ORIGINAL ARTICLE

Trends in Disease Burden in Germany

Results, Implications and Limitations of the Global Burden of Disease Study

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SUMMARY

Background: The Global Burden of Disease (GBD) study is designed to give a comprehensive and standardized assessment of the health of populations around the world. It measures the burden of disease by considering years of life lost due to premature death as well as years lived with disability. The findings enable the identification of secular trends and disparities between countries and can serve as a basis for decision-making in health policy.

Methods: In cooperation with the authors of the GBD study, we summarize the key methods used to assess the burden of disease in terms of disability-adjusted life years (DALYs). We present findings that specifically pertain to Germany, drawn from freely available data of the most recent round of analysis for the years 1990 and 2010.

Results: According to the GBD study, life expectancy in Germany rose from 75.4 years in 1990 to 80.2 years in 2010. Ischemic heart disease and back pain caused the largest number of DALYs lost (2.5 million and 2.1 million, respectively). Over the period of the study, the absolute number of DALYs due to ischemic heart disease dropped by 33%, while the number of DALYs due to low back pain rose by 11%. Nutrition-related risks ranked first among all risk factors considered, accounting for 13.8% of total DALYs, followed by high blood pressure and high body-mass index, accounting for 10.9% each.

Conclusion: In Germany, important changes have been seen over time in the burden of disease attributable to different chronic diseases. Some of these changes reflect the successful interventions of the past, while others indicate a need for new action. The data from Germany that went into the GBD study must be systematically assessed and supplemented by further data relating to questions of specific relevance in this country.

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The original Global Burden of Disease Study, conducted in the late 1980s, represented the first attempt to paint a comprehensive and comparative picture of health and disease in the world population. In the intervening years the method of measuring the burden of disease has been applied both in developing and in developed nations (1–4). The focus is not on the health/disease of individual persons; rather, calculations of disease burden are carried out at the population level. Disease burden data can be used—with due consideration of the known methodological limitations—to aid decision-making processes in the area of health policy. Burden of disease studies use summary measures that combine epidemiological data on mortality and morbidity in one single metric, thus rendering heterogeneous disease states comparable (5, 6).

The new GBD study, carried out by the Institute for Health Metrics and Evaluation (Seattle, USA), presents findings covering the period 1990 to 2010 and provides the first completely revised, comprehensive, and comparative overview of the global health/disease situation (7, 8). The study uses modern Bayesian modeling techniques to combine epidemiological data on disease occurrence, disease consequences, and risk factors in order to improve the conclusiveness of the findings. Some nations (e.g., China and the UK) have already utilized the country-specific GBD 2010 results to:

- Analyze country-specific health trends over time
- Pinpoint successes and challenges in the fields of medicine and public health
- Benchmark with other countries
- Identify potential areas for improvement in public health and draw up recommendations for action (9, 10).

Although many nations worldwide have meanwhile investigated disease burden and quantified health deficits with the aid of summary measures, particularly the disability-adjusted life year (DALY), to date Germany's participation in international debate has been modest and the GBD methodology has been employed only selectively (11–13).

This article therefore sets out to portray the basic methodology of the GBD study and to describe and discuss the freely available data for Germany from GBD 2010. Previous publications have mostly focused on the global findings, and no comprehensive account of the burden of disease in Germany is yet available. This

TABLE 1

Trends in (healthy) life expectancy in the 15 founding members of the EU from 1990 to 2010 (28, 29)

a)		LE		
Rank[1]	Country	1990	2010	Change[2]
1	Italy	77.0 (76.9–77.0)	81.5 (81.3–81.6)	4.5
2	Spain	76.9 (76.9–77.0)	81.4 (81.2–81.5)	4.5
3	Sweden	77.6 (77.5–77.7)	81.4 (81.3–81.5)	3.5
4	France	77.1 (77.0–77.1)	80.9 (80.7–81.1)	3.8
5	Netherlands	77.0 (77.0–77.1)	80.6 (80.5–80.7)	3.6
6	Austria	75.7 (75.6–75.8)	80.6 (80.5–80.7)	4.9
7	**Germany**	**75.4 (75.3–75.4)**	**80.2 (80.1–80.4)**	**4.8**
8	Luxembourg	75.3 (75.0–75.6)	80.2 (79.8–80.5)	4.9
9	Finland	75.1 (75.0–75.2)	80.1 (79.9–80.2)	5
10	Great Britain	75.7 (75.6–75.7)	79.9 (79.9–80.0)	4.2
11	Ireland	74.8 (74.7–75.0)	79.9 (79.7–80.1)	5.1
12	Greece	76.9 (76.8–77.0)	79.6 (79.4–79.8)	2.7
13	Belgium	75.9 (75.8–76.0)	79.5 (79.3–79.8)	3.6
14	Portugal	74.3 (74.2–74.4)	79.4 (79.2–79.5)	5.1
15	Denmark	75.2 (75.0–75.3)	78.9 (78.8–79.1)	3.7

b)		HALE			Change
Rank[1]	Country	1990	2010	Change[2]	LE-HALE
1	Spain	67.5 (65.7–69.1)	70.9 (68.9–72.7)	3.4	1.1
2	Italy	66.7 (64.7–68.5)	70.2 (68.0–72.1)	3.5	1
3	Sweden	66.8 (64.9–68.7)	69.6 (67.4–71.7)	2.8	0.7
4	France	66.5 (64.6–68.4)	69.5 (67.3–71.5)	3	0.8
5	Netherlands	66.5 (64.6–68.3)	69.1 (67.0–70.9)	2.6	1
6	Austria	65.8 (63.7–67.5)	69.1 (66.9–71.2)	3.3	1.6
7	**Germany**	**65.3 (63.4–67.0)**	**69.0 (66.9–70.9)**	**3.7**	**1.1**
8	Ireland	65.2 (63.3–67.1)	68.9 (66.6–70.8)	3.7	1.4
9	Greece	66.5 (64.4–68.4)	68.7 (66.5–70.6)	2.2	0.5
10	Great Britain	65.4 (63.4–67.2)	68.6 (66.4–70.5)	3.2	1
11	Portugal	64.4 (62.3–66.2)	68.6 (66.3–70.5)	4.2	0.9
12	Belgium	65.7 (63.6–67.5)	68.5 (66.4–70.5)	2.8	0.8
13	Luxembourg	65.2 (63.1–67.1)	68.4 (65.9–70.5)	3.2	1.7
14	Denmark	65.3 (63.3–67.1)	67.9 (65.8–69.8)	2.6	1.1
15	Finland	63.8 (61.6–65.9)	67.3 (64.8–69.6)	3.5	1.5

