1.5	1.1	0.7	0.7	0.7	0.7	0.7	0.6
X85–Y09[R]	2.5	2.5	2.5	2.5	2.5	2.6	1.9	1.9	1.9	2.0	2.0	2.1

Source of relative risk: G, Gutjahr et al. [2]; R, Rehm et al. [1]; (R), own calculations based on Rehm et al. [1]; S, Single et al. [15].

Relative risks were taken from international studies. For diseases solely caused by alcohol consumption (e.g., alcohol dependence), we assumed that moderate alcohol consumption is not harmful enough to initiate them (except for "alcoholic liver disease" for which a joint relative risk with "fibrosis and cirrhosis of the liver" was used). Table 1 lists by ICD-10-GM-Code [14] the diseases taken into account and the calculated AAFs used. Caused disorders include neoplasms, nervous, circulatory and digestive disorders, psoriasis, injuries, poisoning, and drowning, whereas avoided disorders include diabetes mellitus, coronary heart disease, stroke, and cholelithiasis. Problematically, no German statistics code morbidity based on injuries, poisonings, and nonfatal drowning by their external causes (V01-Y98). Thus, AAFs based on AAFs indicated by Rehm et al. [1] were conservatively estimated, and a fraction of 10% of these was assumed to result from moderate alcohol consumption for the following diagnoses: injuries (S00-T19, T33-T35, T68, T69, T74, T79, T89-T94, T98.0-T98.2), poisonings (T36-T65, T96, T97), and drowning (T75.1).

Caused and Avoided Mortality

An official statistic listing all deaths in Germany [16] provided data to estimate attributable mortality. The causes of death are based on (usually external) postmortem examinations and coded via four digit ICD-10-Code, age, sex, and—with accidents or violence—external cause of death [16]. To determine attributable deaths, the number of deaths was multiplied with the AAF by disease, sex, and age.

Lost and Gained YPL and QALYs

To determine YPL due to mortality, expected future life-years were calculated based on a life-table method using German mortality statistic [17] and age- and sex-specific attributable deaths. The calculation of QALYs due to mortality was performed analogously, whereas the future life-years were weighted by age- and sex-specific EuroQoL-5D (EQ-5D) index scores [18]. Based on the distribution of EQ-5D health states measured in a representative random sample of the German population [19], age- and sex-specific mean EQ-5D index scores were derived using the algorithm that Greiner et al. [18] had developed for Germany.

Caused and Avoided Morbidity-Related Resource Utilization and Societal Costs

We determined direct costs through hospitals, outpatient care (registered doctors, other medical professions, costs of pharmacies, home care, as well as costs of "other outpatient institutions"), rehabilitation, nursing homes, out-of-pocket expenses, and determinable nonmedical costs of rescue services, administration, prevention, research, education, and investments.

To calculate direct cost DC_1 of hospital care (H) and rehabilitation (R), age-, sex-, and disease-specific treatment days ID_H and ID_R were taken from official statistics [20,21] and multiplied by AAF and by average daily cost C_{1H} and C_{1R} [22,23]:

$$DC_1 = AAF * (ID_H * C_{1H} + ID_R * C_{1R}) \qquad (2)$$

Due to data restrictions, direct costs of outpatient care, nursing homes, out-of-pocket expenses, rescue services, administration, and prevention DC_2 were determined from an official cost-of-illness-statistic [24]. Because this statistic lists costs C_2 mostly for disease groups i defined by less than 3 ICD-digits, we calculated the sex-specific proportions of alcohol attributable hospital cases IC for a diagnosis j in all hospital cases of disease group i. These proportions were then multiplied with the costs reported in the statistic:

$$DC_{2(j)} = \frac{AAF_j * IC_j}{IC_i} * C_{2(i)} \quad (3)$$

For education, research, and investments, only total expenses C_3 were available [25]. To determine attributable direct costs DC_3, the sex- and disease-specific proportion of calculated attributable direct costs DC_1 and DC_2 in the total costs of inpatient and outpatient health care [24] was determined and applied to C_3:

$$DC_3 = \frac{DC_1 + DC_2}{C_1 + C_2} * C_3 \quad (4)$$

We calculated indirect costs for mortality, early retirement, and sickness absence using the human capital approach and discounting future loss of productivity P for mortality and early retirement at a rate of $r = 5\%$ [26]. Productivity of paid work was determined by multiplying the sum of age- and sex-specific gross salaries GS [27] and employers contributions to social insurance S [28] with the age- and sex-specific probability to work p_w [17]. Unpaid work comprises activities in the household that could be transferred to a third party against payment and was determined by multiplying age- and sex-specific yearly hours of unpaid work T [29] with the net income of €7.10 per hour for a home help [29]:

