Chapter 26

Mortality and burden of disease attributable to individual risk factors

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Population attributable fractions (PAFs) for mortality and burden of disease attributable to individual risk factors were calculated, as described in chapter 25, using risk factor exposure and hazard estimates provided in risk factor chapters. Mortality and burden of disease attributable to individual risk factors were then calculated by multiplying the PAFs by the estimates of total mortality and burden of disease from the Global Burden of Disease (GBD) databases in each of the 224 subregion-age-sex groups, as described in chapter 25. These results are presented in the Annex Tables for each risk factor and summarized here across risks.

1. Aggregate disease burden attributable to individual risk factors

All-cause mortality and burden of disease estimates for females and males attributable to CRA risk factors in the 14 subregions[1] are presented in Table 26.1. Figure 26.1 shows the contribution of the 20 leading global risk factors to mortality and burden of disease in the world and three broad combinations of subregions—demographically and economically developed (AMR-A, EUR and WPR-A), low-mortality developing (AMR-B, EMR-B, SEAR-B and WPR-B) and high-mortality developing (AFR, AMR-D, EMR-D and SEAR-D). Figure 26.2 presents the burden of disease due to the leading 10 risk factors for each subregional grouping, also showing the cause composition, divided into broad groups of diseases and injuries. The different ordering of risk factors in their contributions to mortality and disease burden reflects the age profile of mortality (e.g. under-five mortality for underweight has larger

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Table 26.1(a) Mortality for females and males due to selected risk factors in 14 subregions

	AFRICA Mortality stratum		*THE AMERICAS* Mortality stratum			*EASTERN MEDITERRANEAN* Mortality stratum	
	High child, high adult	*High child, very high adult*	*Very low child, very low adult*	*Low child, low adult*	*High child, high adult*	*Low child, low adult*	*High child, high adult*
	Male/Female	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*
Total population (000s)	147 133/146 945	171 600/173 915	160 494/164 689	213 309/217 623	35 471/35 759	72 156/66 903	174 275/168 301
Total mortality (000s)	2 206/2 050	3 154/3 001	1 342/1 392	1 459/1 120	290/237	409/287	1 750/1 602
Childhood and maternal undernutrition							
Childhood and maternal underweight	438/402	487/441	0/0	14/11	14/11	8/8	223/229
Iron deficiency anaemia	59/67	65/80	2/3	13/13	3/4	3/4	36/44
Vitamin A deficiency	90/112	120/151	0/0	2/3	2/2	0/0	34/53
Zinc deficiency	74/68	128/116	0/0	3/2	5/4	2/2	44/45
Other nutrition-related risk factors and physical inactivity							
High blood pressure	87/128	79/116	179/191	170/162	20/20	76/57	164/171
High cholesterol	34/52	36/53	161/189	88/79	10/9	51/31	114/101
Overweight and obesity (high BMI)	14/19	21/35	135/137	117/144	15/18	36/28	58/67
Low fruit and vegetable consumption	21/31	33/41	92/79	81/58	7/7	27/15	51/48
Physical inactivity	20/25	21/27	74/81	52/55	6/6	21/13	47/43
Addictive substances							
Smoking and oral tobacco use	43/7	84/26	352/294	163/58	5/1	43/10	114/19
Alcohol use	53/15	125/30	27/-22	207/39	22/6	6/1	8/1
Illicit drug use	5/1	1/0	10/7	7/4	1/0	5/1	18/4
Sexual and reproductive health							
Unsafe sex	198/234	805/923	8/8	22/27	17/11	0/4	33/39
Non-use and use of ineffective methods of contraception	NA/16	NA/33	NA/0	NA/5	NA/4	NA/1	NA/23
Environmental risk factors							
Unsafe water, sanitation and hygiene	129/103	207/169	0/1	16/15	13/10	9/9	117/135
Urban air pollution	11/11	5/5	14/14	16/14	3/2	5/3	28/23
Indoor air pollution from household use of solid fuels	93/80	118/101	0/0	7/9	5/5	1/1	56/60
Lead exposure	5/4	4/3	2/1	14/7	2/1	5/2	12/6
Global climate change	9/9	18/18	0/0	0/0	0/0	0/0	10/11
Occupational risk factors							
Risk factors for injury	14/1	18/1	3/0	17/1	2/0	8/0	27/2
Carcinogens	1/0	1/0	7/2	4/1	0/0	1/0	1/0
Airborne particulates	5/2	7/3	12/2	9/1	1/0	1/0	9/2
Ergonomic stressors	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Noise	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Other selected risks factors							
Contaminated injections in health care settings	10/7	27/23	0/0	1/0	1/1	0/0	24/20
Child sexual abuse	0/0	2/1	1/1	1/0	0/0	0/0	1/1