Mean values (incl. 95% UI); [1] based on mean for 2010; [2] based on change in mean;
LE, life expectancy; HALE, health-adjusted life expectancy

TABLE 2 a

Burden of disease for the 21 major disease groups on the second level of the GBD classification system (Germany 2010) (30)

Rank	Cause	DALY	YLL	YLD
	Men			
1	Cardiovascular and circulatory diseases	2 551 248	2 252 040	299 208
2	Cancer	2 452 880	2 375 480	77 400
3	Musculoskeletal disease	1 679 000	16 860	1 662 140
4	Mental and behavioral disorders	1 305 863	192 543	1 113 320
5	Diabetes, urogenital, blood-related and endocrine disorders	733 326	320 654	412 672
6	Unintentional injury	614 616	183 137	431 479
7	Chronic respiratory diseases	578 996	325 573	253 423
8	Other non-communicable diseases	545 057	61 685	484 372
9	Neurological disorders	491 927	202 664	289 263
10	Transport injuries	345 240	170 269	174 971
11	Intentional injuries	328 251	310 882	17 369
12	Cirrhosis	292 923	288 070	4853
13	Diarrhea, lower respiratory tract disease, and other infectious diseases	255 849	172 406	83 443
14	Digestive diseases	193 883	138 585	55 298
15	Neonatal disorders	95 752	69 727	26 025
16	Nutritional deficiencies	43 650	5476	38 174
17	HIV/AIDS and tuberculosis	33 241	24 171	9069
18	Other communicable diseases	25 528	16 633	8895
19	NTDs* and malaria	5810	1794	4016
20	Maternal disorders	0	0	0
21	War and desasters	0	0	0

*NTDs: neglected tropical diseases; DALY, disability-adjusted life years; YLL, years of life lost due to premature death; YLD, years lived with disability

paper aims to present the major causes of the disease burden in Germany, the corresponding risk factors, and the trends over time. We also compare the disease burdens of a selected set of European countries, including Germany.

Methods

The data sources, statistical analyses, and modeling procedures employed have been previously described in great detail by the authors of the GBD 2010 Study (8, 14–20). We therefore confine ourselves to the key points of the methods.

GBD 2010 employed the summary measure DALY, combining epidemiological data on mortality and morbidity in one measure (see *eBox 1* for details of the DALY and *eBox 2* for the basic methodology of the study).

Main input data on mortality and morbidity

The calculation of DALYs in the GBD study was preceded by an analysis of the basic epidemiological data that would be required. In the framework of the study, data drawn from reviews and subsequent meta-analyses and from publicly available sources were subjected to statistical processing (see, for example, publications on ischemic heart disease [21] and depression [22]). Depending on data quantity and quality, estimates were based primarily on either country-specific data sources or were derived from prediction models accounting for incomplete or qualitatively insufficient data (for details see [8, 18, 23, 24]).

For Germany, the official death registry data and ICD-coded cause of death statistics were used. Various publicly available sources were drawn upon to estimate disease prevalences, because national health

TABLE 2 b

Burden of disease for the 21 major disease groups on the second level of the GBD classification system (Germany 2010) (30)

	Women			
Rank	Cause	DALY	YLL	YLD
1	Musculoskeletal disease	2 092 654	23 344	2 069 310
2	Cardiovascular and circulatory diseases	2 072 319	1 788 880	283 439
3	Cancer	1 807 685	1 726 940	80 745
4	Mental and behavioral disorders	1 460 018	56 358	1 349 660
5	Diabetes, urogenital, blood-related and endocrine disorders	737 065	277159	459 906
6	Neurological disorders	664 661	186 003	478 658
7	Other non-communicable diseases	608 604	56 458	552 146
8	Chronic respiratory diseases	489 548	208 274	281 274
9	Unintentional injury	460 015	112 969	347 046
10	Diarrhea, lower respiratory tract disease, and other infectious diseases	233 992	147 256	86 736
11	Digestive diseases	196 593	145 869	50 724
12	Transport injuries	147 146	54 811	92 335
13	Cirrhosis	138 381	135 707	2 674
14	Intentional injuries	107 181	102 661	4 520
15	Neonatal disorders	72 358	52 003	20 355
16	Nutritional deficiencies	25 210	7 504	17 706
17	Other communicable diseases	19 991	12 846	7 145
18	HIV/AIDS and tuberculosis	10 900	8 091	2 809
19	Maternal disorders	5 558	2 715	2 843
20	NTDs and malaria	5 212	4 054	1 158
21	War and desasters	0	0	0

NTDs: neglected tropical diseases; DALY, disability-adjusted life years; YLL, years of life lost due to premature death; YLD, years lived with disability

monitoring by the Robert Koch Institute (RKI) providing nationally representative prevalence estimates at regular intervals was not set up until 2008 (25).

Disability weights
Alongside the basic parameters, calculation of DALYs requires quantification of the impairment to health resulting from disease or injury. To this end, disability weights were established for all of the health states considered for GBD 2010 with the aid of population-based studies and used uniformly for all 187 nations *(eBox 1)* (17).

Quantitative parameters
The findings of the GBD 2010 Study for Germany are presented as DALYs, years lived with disability (YLDs), years of life lost (YLLs), life expectancy (LE), and health-adjusted life expectancy (HALE) (26) (for details on summary measures see [5]). All results are