$$P = (GS + S) * p_w + T * €7.10 \quad (5)$$

To determine indirect costs from sickness absence IC_1, we multiplied the AAF by age-, sex-, and disease-specific sickness absence days SAD [30] and rehabilitation days ID_R (not covered by SAD-statistics) as well as productivity. Because the SAD statistic covered only 13.2 million insured persons, the sickness absence days were extrapolated to the total German population:

$$IC_1 = AAF * (SAD + ID_R) * P \quad (6)$$

Indirect costs from early retirement IC_2 were determined by multiplying the AAF with age-, sex-, and disease-specific early retirement cases ER [31] and the degree of permanent productivity reduction PR. Productivity P of the reference year was halved, assuming that some cases will occur at the beginning of the year and others at the end. Indirect costs of future years n were determined by estimating the probabilities p_l of a person at age A to reach future life-years up to 95 years. From age 70 years on (unpaid) productivity was reduced by 10% every 5 years:

$$IC_2 = AAF * ER * PR * \left[0.5 * P + \sum_{A+1}^{95} p_l * P * \frac{1}{(1+r)^n}\right] \quad (7)$$

Indirect costs from mortality were calculated analogously to the indirect costs from early retirement, based on age-, sex-, and disease-specific deaths M [16]:

$$IC_3 = AAF * M * \left[0.5 * P + \sum_{A+1}^{95} p_l * P * \frac{1}{(1+r)^n}\right] \quad (8)$$

Sensitivity Analysis

To test the robustness of our analysis, different parameters were varied.

- For relative risks, values were set lying 10% or 20% above and below base values over all nonabstinent categories of consumption. To calculate meaningful net effects, a stronger harmful effect was combined with a stronger protective effect, and vice versa. If varied relative risks for harmful (protective) effects were <1 (>1), the value "1" was set.
- For persons aged 60 years and older, prevalence of all nonabstinent consumption classes was decreased by 5% every 5 years.
- For the following diseases solely caused by alcohol consumption (ICD-10-GM 2006), 10% of their mortality and morbidity were considered to result from moderate alcohol consumption: F10, G31.2, G62.1, G72.1, I42.6, K29.2, K86.0, P04.3, Q86.0 [14].
- EuroQoL-5D index scores were calculated with an algorithm for the general British population published by Dolan et al. [32].
- Discounting was performed with rates of 0% and 10%, and indirect costs caused by mortality and early retirement were determined only for 4 months (friction cost approach).
- Calculating indirect costs was performed without considering unpaid work and, alternatively, with valuing unpaid work by the labor costs (gross salary plus employer's contribution to social insurance) of a home help.

Results

Mortality

Moderate alcohol consumption led to 14,457 (29,918) caused (avoided) deaths, corresponding to a net effect of 15,461 avoided deaths (Table 2). In total, 56% of caused as well as avoided deaths were females. Of caused deaths 86% were divided almost equally among neoplasm and circulatory diseases, whereas circulatory diseases accounted for 96% of avoided deaths.

Figure 1 shows caused and avoided mortality that differs considerably between age groups. With males (females), moderate alcohol consumption caused more deaths than those avoided up to the age range of 55 to 60 (62.5–67.5) years. Beginning with this age range, the number of avoided deaths increased clearly, and in the highest age range it was more than double the number of caused deaths. Figure 2 shows the ratio of caused (avoided) deaths per moderate consumer in the total deaths per inhabitant. It is obvious that the ratio of avoided mortality continuously rises with age up to more than 5%, whereas the ratio of caused mortalityreaches up to about 4% in the age range 50 to 55 years and then decreases in females (males) to 2% (1.3%).

YPL and QALYs

The caused (avoided) deaths were related to 205,691 lost and 300,382 gained YPL (Table 2) with a net effect of 94,691 gained YPL, which corresponds to 14.2, 10.0, and 6.1 YPL per caused, avoided, and net avoided death. About 50% of the lost YPL were due to deaths by neoplasm, which amounted to 42% of caused deaths, whereas 26% of lost YPL were due to circulatory diseases, which made up 44% of caused deaths.