	EUROPE		*SOUTH-EAST ASIA*		*WESTERN PACIFIC*			
	Mortality stratum		*Mortality stratum*		*Mortality stratum*			
Very low child, very low adult	*Low child, low adult*	*Low child, high adult*	*Low child, low adult*	*High child, high adult*	*Very low child, very low adult*	*Low child, low adult*	*WORLD*	
Male/Female	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Total*
201 514/210 376	108 182/110 277	114 051/129 133	147 173/146 646	639 087/602 719	75 796/78 558	785 055/747 878	3 045 295/2 999 722	6 045 017
2 020/2 054	1 034/916	1 878/1 721	1 234/1 022	6 358/5 764	616/519	5 483/4 944	29 232/26 629	55 861
0/0	9/8	0/0	40/29	573/614	0/0	95/94	1 900/1 848	3 748
2/3	3/3	2/2	15/19	139/185	0/0	34/39	375/466	841
0/0	0/0	0/0	10/13	68/101	0/0	7/9	333/445	778
0/0	2/2	0/0	5/4	132/141	0/0	6/6	400/389	789
325/354	281/289	514/671	133/139	668/519	85/76	711/758	3 491/3 649	7 141
265/282	144/136	387/518	72/40	488/507	39/39	222/265	2 112/2 303	4 415
183/197	117/141	202/265	44/58	42/110	21/20	163/184	1 168/1 423	2 591
95/75	80/67	234/247	55/48	378/311	26/19	269/232	1 449/1 277	2 726
103/103	64/62	147/175	34/34	218/185	23/19	132/134	961/961	1 922
531/145	255/53	548/73	181/12	785/132	128/49	661/137	3 893/1 014	4 907
65/-85	100/25	338/88	51/9	148/21	23/-28	465/66	1 638/166	1 804
11/6	3/1	18/5	13/1	40/8	2/1	28/2	163/41	204
3/9	1/8	3/13	30/25	231/177	0/3	18/36	1 370/1 516	2 886
NA/0	NA/0	NA/0	NA/7	NA/56	NA/0	NA/3	NA/149	149
0/1	8/7	1/1	25/21	326/327	0/0	42/35	895/835	1 730
12/11	20/18	22/24	17/15	72/60	10/8	176/179	411/388	799
0/0	8/9	1/3	15/22	218/304	0/0	137/366	658/961	1 619
4/2	15/8	26/13	6/3	38/19	0/0	21/10	155/79	234
0/0	0/0	0/0	1/0	35/38	0/0	2/1	76/78	154
4/0	5/0	15/1	19/1	79/5	2/0	78/5	291/19	310
12/2	6/1	13/2	3/0	11/1	4/1	28/8	92/17	109
17/2	7/2	15/3	10/3	54/17	4/1	113/54	264/92	356
0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
0/0	1/0	6/4	19/9	92/62	0/0	137/58	317/184	501
1/1	1/1	3/2	1/0	16/18	1/1	10/14	38/41	79