given as means or modes with 95% uncertainty intervals (95% UI). Like the confidence interval, the 95% UI reflects estimation-related uncertainties, but additionally accounts for uncertainties from other sources, e. g. modeling uncertainties.
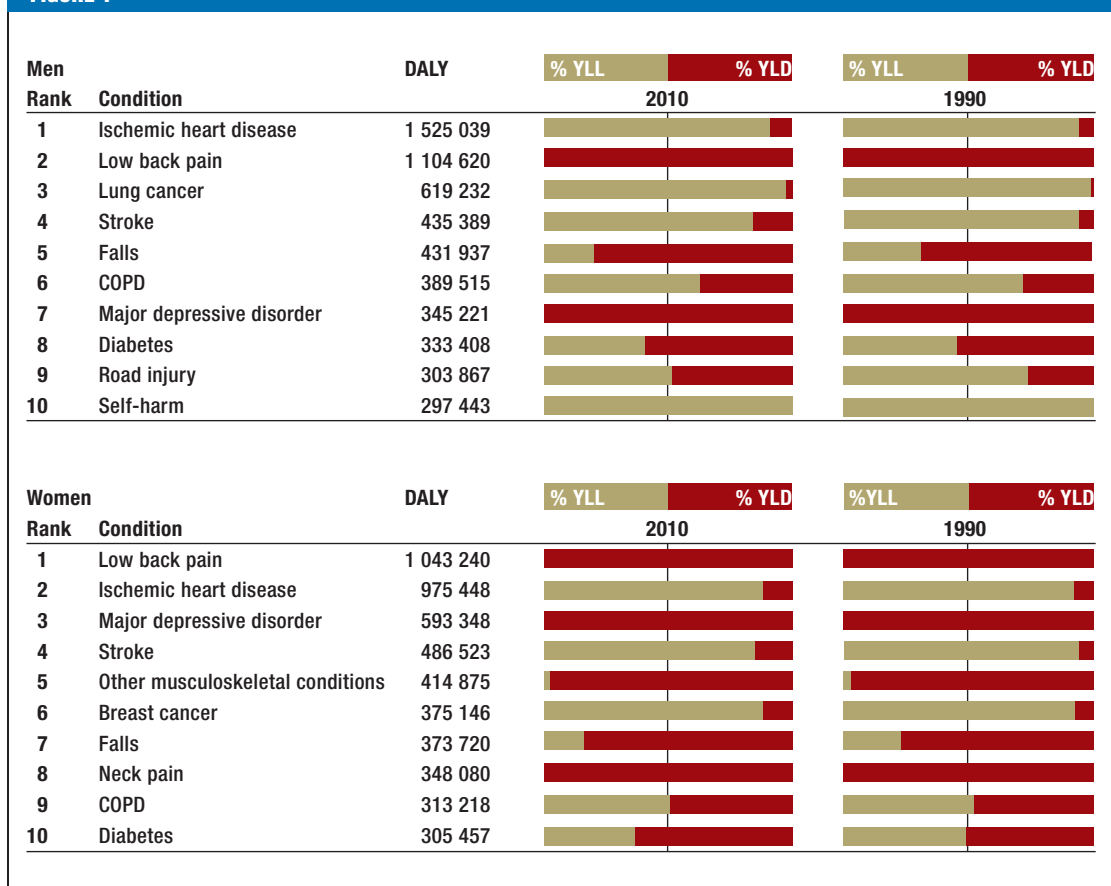
For the present paper we drew data for the disease burden in Germany from the visualization tools of the Institute for Health Metrics and Evaluation (IHME) (27), the Global Health Data Exchange (GHDx) database (28), and additional material provided by the IHME.

Results
(Healthy) life expectancy
According to the calculations of the GBD 2010 Study, the mean LE in Germany increased by 4.8 years from 75.4 (95% UI 75.3 to 75.4) in 1990 to 80.2 (95% UI 80.1 to 80.4) in 2010 *(Table 1)*. Sex-specific analyses (data not shown) revealed that the increase was greater for men than for women: in men the LE rose by 5.6

FIGURE 1

Men

Rank	Condition	DALY	% YLL / % YLD 2010	% YLL / % YLD 1990
1	Ischemic heart disease	1 525 039		
2	Low back pain	1 104 620		
3	Lung cancer	619 232		
4	Stroke	435 389		
5	Falls	431 937		
6	COPD	389 515		
7	Major depressive disorder	345 221		
8	Diabetes	333 408		
9	Road injury	303 867		
10	Self-harm	297 443		

Women

Rank	Condition	DALY	% YLL / % YLD 2010	% YLL / % YLD 1990
1	Low back pain	1 043 240		
2	Ischemic heart disease	975 448		
3	Major depressive disorder	593 348		
4	Stroke	486 523		
5	Other musculoskeletal conditions	414 875		
6	Breast cancer	375 146		
7	Falls	373 720		
8	Neck pain	348 080		
9	COPD	313 218		
10	Diabetes	305 457		

years, from 71.9 (95% UI 71.8 to 72.0) to 77.5 (95% UI 77.3 to 77.7), in women the LE rose by 4.4 years, from 78.4 (95% UI 78.4 to 78.5) to 82.8 (95% UI 82.6 to 83.1). Thus the difference in LE between women and men decreased by 1.2 years (29). The overall rise in HALE was 3.7 years, markedly below that for total LE *(Table 1)*. Again, the increase was much greater for men (3.9 years) than for women (2.7) during the study period. Among the 15 founding members of the European Union, Germany ranked seventh for LE and HALE in 2010 *(Table 1)*.

Mortality

The GBD 2010 Study showed that ischemic heart disease (195 797 deaths) was by far the most common cause of death in Germany in 2010 *(eFigure 1)*. This was true both for women (99 364 [95% UI 90 760 to 122 070]) and for men (96 433 [95% UI 89 980 to 110 219]). The second most common overall cause of death was stroke (76 291 deaths). In sex-specific analyses, this held true for women, while for men the second leading cause of death was lung cancer. Altogether, cardiovascular diseases played a greater role in women (483 deaths/100 000) than in men (394/100 000) (data not shown) (30).

The absolute numbers of deaths from the two leading overall causes of death decreased considerably during the study period, by 24% and 34% respectively *(eFigure 1)*. The age-standardized rates per 100 000 of the population decreased even more, by 47% and 53% respectively. In contrast, the absolute numbers of deaths increased for lung cancer (+18%), chronic obstructive pulmonary disease (COPD) (+1%), other cardiovascular diseases (+15%), chronic lower respiratory diseases (+13%), diabetes (+1%), and hypertensive heart disease (+2%).