The lost (gained) YPL corresponded to 179,964 (258,284) QALYs, resulting in a net effect of 78,320 QALYs gained. The distribution of lost and gained QALYs throughout sex and diagnosis essentially corresponded to the distribution of YPL.

Table 2 Caused and avoided deaths, lost and gained years of potential life (YPL), quality-adjusted life-years (QALYs), and net effects attributable to moderate alcohol consumption by disease groups

	Caused deaths, lost YPL, and QALYs			Avoided deaths, gained YPL, and QALYs			Net effect*		
Disease group	Male	Female	Both sexes†	Male	Female	Both sexes†	Male	Female	Both sexes†
Neoplasm									
Deaths	3,108	2,978	6,086	0	0	0	3,108	2,978	6,086
YPL	53,225	49,520	102,745	0	0	0	53,225	49,520	102,745
QALY	47,860	42,311	90,171	0	0	0	47,860	42,311	90,171
Diabetes mellitus									
Deaths	0	0	0	0	1,009	1,009	0	−1,009	−1,009
YPL	0	0	0	0	9,336	9,336	0	−9,336	−9,336
QALY	0	0	0	0	7,745	7,745	0	−7,745	−7,745
Circulatory									
Deaths	1,788	4,512	6,300	12,909	15,888	28,797	−11,121	−11,376	−22,497
YPL	18,839	35,052	53,891	152,522	137,431	289,952	−133,683	−102,379	−236,061
QALY	16,735	28,935	45,669	135,790	113,818	249,608	−119,056	−84,884	−203,939
Nervous									
Deaths	78	93	171	0	0	0	78	93	171
YPL	1,936	1,841	3,777	0	0	0	1,936	1,841	3,777
QALY	1,772	1,605	3,377	0	0	0	1,772	1,605	3,377
Digestive									
Deaths	965	555	1,521	33	79	112	932	476	1,409
YPL	20,612	12,299	32,911	345	749	1,094	20,267	11,550	31,817
QALY	18,689	10,666	29,355	306	625	931	18,383	10,041	28,424
Injury and poisoning									
Deaths	313	67	380	0	0	0	313	67	380
YPL	10,622	1,746	12,368	0	0	0	10,622	1,746	12,368
QALY	9,842	1,550	11,391	0	0	0	9,842	1,550	11,391
Total									
Deaths†	6,252	8,133	14,457	12,943	16,976	29,918	−6,691	−8,843	−15,461
YPL†	105,234	100,457	205,691	152,867	147,515	300,382	−47,633	−47,058	−94,691
QALY†	94,897	85,067	179,964	136,096	122,188	258,284	−41,199	−37,121	−78,320

*Positive (negative) values indicate caused (avoided) deaths and lost (gained) YPL or QALYs, respectively.
†Sums may not sum to one because of rounding.

Morbidity-Related Resource Utilization and Societal Costs

Table 3 shows caused and avoided resource utilization from morbidity. Up to 1.60% of sector-specific resource utilization was caused by moderate alcohol consumption, yet concurrently up to 1.78% of resource utilization was avoided. The dominance of either caused or avoided utilization varied by sector. Net effects varied between −1.44% and +1.06% of resource utilization.

All together, moderate alcohol consumption resulted in €5679 million of costs, whereas €4699 million costs were avoided, corresponding to a net excess of €980 million (Table 4). In total, 54% (45%) of caused (avoided) costs were direct costs. More than half of caused direct costs resulted from outpatient care. With females a noteworthy net-saving of costs resulted for inpatient treatment (€103 million) and nursing home care (€238 million).

Indirect costs were just as strongly caused (€2630 million) as avoided (€2604 million). Mortality accounted for 77% of caused, but for 86% of avoided indirect costs. It further occurred that caused indirect costs resulted equally from paid (51%) and unpaid (49%) work, whereas 66% of avoided indirect costs resulted from unpaid work. A clear net-saving of costs was seen for indirect costs from unpaid work based on mortality.