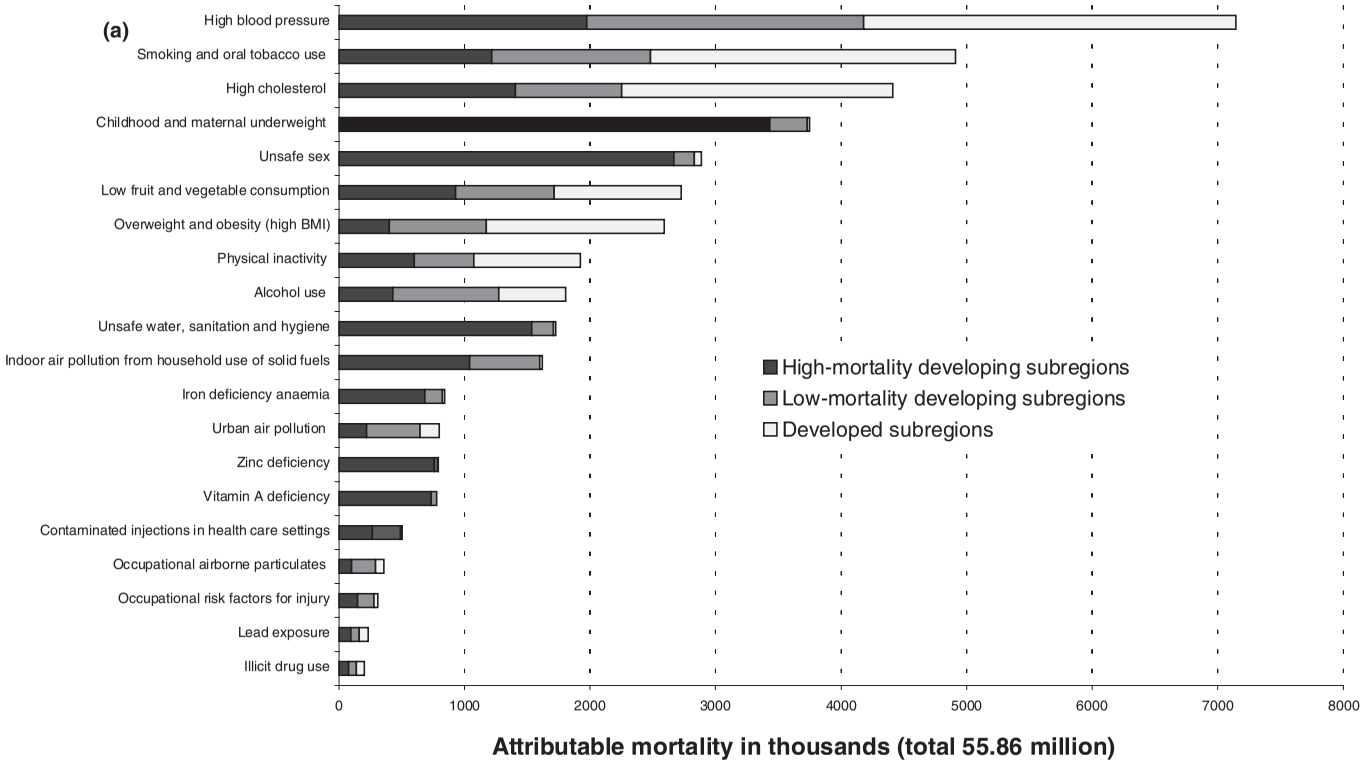
Table 26.1(b) Burden of disease for females and males due to selected risk factors in 14 subregions