The increase in the overall absolute number of deaths can be attributed largely to demographic

TABLE 3

Comparison of age-standardized DALY rates per 100 000 of the population for the 10 most frequent causes of disease burden (32)

Rank[*]		DE	BE	DK	FI	FR	GR	UK	IE	IT	LU	NL	A	PT	ES	SE
1	Low back pain	2033	1742 (1)	2014 (1)	1832 (1)	1906 (1)	1806 (1)	1931 (1)	1879 (1)	1570 (1)	1882 (1)	1749 (1)	1910 (1)	1890 (1)	1093 (1)	1982 (1)
2	Ischemic heart disease	1406	1300 (2)	1266 (2)	1585 (2)	814 (3)	1711 (2)	1310 (2)	1487 (2)	1019 (2)	1209 (3)	980 (3)	1311 (2)	960 (2)	963 (2)	1202 (2)
3	Major depressive disorder	1027	842 (3)	1068 (3)	1264 (3)	1014 (2)	1031 (3)	656 (5)	856 (3)	1024 (3)	1383 (2)	1700 (2)	1056 (3)	914 (4)	922 (3)	1006 (3)
4	Neck pain	610	613 (7)	579 (8)	726 (5)	609 (8)	619 (7)	607 (6)	616 (4)	618 (5)	617 (5)	609 (6)	610 (6)	622 (6)	610 (5)	566 (4)
5	Lung cancer	576	705 (5)	741 (5)	387 (13)	644 (6)	661 (6)	595 (7)	536 (8)	505 (9)	581 (7)	734 (4)	519 (8)	447 (11)	534 (7)	371 (17)
6	Falls	560	602 (9)	566 (9)	656 (7)	593 (9)	567 (8)	559 (8)	570 (6)	549 (6)	601 (6)	546 (7)	611 (4)	565 (8)	535 (9)	548 (5)
7	Other musculoskeletal conditions	531	532 (11)	544 (11)	528 (10)	540 (10)	513 (9)	542 (11)	537 (9)	520 (8)	526 (9)	533 (8)	526 (9)	532 (9)	546 (6)	524 (6)
8	Road injuries	514	766 (4)	554 (10)	528 (9)	633 (7)	895 (5)	500 (13)	551 (7)	657 (4)	611 (4)	458 (11)	600 (5)	709 (5)	597 (4)	447 (9)
9	Stroke	488	557 (10)	638 (7)	592 (8)	453 (12)	939 (4)	542 (10)	508 (10)	537 (7)	573 (8)	495 (10)	491 (13)	975 (3)	505 (10)	484 (8)
10	Anxiety disorders	495	360 (15)	381 (16)	437 (16)	675 (4)	498 (10)	555 (9)	408 (13)	368 (13)	588 (12)	506 (9)	374 (17)	484 (12)	287 (16)	471 (11)

Note: Age-standardized DALY rates (mean) per 100 000 of the population (standardized to WHO world population 2001)
[*] Rank in Germany (rank in other countries shown in parentheses)

changes in the population, because the age-standardized rates show that all of the 10 most common causes of death are on the decrease. Apart from the 10 leading causes of death the trends for absolute numbers of deaths and age-standardized death rates are rising for several disease groups, including Alzheimer's disease and other dementias (+244% and +119% respectively), chronic kidney disease (+106% and +33% respectively), and atrial fibrillation (+501% and +304% respectively) (30).

Disability-adjusted life years
A total of 23.9 (95% UI 22 to 26) million healthy years of life were lost due to disease and injury in Germany in 2010, 52.7% of them in men. Compared with 1990 (25.7 million DALYs), the absolute number of DALYs went down by 7.3% and the age-standardized DALYs decreased from 25 197 (95% UI 23 299 to 27 306) to 19 527 (95% UI 17 646 to 21 560) per 100 000 of the population (31).

At the first level of the GBD classification system, 3.5% (circa 0.83 million DALYs) of the total burden of disease in Germany could be attributed to group I (communicable, maternal neonatal and nutrional disorders), 88.1% (circa 21 million DALYs) to group II (non-communicable diseases), and 8.4% (circa 2 million DALYs) to group III (injuries) (31).
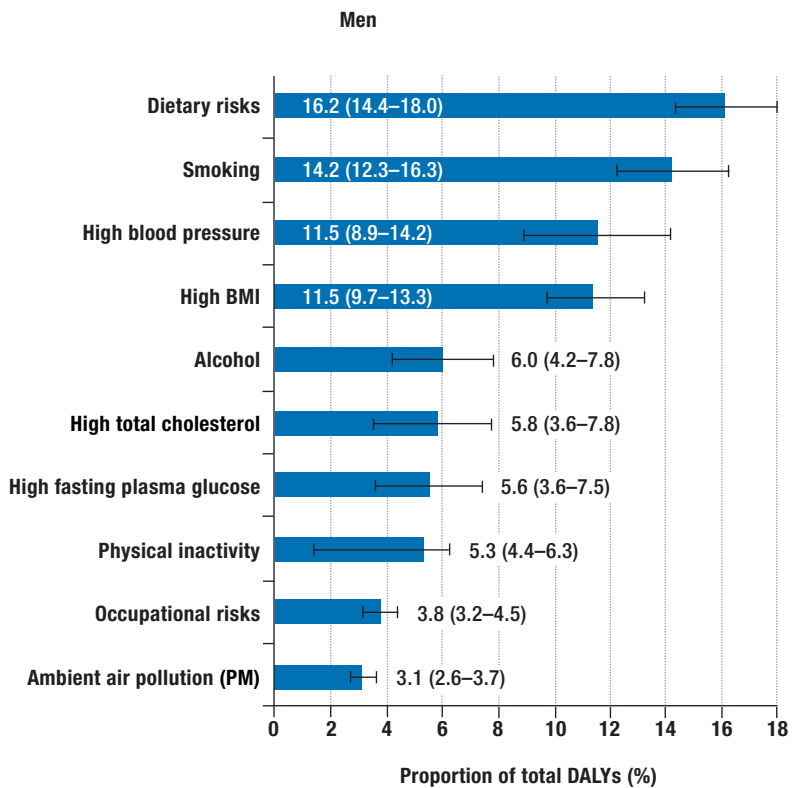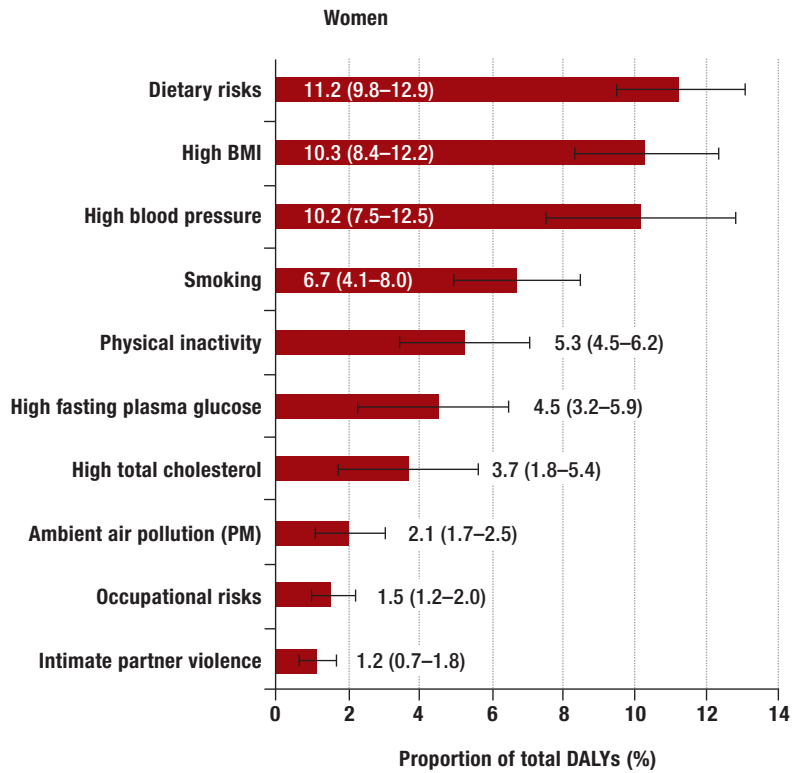
At the second level of the GBD classification system (21 major disease groups), the most important disease groups are cardiovascular and circulatory diseases (19.4%), malignant neoplasms (17.9%), musculoskeletal disorders (15.8%), and mental and behavioral disorders (11.4%). Stratification by sex shows that the leading cause of lost healthy years in women is not cardiovascular diseases but musculoskeletal disorders (*Table 2a* and *b*) (31).