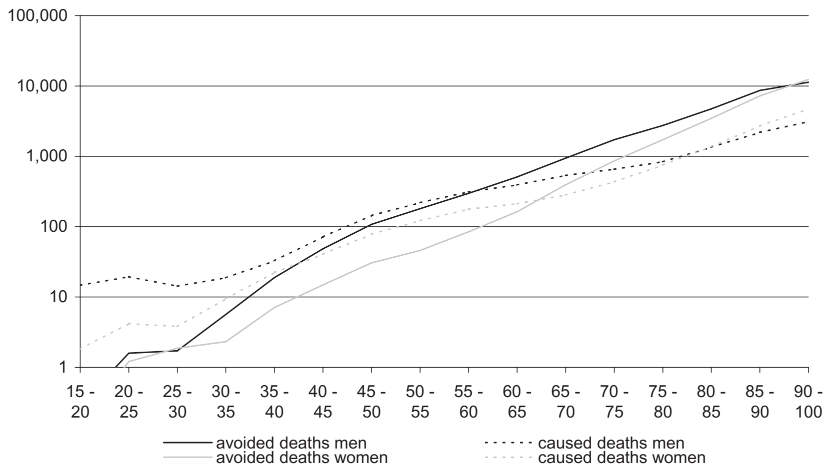

Figure 1 Caused and avoided deaths per million of moderate alcohol consumers by age (half-logarithmic scale).

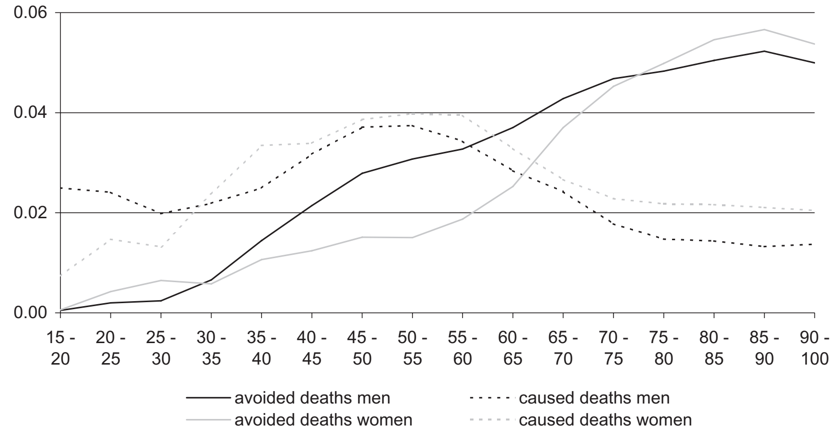

Figure 2 Age-specific ratio of deaths attributable to moderate alcohol consumption per moderate consumer to overall deaths per inhabitant.

By diagnosis (Table 5) 65% (75%) of caused (avoided) direct costs occurred with circulatory diseases. With indirect costs, 47% of caused costs resulted from neoplasms, whereas 96% of avoided costs came from circulatory diseases. Interestingly, circulatory diseases resulted with net-excess in direct costs, mainly resulting from outpatient treatment of hypertension, but net-savings for indirect costs, mainly from unpaid work in patients with coronary heart disease. For digestive diseases, net-savings appeared for direct costs, mainly from avoided inpatient treatment of cholelithiasis, whereas net-excess appeared in indirect costs mainly from mortality resulting from liver cirrhosis.

Sensitivity Analysis

Table 6 shows that variations in relative risks led to strong variations of the base results. Hereby relative changes in protective effects were greater than in harmful effects. An increase in relative risks for harmful effects and a concurrent decrease in relative risks for protective effects increased the protective net effect for deaths, YPL, and QALYs, and also produced a net cost saving. In contrast, a decrease (increase) of relative risks for harmful (protective) effects led to a decrease or even a sign-change in net effects for deaths, YPL, and QALYs. Assuming decreasing alcohol consumption in the elderly mostly affected mortality and least costs. Again, the influence on protective effects was considerably stronger than on harmful effects. Including 10% of diseases caused by definition from alcohol changed the number of deaths, YPL, and QALYs minimally. Nevertheless, this increased the caused costs by 12%, based mainly on costs for "mental and behavioral disorders from alcohol." In addition, strong increases in cost came from not discounting and valuing unpaid work with the labor costs of a home help. Calculating indirect costs with friction costs and not considering unpaid work strongly reduced costs.