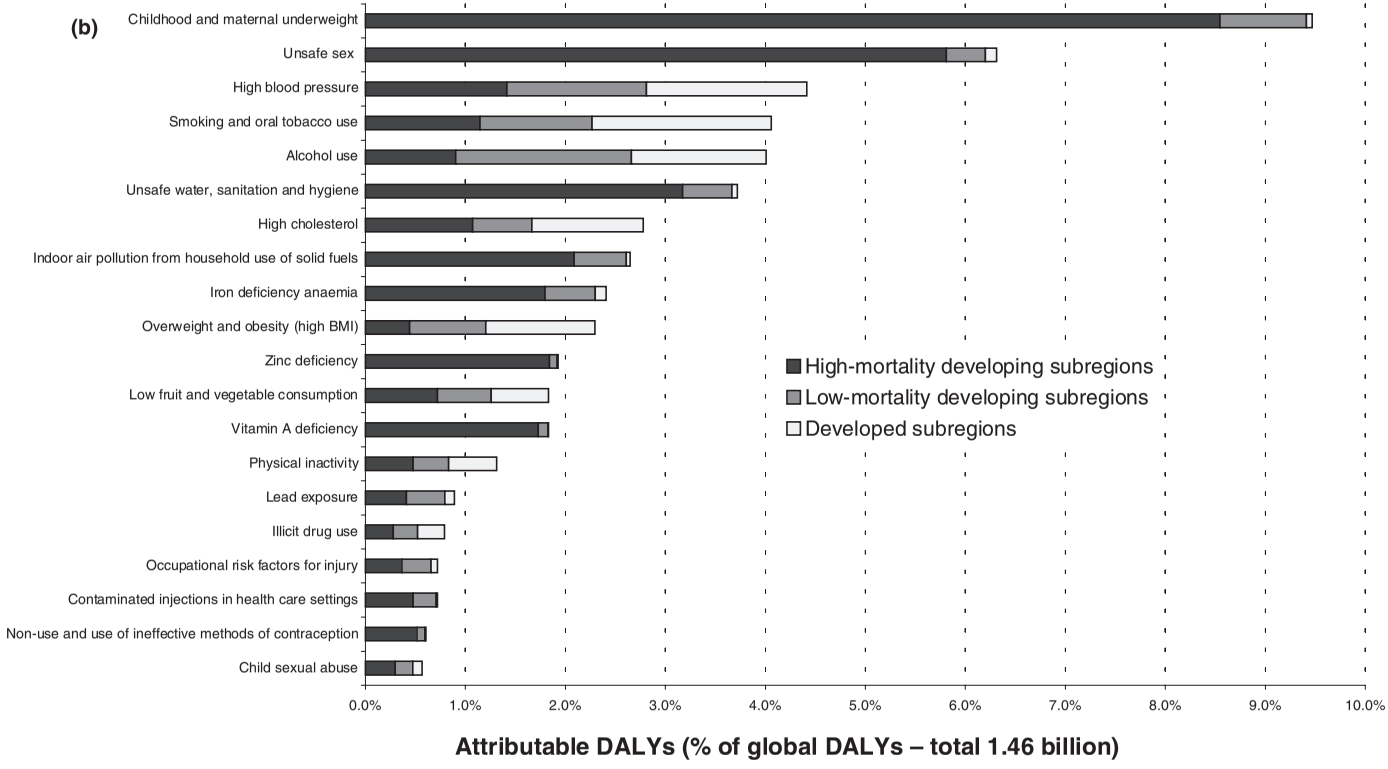
	AFRICA Mortality stratum		*THE AMERICAS* Mortality stratum			*EASTERN MEDITERRANEAN* Mortality stratum	
	High child, high adult	*High child, very high adult*	*Very low child, very low adult*	*Low child, low adult*	*High child, high adult*	*Low child, low adult*	*High child, high adult*
	Male/Female	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*
Total population (000s)	147 133/146 945	171 600/173 915	160 494/164 689	213 309/217 623	35 471/35 759	72 156/66 903	174 275/168 301
Total DALYs (000s)	73 650/70 695	103 191/101 977	24 480/21 804	45 372/35 065	9 158/7 895	12 590/10 131	55 790/54 140
Childhood and maternal undernutrition							
Childhood and maternal underweight	15 530/14 375	17 189/15 710	12/11	570/498	512/410	324/312	8 203/8 407
Iron deficiency anaemia	2 263/2 521	2 451/2 905	223/255	446/465	121/217	239/277	1 449/1 746
Vitamin A deficiency	3 178/3 856	4 208/5 167	0/0	79/103	53/68	9/8	1 159/1 758
Zinc deficiency	2 625/2 414	4 563/4 150	1/1	115/99	174/138	66/63	1 547/1 574
Other nutrition-related risk factors and physical inactivity							
High blood pressure	980/1 295	984/1 177	1 642/1 141	1 807/1 438	208/178	840/570	1 781/1 698
High cholesterol	395/563	456/578	1 451/1 012	1 070/803	109/87	605/320	1 273/1 051
Overweight and obesity (high BMI)	246/318	341/546	1 825/1 654	1 505/1 918	189/234	534/456	882/1 027
Low fruit and vegetable consumption	253/354	434/471	833/536	896/581	72/67	322/172	607/550
Physical inactivity	225/280	262/309	691/576	582/585	61/68	265/164	559/492
Addictive substances							
Smoking and oral tobacco use	591/97	1 311/367	3 567/2 606	2 190/813	51/14	593/197	1 780/379
Alcohol use	1 441/393	3 621/785	2 925/702	7 854/1 443	789/170	162/22	328/36
Illicit drug use	543/156	495/163	808/379	791/310	200/71	449/78	620/153
Sexual and reproductive health							
Unsafe sex	6 205/7 753	24 059/29 664	281/235	843/912	521/310	30/162	1 125/1 508
Non-use and use of ineffective methods of contraception	NA/997	NA/1 732	NA/2	NA/375	NA/203	NA/119	NA/1 210
Environmental risk factors							
Unsafe water, sanitation and hygiene	3 797/3 119	6 365/5 355	31/30	686/603	436/320	314/315	3 797/4 506
Urban air pollution	153/132	80/67	87/65	133/99	24/20	47/30	305/253
Indoor air pollution from household use of solid fuels	3 036/2 358	3 865/3 059	2/4	193/251	175/154	32/32	1 817/1 691
Lead exposure	512/488	460/433	68/49	907/789	140/125	238/187	606/504
Global climate change	321/305	631/636	1/2	35/36	13/10	10/10	357/391
Occupational risk factors							
Risk factors for injury	486/39	583/46	82/6	606/51	80/6	253/18	961/68
Carcinogens	9/2	13/4	56/16	38/8	3/1	12/1	18/2
Airborne particulates	106/37	141/69	184/36	213/44	21/4	37/4	148/39
Ergonomic stressors	21/16	25/20	17/10	32/15	4/2	9/3	25/16
Noise	109/49	127/60	92/31	122/43	15/6	60/21	142/88
Other selected risks factors							
Contaminated injections in health care settings	244/187	804/742	0/0	13/5	20/12	0/0	437/390
Child sexual abuse	49/102	167/238	98/320	147/118	46/27	41/83	85/225