At the fourth level of detail, ischemic heart disease (men) and low back pain (women) were identified as by far the most common causes of lost healthy years *(eFigure 2)*. Despite the prominent place occupied by ischemic heart disease, the disease burden in absolute DALYs fell by a median 27% (rate: –52%) in men and 41% (rate: –54%) in women between 1990 and 2010 *(eFigure 2)*. In contrast, the absolute DALYs rose by 19% (rate: 2%) in men and by 4% (rate: −3%) in women over the same period.

With regard to DALY rates, the generally decreasing or moderately increasing tendencies among the 30 most frequent causes of lost healthy years are accompanied by an increase in DALY rates due to Alzheimer's disease and other dementias of 26% (from 157 to 198 DALYs/100 000) for men and 16% (from 182 to 210 DALYs/100 000) for women (30).

For ischemic heart disease, the greatest part of the disease burden can be attributed to the YLLs, i.e., to premature deaths. In contrast, all of the low back pain DALYs are due to morbidity effects (YLDs) *(Figure 1)*. The relevance of YLDs for the majority of the 10 most common diseases increased in the period 1990 to 2010 *(Figure 1)* (30).

FIGURE 2

Women

Risk factor	Value
Dietary risks	11.2 (9.8–12.9)
High BMI	10.3 (8.4–12.2)
High blood pressure	10.2 (7.5–12.5)
Smoking	6.7 (4.1–8.0)
Physical inactivity	5.3 (4.5–6.2)
High fasting plasma glucose	4.5 (3.2–5.9)
High total cholesterol	3.7 (1.8–5.4)
Ambient air pollution (PM)	2.1 (1.7–2.5)
Occupational risks	1.5 (1.2–2.0)
Intimate partner violence	1.2 (0.7–1.8)

Proportion of total DALYs (%)

Men

Risk factor	Value
Dietary risks	16.2 (14.4–18.0)
Smoking	14.2 (12.3–16.3)
High blood pressure	11.5 (8.9–14.2)
High BMI	11.5 (9.7–13.3)
Alcohol	6.0 (4.2–7.8)
High total cholesterol	5.8 (3.6–7.8)
High fasting plasma glucose	5.6 (3.6–7.5)
Physical inactivity	5.3 (4.4–6.3)
Occupational risks	3.8 (3.2–4.5)
Ambient air pollution (PM)	3.1 (2.6–3.7)

Proportion of total DALYs (%)

Attributable disease burden for the 10 principal risk factors in Germany, 2010 (stratified by sex, with error bars showing the 95% UI) (30, 31). BMI, body mass index; PM, particulate matter; DALYs, disability-adjusted life years

Germany in comparison with other European countries

Comparison of the founding members of the European Union shows that the three leading causes of DALYs are distributed similarly, with minor deviations, in all 15 countries. However, Germany shows the highest rates for low back pain and is near the top of the rankings for ischemic heart disease and depression *(Table 3)* (32).

Risk factors

According to the findings of the GBD 2010 Study the most significant risk factor is the complex of nutrion-related risks, to which can be attributed 13.8% (95% UI 12.3 to 15.4) of the total DALYs and 26% (95% UI 23.4 to 28.4) of all deaths. High blood pressure and high body mass index (BMI) jointly occupy second place, each accounting for 10.9% of total DALYs (31). Within the risk factor cluster of nutrition-related factors (14 individual factors) (20), the most important in Germany are diets low in nuts, fruits, and seeds or high in sodium (31).

The risk factor complex of nutrition-related factors accounts for 16.2% of DALYs in men, compared with 11.2% in women. Smoking and alcohol abuse are more important factors in men than in women, while high BMI seems to be a more serious risk for women than for men *(Figure 2)* (31).

The disease burden attributable to all 10 most frequent risk factors decreased considerably over the study period, with regard to both absolute DALYs and age-standardized DALY rates. The highest reductions in rates were seen for air pollution (−67%; 95%UI −70 to −64), high total cholesterol (−58%; 95%UI −70 to −46), and high blood pressure (−54%; 95%UI −61 to −46) (data not shown) (31).

Discussion

The results of the GBD 2010 Study indicate changes in the importance of chronic diseases and reflect demographic trends and intervention effects. Comparison of LE with HALE clearly shows that residents of Germany are living longer than in 1990, but that a portion of the extra years of life is spent in a state of reduced health. Altogether, there is a pronounced shift of disease burden towards morbidity effects (YLDs). On one hand this represents a success, because for example fewer people are dying of myocardial infarction, but on the other hand it is a challenge, because patients living with the long-term consequences of coronary heart disease have to receive appropriate care.