Discussion

Mortality

According to our analysis, 15,461 more deaths were avoided than caused from moderate alcohol consumption in Germany in

Table 3 Quantity of caused and avoided resource utilization due to morbidity attributable to moderate alcohol consumption as well as net effects

	Caused resource utilization				Avoided resource utilization				Net effect*
	Male	Female	Both sexes†	Percentage of overall utilization	Male	Female	Both sexes†	Percentage of overall utilization	Percentage of overall utilization†
Acute hospitals									
Cases	81,136	108,716	189,851	1.15	102,830	119,836	222,666	1.36	–0.21
Days	702,290	1,014,688	1,716,978	1.08	770,141	1,319,153	2,089,293	1.31	–0.23
Nursing home care									
Proportion (%)‡	0.12	0.26	0.38	0.38	0.06	1.72	1.78	1.78	–1.4
Outpatient treatment									
Proportion (%)‡	0.66	0.94	1.6	1.6	0.18	0.36	0.54	0.54	1.06
Inpatient rehabilitation									
Cases	10,632	14,485	25,117	1.23	14,014	6,228	20,242	0.99	0.24
Days	266,088	363,233	629,321	1.02	340,434	177,387	517,821	0.85	0.17
Outpatient rehabilitation									
Cases	170	76	246	0.6	604	247	851	2.04	–1.44
Nonmedical costs									
Proportion (%)‡	0.71	0.85	1.56	1.56	0.42	0.77	1.19	1.19	0.37
Inability to work§									
Days	2,006,167	2,118,998	4,125,165	0.83	1,296,601	634,430	1,931,031	0.39	0.44
Early retirement									
Cases	268	171	439	0.25	215	134	350	0.2	0.05

*Positive (negative) values indicate caused (avoided) resource utilization.
†Sums may not sum to one because of rounding.
‡Proportion refers to sector-specific overall expenses.
§Including days lost due to acute hospital and inpatient rehabilitation.

Table 4 Caused and avoided costs, as well as net costs attributable to moderate alcohol consumption in millions of Euros by sector

	Caused costs			Avoided costs			Net costs*		
Cost category	Male	Female	Both sexes†	Male	Female	Both sexes†	Male	Female	Both sexes†
Direct costs									
Inpatient treatment	239	346	585	262	449	712	−23	−103	−127
Nursing home care	20	43	63	10	281	291	10	−238	−228
Outpatient treatment	732	1033	1765	200	399	599	532	634	1166
Rehabilitation	27	37	64	35	18	53	−8	19	11
Nonmedical costs	260	312	572	156	283	439	104	29	133
Total direct costs†	1278	1771	3049	663	1431	2094	615	340	955
Indirect costs paid work									
Mortality	728	170	898	548	69	617	180	101	281
Early retirement	35	13	48	25	9	34	10	4	14
Inability to work	249	147	396	186	49	235	63	98	161
Total indirect costs paid work†	1012	330	1342	758	128	886	254	202	456
Indirect costs unpaid work									
Mortality	523	594	1117	799	827	1626	−276	−233	−509
Early retirement	17	18	34	13	14	27	4	4	7
Inability to work	48	88	136	36	28	65	12	60	71
Total indirect costs unpaid work†	588	700	1288	849	870	1718	−261	−170	−430
Direct and indirect costs†	2878	2801	5679	2270	2428	4699	608	373	980

*Positive (negative) values indicate caused (avoided) cost.
†Sums may not sum to one because of rounding.

2002. The effect of moderate alcohol consumption differed clearly according to age. Up to the age range 55 to 60 (62.5–67.5) years, more deaths were caused than avoided in males (females). Here we see (Fig. 2) that the preponderance of avoided mortality from this age range on results from both a continual relative increase of avoided mortality and a relative decrease of caused mortality. Because constant consumption prevalence and thus constant attributable fractions were assumed from age 50 years on, these changes in age-specific attributable mortality were due to changes in total mortality structure. This especially means the age-dependent relative increase in avoided mortality resulted almost exclusively from a relative increase of mortality through coronary heart disease in the entire mortality. In fact, in the age groups up to 60 years, the overall number of deaths due to coronary heart disease was 9834 compared to 32,903 deaths from diseases for which moderate alcohol consumption is

Table 5 Caused and avoided costs, as well as net costs attributable to moderate alcohol consumption in millions of Euros by disease groups

	Caused costs			Avoided costs			Net costs*		
Cost category	Male	Female	Both sexes†	Male	Female	Both sexes†	Male	Female	Both sexes†
Direct costs									
Neoplasms	184	317	501	0	0	0	184	317	501
Diabetes mellitus	0	0	0	0	174	174	0	−174	−174
Circulatory	807	1177	1984	541	1031	1572	266	146	412
Nervous	39	51	90	0	0	0	39	51	90
Digestive	33	27	60	54	119	173	−21	−92	−113
Skin	51	45	95	0	0	0	51	45	95
Injury and poisoning	29	17	46	0	0	0	29	17	46
Not classifiable	136	136	272	68	107	175	68	29	97
Total direct costs†	1278	1771	3049	663	1431	2094	615	340	955
Indirect costs									
Neoplasms	705	540	1245	0	0	0	705	540	1245
Diabetes mellitus	0	0	0	0	66	66	0	−66	−66
Circulatory	312	306	618	1592	908	2501	−1280	−602	−1883
Nervous	38	24	62	0	0	0	38	24	62
Digestive	297	119	417	15	23	38	282	96	379
Skin	18	9	26	0	0	0	18	9	26
Injury and poisoning	230	32	262	0	0	0	230	32	262
Not classifiable	0	0	0	0	0	0	0	0	0
Total indirect costs†	1600	1030	2630	1607	997	2604	−7	33	26
Direct and indirect costs									
Neoplasms	889	858	1747	0	0	0	889	858	1747
Diabetes mellitus	0	0	0	0	240	240	0	−240	−240
Circulatory	1118	1483	2602	2133	1939	4073	−1015	−456	−1471
Nervous	77	75	152	0	0	0	77	75	152
Digestive	331	146	477	69	143	211	262	3	266
Skin	68	53	122	0	0	0	68	53	122
Injury and poisoning	258	50	308	0	0	0	258	50	308
Not classifiable	136	136	272	68	107	175	68	29	97
Total costs†	2878	2801	5679	2270	2428	4699	608	373	980

*Positive (negative) values indicate caused (avoided) cost.
†Sums may not sum to one because of rounding.

Table 6 Sensitivity analysis: percentage change compared to baseline value and absolute net effects when key parameters are varied

	Harmful effects (H)			Protective effects (P)			New net effect*		
Parameter changed	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female	Both sexes
Relative Risks: H +10%/P −10%†									
Deaths	+36	+40	+38	+67	+61	+64	−13,156	−15,986	−29,142
YPL	+40	+48	+44	+68	+61	+64	−108,768	−88,675	−197,443
QALYs	+40	+49	+44	+68	+61	+65	−95,081	−70,293	−165,374
Cost in millions of euros	+34	+39	+37	+79	+55	+66	−188	138	−50
Relative Risks: H +20%/P −20%†									
Deaths	+52	+69	+61	+150	+136	+142	−22,898	−26,309	−49,207
YPL	+54	+81	+67	+151	+135	+143	−221,494	−165,134	−386,628
QALYs	+54	+82	+67	+151	+135	+144	−195,336	−132,835	−328,171
Cost in millions of euros	+51	+65	+58	+176	+121	+147	−1,927	−736	−2,662
Relative Risks: H −10%/P +10%†									
Deaths	−20	−36	−29	−50	−50	−50	−1,448	−3,174	−4,621
YPL	−17	−38	−28	−50	−50	−50	10,794	−11,703	−909
QALYs	−17	−38	−27	−50	−50	−50	10,705	−8,610	2,095
Cost in millions of euros	−21	−38	−29	−51	−44	−47	1,139	391	1,530
Relative Risks: H −20%/P +20%†									
Deaths	−47	−59	−54	−93	−88	−90	2,321	1,324	3,645
YPL	−47	−66	−56	−93	−87	−90	44,328	15,747	60,075
QALYs	−47	−66	−56	−93	−87	−90	40,172	13,407	53,579
Cost in millions of euros	−49	−63	−56	−93	−73	−82	1,310	386	1,696
Less consumption in elderly									
Deaths	−7	−13	−11	−18	−26	−23	−4,713	−5,500	−10,213
YPL	−3	−8	−6	−13	−21	−17	−31,732	−24,783	−56,515
QALYs	−3	−8	−6	−13	−21	−16	−27,232	−18,881	−46,113
Cost in millions of euros	−3	−7	−5	−6	−17	−12	658	579	1,237
10% of diseases with AAF = 1									
Deaths	+8	+1	+4	±0	±0	±0	−6,211	−8,724	−14,862
YPL	+11	+3	+7	±0	±0	±.0	−36,166	−43,914	−80,080
QALYs	+11	+3	+7	±0	±0	±0	−30,763	−34,373	−65,136
Cost in millions of euros	+18	+6	+12	±0	±0	±0	1,114	547	1,661
German EQ-5D Index values									
QALYs	−5	−7	−6	−6	−8	−7	−38,372	−33,397	−71,769
Discount rate 0%									
Cost in millions of euros	+25	+16	+21	+26	+14	+20	745	456	1,201
Discount rate 10%									
Cost in millions of euros	−12	−7	−10	−14	−8	−11	580	361	941
Friction cost approach									
Cost in millions of euros	−25	−6	−16	−24	−3	−13	420	273	693
No valuation of unpaid work									
Cost in millions of euros	−20	−25	−23	−37	−36	−37	868	542	1,410
High valuation of unpaid work									
Cost in millions of euros	+24	+30	+27	+45	+43	+44	295	170	465