One notable trend between 1990 and 2010 was the increase in the importance of back pain in both women and men. Although the health surveys of the RKI show that the prevalence of low back pain was considerably higher in women than in men in the years 2003 and 2009 (33), GBD 2010 reveals a higher disease burden for men.

Looking at the input data it was identified that data for Germany were only included up to 2006; for later years, estimates were derived from prediction models that contained no actual data from Germany. This explains why the uncertainty intervals are large and indicate limited data.

Comparison of the GBD 2010 findings with the official causes of death statistics shows that ischemic heart disease is the leading cause of death in both data sources. The number of deaths cannot be compared ad hoc because of the correction algorithms applied in the estimation process for causes of death in the GBD study (34, 35).

The increase in the burden of disease imposed by Alzheimer's disease and other dementias is striking. At the same time, dementias exemplify how important it is for estimates of trends in disease burden to be accompanied by detailed monitoring of disease incidence and prevalence and of the prevalence of the principal risk factors. Numerous factors (demographic trends, progress in the prevention of cardiovascular disease, advances in diagnosis and treatment) can influence incidence, prevalence, and mortality in many different ways (36, 37).

According to the GBD 2010 Study, poor nutrition is responsible for the loss of many healthy years of life, particularly through premature death (2.8 [95% UI 2.6 to 3.1] million YLLs). Despite the general decrease in overall disease burden, nutrition-related factors remained by far the greatest risk in 2010, and preventive measures as well as public awareness campaigns should be tailored accordingly. Inadequate nutrition favors risk factors such as hypertension, impaired glucose tolerance, high BMI, and high cholesterol. In view of the complexity of nutrition-related health risks, it is important to observe the prevalence of particular patterns of nutrition and also of individual components (e.g., salt and alcohol) at the population level and ascertain their contribution to impairments of health.

Limitations and recommendations

The new GBD 2010 Study provides many advances in the comprehensive analysis of health trends at the population level. One crucial limitation, however, is that so far regularly collected data representative of the population in Germany have not continuously been available, so that the investigators have had to rely on freely accessible data. As already shown in other country-specific analyses (e.g., China and Turkey), countries often possess further national and regional health data that can help to improve the quality of the models and the validity of the estimates (Christopher Murray, personal communication).

For example, data collected in Germany as part of the RKI's national health monitoring (e.g., the German Health Interview and Examination Survey for Adults [DEGS]) were not included in GBD 2010, although they will be included in ongoing GBD analyses. Looking at the DALYs for Germany, it is noticeable that the uncertainty intervals for some diseases are very wide. This can be attributed in part to the limited availability or insufficient quality of the data.

It is important to point out that international data also feature considerable variations of uncertainty intervals,

individual countries, providing insight into major changes in population health and new challenges in prevention and care. The crucial prerequisites are availability of data, adaptation to the circumstances of the country concerned, and refinement of the methods. In Germany, the nationwide health monitoring by the Robert Koch Institute provides a good basis for initiating a national burden of disease study (NBD Germany) in cooperation with German and international partners.

and this should always be borne in mind when comparisons are made. For this reason the international efforts to establish mandatory standards in the acquisition and analysis of health data (especially morbidity data) should be intensified, in order to improve the basis for the calculation of DALYs and thus the validity of international comparisons.

The data sources used for Germany should now be carefully reviewed—as already described for low back pain—and the gaps filled, to provide a broader and stronger basis for the German results. In this regard, sub-national analyses of the disease burden would be very useful in identifying any variation in the distribution of the burden in different parts of the country. Close cooperation between health institutions in Germany and the organizers of the GBD study would be beneficial in setting up a concerted national burden of disease study for Germany (NBD Germany). This study should include analyses of the methodological, ethical, and legal aspects of disability weights (38).

Disability weights constitute a very important aspect of the calculation of DALYs and have been criticized particularly with regard to the universal application of global disability weights, as well as certain methodological limitations. The criticism has focused on the way in which the descriptions of health states in the population-based studies were formulated so as to be comprehensible to a layperson, which may, for instance, possibly have led to the establishment of relatively low disability weights for severe visual impairment or blindness (39).

Conclusion

Comprehensive analyses and evaluations of trends in the health status of populations along the lines of the Global Burden of Disease Study are also helpful for

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eFIGURE 1

Rank	Cause of death	Deaths 1990	Rank	Deaths 2010	Change % (abs.)	Change % (rate)*
1 (1-1)	Ischemic heart disease	256489 (241964-268047)	1 (1-1)	195797 (184626-219331)	-24 (-28 to -15)	-47 (-50 to -40)
2 (2-2)	Stroke	113814 (95388-122415)	2 (2-2)	76291 (68497-87093)	-34 (-40 to -17)	-53 (-57 to -42)
3 (3-5)	Lung cancer	39449 (32187-51639)	3 (3-4)	44748 (33076-55155)	18 (-11 to 28)	-13 (-34 to -6)
4 (3-5)	COPD	34359 (31002-37565)	4 (4-5)	34539 (31017-38135)	1 (-8 to 10)	-28 (-34 to -23)
5 (3-5)	Colorectal cancer	33354 (27985-38767)	5 (3-6)	32083 (28516-44426)	-7 (-16 to 35)	-33 (-38 to -3)
6 (6-8)	Other cardiovascular and circulatory diseases	25071 (23698-26628)	6 (5-7)	28818 (26239-31472)	15 (3 to 27)	-22 (-29 to -14)
7 (6-10)	Lower respiratory infections	22948 (19777-28300)	7 (5-9)	25540 (20296-31095)	13 (-17 to 43)	-21 (-42 to -3)
8 (7-11)	Cirrhosis	20934 (18440-24651)	8 (7-12)	20850 (18441-24765)	1 (-12 to 16)	-29 (-37 to -19)
9 (7-12)	Diabetes	20567 (18009-23536)	9 (7-14)	21136 (15446-27911)	2 (-18 to 46)	-29 (-42 to -4)
10 (6-13)	Hypertensive heart disease	20436 (15339-27671)	10 (8-13)	19020 (15919-21878)	-8 (-20 to -1)	-32 (-39 to -26)
11 (6-13)	Stomach cancer	19462 (14832-27121)	11 (9-14)	18079 (16366-19632)	-2 (-13 to -7)	-29 (-36 to -23)
12 (10-13)	Breast cancer	18583 (17375-20360)	12 (7-21)	17405 (9296-25845)	244 (32 to 424)	119 (-4 to 221)
13 (10-15)	Self-harm	15748 (12146-19664)	13 (9-20)	16618 (10527-20602)	106 (8 to 147)	33 (-42 to 55)
14 (13-18)	Falls	12106 (9974-15011)	14 (10-19)	15222 (11096-19762)	38 (6 to 56)	2 (-21 to 15)
15 (14-18)	Road injuries	11771 (9879-13646)	15 (8-24)	14658 (7829-23966)	32 (-6 to 82)	-5 (-32 to 30)
16 (14-18)	Rheumatic heart disease	11581 (10121-13330)	16 (11-20)	13474 (10297-18939)	-31 (-40 to -18)	-49 (-55 to -41)
17 (14-20)	Pancreatic cancer	11204 (8412-15199)	17 (10-23)	12713 (7965-19778)	501 (248 to 979)	304 (142 to 610)
18 (13-25)	Prostate cancer	11182 (6460-17748)	18 (12-21)	12518 (9817-17294)	-23 (-32 to 11)	-35 (-45 to -10)
19 (15-22)	Chronic kidney disease	8879 (7642-11967)	19 (14-22)	12229 (9262-15446)	1 (-27 to 31)	-28 (-46 to -11)
20 (19-23)	Cardiomyopathy	7960 (7407-9428)	20 (16-21)	11295 (9826-12734)	43 (18 to 63)	-4 (-16 to 9)
28 (19-37)	Alzheimer's disease	5504 (4098-9742)	27 (24-34)	6425 (5144-7901)	-45 (-56 to -30)	-63 (-69 to -54)
48 (42-53)	Atrial fibrillation	2091 (1500-2916)	30 (24-36)	5469 (4689-7584)	-56 (-61 to -34)	-60 (-65 to -40)