*Positive (negative) values indicate caused (avoided) deaths or costs and lost (gained) YPL or QALYs, respectively.
†Variations of relative risks leading to relative risks for protective effects larger than 1 or for harmful effects smaller than 1, were set at 1.
AAF, alcohol attributable fraction; EQ-5D, EuroQoL-5D; QALYs, quality-adjusted life-years; YPL, years of potential life.

considered a risk factor [16]. Yet, in the age groups older than 60 years, 154,958 total deaths occurred due to coronary heart disease, compared to 82,202 deaths from diseases harmfully associated with moderate alcohol consumption. This shift in total mortality caused the positive net effect on deaths and subsequent YPL and QALYs.

Yet, the net effect on avoided deaths must be critically viewed, because it can be overestimated for various reasons:

We assumed that consumption prevalence of those over 59 corresponded to that of the 50 to 59 age range. Nevertheless, based on increasing morbidity, alcohol consumption can decrease or stop completely with increasing age [33]. The assumption of a declining proportion of consumers from age 59 years on in the sensitivity analysis led to a decrease in avoided deaths by 23%, whereas caused deaths decreased by only 11%.

Various authors have found evidence that the protective effect of moderate alcohol consumption may be overestimated. Fillmore et al. [33] found in a meta-analysis that moderate consumers have neither a lower total mortality nor a lower mortality from coronary heart disease, if the abstinent comparison group comprises no former or occasional alcohol consumers. A 29-year follow-up study of Finnish males (Strandberg et al. [34] found no significant difference in mortality between abstainers and moderate alcohol consumers. In the sensitivity analysis, variations of relative risks led to considerable changes of net effects, and the protective net effect decreased substantially or disappeared, when the protective alcohol effect was reduced.

One can assume that moderate alcohol consumption, especially in young people, can present a risk factor for later alcohol abuse or dependency. Grant et al. [35] could demonstrate that the risk of becoming alcohol-dependent is smaller when alcohol consumption begins later. This means that probably a portion of prevalence for alcohol abuse and dependency today can be traced to moderate alcohol consumption—in other words, is "attributable." Thus, a portion of the current deaths from extreme alcohol consumption may be attributable to moderate alcohol consumption.

Finally, one must also expect that the number of deaths from coronary heart disease tends to be overestimated in statistics on causes of death, because the entries in these statistics are mostly based on external examinations. Here the danger is present that the frequent cause of death "coronary heart disease" is untruly given in several cases, especially among the old. This point is problematic, because the majority of the protective alcohol effects on mortality and subsequent YPL and QALYs are based on avoided deaths due to coronary heart disease.

All these aspects imply a tendency to overestimate the protective net effects, which is all the more critical, because they work together multiplicatively in concurrent manifestation and may decrease the protective effect strongly.

YPL and QALYs

Moderate alcohol consumption resulted in 205,691 (300,382) YPL lost (gained). Differences in the YPL per death resulted from the fact that avoided deaths tended to occur in more advanced ages than caused deaths. This also explains the differences between the distributions of deaths and YPL by diagnoses. As expected, the number of QALYs was smaller than the number of YPL, because they were determined with EQ-5D index scores of the general population, which does not have full quality of life. Also, quality of life decreases with age [19], resulting in a smaller ratio of gained to lost QALYs compared to YPL.

One must note that we did not consider QALYs other than due to mortality and of course, all uncertainties discussed in connection with mortality are also valid for YPL and QALYs.