The 20 most frequent causes of death in Germany and how they changed between 1990 and 2010 (incl. 95% UI) (red: group I; blue: group II; green: group III) (30)

*Standardized on the basis of the WHO world population 2001

**Including other dementias

eFIGURE 2

Men

Rank	x̄ (95%UI)	Men	DALYS 1990	Rank	x (95%UI)	DALYS 2010	% Change	% Change (rate)*
1	1.0 (1-1)	Ischemic heart disease	2062810 (1920080-2225380)	1	1.0 (1-1)	1525040 (1411380-1738710)	-27 (-32 to -18)	-52 (-55 to -45)
2	2.1 (2-3)	Low back pain	927728 (638470-1267270)	2	2.0 (2-2)	1104620 (745684-1500700)	19 (2 to 40)	2 (-13 to 19)
3	3.0 (2-5)	Lung cancer	675921 (533972-912512)	3	3.1 (3-4)	619232 (457991-804560)	-8 (-21 to 0)	-37 (-46 to -31)
4	4.2 (3-6)	Stroke	586350 (482505-633336)	4	4.8 (4-7)	435388 (373687-483282)	-26 (-32 to -15)	-53 (-56 to -46)
5	4.8 (3-6)	Road injuries	546362 (460877-635859)	5	5.1 (3-8)	431938 (322845-580305)	37 (14 to 63)	0 (-16 to 20)
6	6.7 (6-9)	COPD	418553 (356058-489041)	6	6.2 (4-10)	389515 (321375-465776)	-7 (-16 to 2)	-37 (-44 to -30)
7	6.8 (5-10)	Self-harm	414232 (309611-544668)	7	8.3 (4-14)	345221 (245746-481307)	10 (-19 to 55)	2 (-26 to 43)
8	8.3 (6-11)	Cirrhosis	364571 (300430-453086)	8	8.4 (6-13)	333408 (262912-428304)	31 (10 to 55)	-7 (-22 to 0)
9	9.9 (7-13)	Falls	315624 (244342-413407)	9	10.3 (7-14)	303867 (243220-392832)	-45 (-54 to -27)	-49 (-57 to -31)
10	10.3 (6-15)	Major depressive disorder	312784 (212741-444573)	10	10.4 (5-16)	297443 (216104-403731)	-29 (-44 to -4)	-35 (-50 to -14)
13	10.5 (7-15)	Diabetes	253530 (202080-322628)	11	10.6 (7-15)	292923 (235855-360753)	19 (-30 to -11)	-39 (-47 to -33)

Women

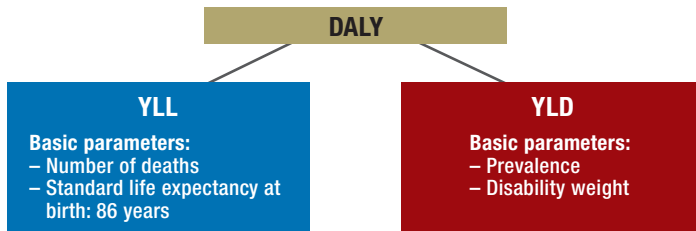| Rank	x̄ (95%UI)	Women	DALYS 1990	Rank	x̄ (95%UI)	DALYS 2010	% Change	% Change (rate)*
1	1.0 (1-1)	Ischemic heart disease	1615380 (1454890-1765380)	1	1.4 (1-2)	1043240 (713376-1408400)	4 (-11 to 22)	-3 (-17 to 13)
2	2.2 (2-3)	Low back pain	1003370 (704577-1374510)	2	1.7 (1-2)	975447 (873104-1202230)	-41 (-46 to -25)	-54 (-59 to -39)
3	2.3 (2-3)	Stroke	804389 (659048-860892)	3	3.3 (3-6)	593348 (395859-814686)	7 (-23 to 49)	2 (-27 to 41)
4	4.2 (3-6)	Major depressive disorder	554754 (387435-766008)	4	4.1 (3-6)	486524 (418006-558702)	-41 (-46 to -25)	-51 (-55 to -41)
5	5.3 (4-7)	Breast cancer	429160 (398992-465428)	5	6.1 (3-12)	414875 (272038-614558)	14 (-33 to 93)	3 (-40 to 75)
6	7.3 (6-10)	Diabetes	355842 (286564-441067)	6	6.6 (5-9)	375146 (345078-405430)	-12 (-21 to -5)	-29 (-36 to -23)
7	7.5 (4-12)	Other MD**	366219 (240720-544734)	7	6.9 (4-10)	373719 (272791-499330)	8 (-8 to 27)	-12 (-25 to 4)
8	8.0 (5-12)	Falls	344252 (254917-458805)	8	8.2 (4-13)	348080 (241476-491522)	8 (-8 to 27)	0 (-15 to 18)
9	8.9 (5-13)	Neck pain	321548 (218017-453441)	9	9.7 (6-13)	313218 (249943-392491)	15 (3 to 28)	-2 (-12 to 10)
10	10.0 (7-13)	Bowel cancer	295472 (230581-375049)	10	10.1 (7-13)	305456 (243534-394397)	-14 (-27 to 3)	-27 (-39 to -10)
12	11.0 (8-14)	COPD	273470 (222425-342353)	15	14.5 (8-17)	218103 (186620-344726)	-30 (-37 to 18)	-42 (-48 to -2)