Morbidity-Related Resource Utilization and Societal Costs

With respect to resource utilization, there were harmful and also protective net effects of differing strengths. With hospital treatment there was a protective net effect, but the ratio of protective to harmful effects was in context clearly smaller than with mortality. This may result from the fact that caused morbidity encompasses diseases involving more frequent hospital stays (e.g., neoplasms) or longer stays for treatment (e.g., severe accidents) than avoided morbidity in coronary heart disease. With nursing home care it occurred that 97% of avoided use of resources was due to females. This resulted from several circumstances: among avoided diseases, a total of 76% of resources used for nursing home care were due to stroke. Thereof, 78% were due to females, and the attributable fractions of stroke for females were substantially greater than for males.

A total of €5679 million (€4699 million) in costs were caused (avoided), equaling net costs of €980 million. Here we noticed various aspects. Caused and avoided indirect costs were almost equally high. Yet, avoided indirect costs resulted mainly from unpaid work, whereas caused indirect costs resulted equally from paid and unpaid work. This distinction results from protective alcohol effects occurring primarily in advanced age groups, which do considerable unpaid but no paid work.

The proportion of caused (avoided) direct costs in the total costs of moderate alcohol consumption was 54% (45%)—relatively large, in particular for the caused costs. With the costs of total alcohol consumption, the proportion of direct costs in the total caused (avoided) costs was only 35% (36%) [7]. Whereas strong or very strong alcohol consumption leads to high indirect costs from mortality [7], morbidity has a greater significance for moderate alcohol consumption. Yet, high direct costs from inpatient treatment of neoplasms, hypertension, atrial flutter and fibrillation, and especially outpatient treatment of hypertension led to a clear cost excess with direct costs.

When considering costs by disease group and sector, a heterogeneous picture emerged, showing cost savings as well as excess. A disease group (like circulatory diseases) can have cost savings in one sector (indirect costs) and excess costs in another sector (direct costs). In particular, concerning the uncertainty connected with the deaths due to coronary heart disease, one must note that €2076 million, corresponding to 80% of avoided indirect costs and 44% of all avoided costs, were due to mortality from coronary heart disease.

There are some limitations with respect to our calculation of costs. We have not documented various costs such as property damage, crime costs, court costs, diminished efficiency at work or social services. We extrapolated some cost areas, such as outpatient treatment, from high aggregated data. In addition, one must also take uncertainties discussed with mortality into account.

General Limitations

This study was conducted using a top-down approach. This allowed us to use large data sets, which often comprised information for a great proportion of or even the total German population. On the other hand, we were confronted with problems that typically occur when using a top-down approach. For example, in some sectors we had to break down highly aggregated data to single diagnoses (e.g., outpatient treatment), and data quality was sometimes problematic (e.g., causes of death statistics).

Prevalence rates of alcohol consumption used for our analysis were based on self-reported data [13]. It is well known that self-reported data tend to underestimate the real amount of alcohol consumption, especially in people with a high consumption level [36]. Thus, people who consume more than "moderately" may report moderate consumption, whereas people who consume "moderately" may have no incentive to report "abstinence," because moderate alcohol consumption tends to be socially accepted. Taken together, this may lead to an overestimation of the prevalence of moderate alcohol consumption and an underestimation of higher consumption levels. Nevertheless, one may argue that the same bias occurred in studies that estimated relative risks which should to a certain extend compensate possible bias in resulting AAFs.

In general, one must note that there is considerable uncertainty in the results of our study, making our conclusions speculative to some extend. This applies all the more, because we did not find a uniform answer to the question "Is moderate alcohol consumption at all protective or harmful?" Given the heterogeneity of net effects regarding mortality, morbidity-related resource use, and costs, even relative small variations in the underlying data may change our results and conclusions substantially, as shown in our sensitivity analyses. Nevertheless, our study shows that focusing on the protective effects of moderate alcohol consumption may lead to biased conclusions. Even if there is an overall protective effect, it may be quite small and restricted to an older population. Only for mortality (and associated YPL and QALYs) in an older population, we found a protective net effect which was associated with a considerable degree of uncertainty and may thus be overestimated, as discussed above. Thus, our study results call for caution with respect to moderate alcohol consumption as it may be potentially harmful and costly.

Summary and Conclusions

Moderate alcohol consumption appears to have a protective net effect on mortality in more advanced age groups. Yet this result has some uncertainty. In particular, the reliability of the relative risks should especially be further validated under consideration of comorbid risk factors. The societal costs caused by moderate alcohol consumption appear to be higher than the costs avoided resulting in a positive cost excess. In light of these results, moderate alcohol consumption should still be viewed critically, especially among younger age groups.

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