The 10 most frequent causes for DALYs in men and women and the change in burden of disease in Germany between 1990 and 2010 (% change expressed as median) (blue: group II; green: group III) (30)

*Standardized on the basis of the WHO world population 2001

**Other musculoskeletal diseases

eBOX 1

Basic parameters and calculation of DALYs

```
                    DALY

      YLL                        YLD
Basic parameters:          Basic parameters:
– Number of deaths         – Prevalence
– Standard life expectancy – Disability weight
  at birth: 86 years
```

The DALYs comprise two complementary components, years of life lost due to premature death (YLLs) and years lived with disability (YLDs). The unit of measurement is lost years of healthy life.

In the context of burden of disease studies, the term "disability" is used to mean any quantifiable (percentage) deviation from optimal health status.

The mortality component (YLLs) is calculated from the number of persons who have died (N) (by age [a], sex [s], and cause of death [i]) and a global standard, valid for both sexes, for the life expectancy at birth (used to estimate the remaining life expectancy [RLE] at the time of death [ā]): (Equation 1)

$$[1] \quad YLL = \sum_{a=0} N_i^{a,s} \times RLE^{\bar{a},s}$$

The morbidity component (YLDs) is calculated from the prevalence (P) (by age [a] and sex [s]) of the health-impairing condition being investigated (i) and the disability weight (dw) (Equation 2):

$$[2] \quad YLD = \sum_{a=0} P_i^{a,s} \times dw_i$$

The sum of the YLLs and YLDs gives the DALYs (Equation 3):

$$[3] \quad DALY = YLL + YLD$$

● **Disability weights**
The first GBD study introduced the concept of disability weights, used to quantify the impact of diseases and injuries on health by measuring impairments of health on a scale of 0 (complete health) to 1 (a state comparable with death). In the GBD 2010 Study health states were evaluated on the basis of population-based studies in which the participants had to weigh health states against each other in pairwise comparisons and decide which was the healthier (17). Therefore the newly derived disability weights (GBD 2010) reflect the perspective of the population, rather than being based on expert opinion.

Methods of the GBD 2010 study

- **Classification of diseases and injuries**
  The GBD classification is a tree-like structure with five levels of disaggregation. At the highest level (level 1) are the entities of groups I, II, and III. Group I entities include communicable, maternal, neonatal and nutritional disorders. Group II comprises non-communicable diseases, and group III is made up of injuries. The burden of disease is differentiated into 21 major groups (level 2) and further into individual disease endpoints (levels 3 to 5) depending on the detail required (see example for musculoskeletal diseases). The GBD classification is structured in such way that all codes contained in the International Classification of Diseases (ICD) can be clearly assigned to a group at each level of the GBD classification system (24).

| Non-communicable diseases (L1) |
| Musculoskeletal disorders (L2) |
| Osteoarthritis (L3) |
| Rheumatoid arthritis (L3) |
| Gout (L3) |
| Other musculoskeletal disorders (L3) |
| Low back pain, neck pain (L3) |
| Low back pain (L4) |
| Neck pain (L4) |

- **Parameters**
  Alongside the disability-adjusted life years (DALYs) and their two components, the years of life lost due to premature death (YLLs) and years lived with disability (YLDs), the GBD study employs an indicator for healthy life expectancy, the health-adjusted life expectancy (HALE). This measure represents the life expectancy free of health impairments and is thus a suitable parameter for estimation of the effects on life expectancy of changes in population morbidity (16, 24).

- **Prevalence**
  The YLDs are established on the basis of the prevalence of diseases and injuries. The reason for this is that present needs in health care (e.g., for resources) are depicted better by prevalence than by incidence. This is particularly true when incidence is decreasing but prevalence is constant or rising slightly (24).

- **Standard life expectancy**
  The life expectancy at birth was calculated on the basis of the lowest mortality rate observed anywhere in the world and determined as 86 years. The life expectancy at birth was set the same for both sexes because, although differences can be observed, (a) the difference in life expectancy between men and women is continuing to shrink and (b) the goal should be to attain the highest possible life expectancy regardless of sex. The GBD study thus proceeds from the assumption that all people, whatever their origin, ethnicity, or sex, should be able to reach the age defined as standard (24).

- **Age weighting and time discounting**
  On ethical grounds, these two concepts from economic theory were not used for calculation of the burden of disease in the GBD 2010 Study (24).

- **Uncertainty intervals**
  The intensified recourse to modeling methods makes it essential to quantify the uncertainty intervals. These enable portrayal in the final results of all uncertainties present in the input data and arising from modeling processes. The uncertainty intervals reflect, in addition to the estimation-related uncertainty depicted in conventional confidence intervals, uncertainties from other sources, e.g., from modeling. The results are expressed as means or modes with 95% uncertainty intervals.

- **Trends over time**
  The methods of the GBD 2010 Study were applied consistently throughout the period 1990 to 2010. This enabled, for the first time, identification of changes and trends in disease burden (24).

- **Comorbidities**
  Because of the increasing role of comorbidities, potential accompanying conditions were depicted at population level on the basis of microsimulation models. In a second step, the disability weights were adjusted (in a multiplicative approach) to take into account the severity of comorbid states (24).

- **Risk factors**
  As for the epidemiological parameters, data on the 67 investigated risk factors (exposure, exposure effect estimator) were derived from existing databases and literature reviews. The attributable disease burdens were estimated by means of comparative risk assessment, in which a proportion of the disease-specific burden is attributed to a particular risk factor (20).

- **Correction of cause of death**
  Incorrectly or unclearly coded causes of death were redistributed with the aid of a standardized algorithm (19, 35).

- **Age standardization**
  Age standardization was based on the standard world population data for the year 2001 provided by the WHO (40).