EUROPE			SOUTH-EAST ASIA		WESTERN PACIFIC			
Mortality stratum			Mortality stratum		Mortality stratum			
Very low child, very low adult	*Low child, low adult*	*Low child, high adult*	*Low child, low adult*	*High child, high adult*	*Very low child, very low adult*	*Low child, low adult*	*WORLD*	
Male/Female	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Male/Female*	*Total*
201 514/210 376	108 182/110 277	114 051/129 133	147 173/146 646	639 087/602 719	75 796/78 558	785 055/747 878	3 045 295/2 999 722	6 045 017
28 006/25 314	21 304/17 689	35 099/24 144	33 585/29 302	178 923/177 345	8 780/7 591	131 634/110 818	761 562/693 911	1 455 473
10/9	367/324	32/29	1 634/1 239	21 297/22 766	6/6	4 048/3 972	69 733/68 067	137 801
87/211	166/271	110/161	681/847	5 614/6 883	31/81	1 876/2 462	15 756/19 301	35 057
0/0	1/1	0/0	347/406	2 321/3 368	0/0	241/306	11 596/15 042	26 638
0/0	65/56	5/4	197/152	4 635/4 961	0/0	208/219	14 201/13 833	28 034
2 624/1 828	2 699/2 180	5 386/4 632	1 394/1 402	7 010/5 316	781/451	6 783/6 044	34 920/29 350	64 270
2 062/1 317	1 461/996	4 109/3 211	828/412	5 562/5 528	380/227	2 376/2 195	22 136/18 301	40 437
1 922/1 735	1 420/1 445	2 578/2 684	650/818	686/1 939	334/295	2 430/2 804	15 543/17 872	33 415
785/413	777/511	2 431/1 684	614/524	4 139/3 521	237/118	2 718/2 042	15 117/11 544	26 662
852/654	636/494	1 461/1 236	414/409	2 489/2 186	228/160	1 436/1 318	10 159/8 933	19 092
4 991/1 464	3 381/715	7 230/832	2 712/180	10 474/1 621	994/325	8 313/1 296	48 177/10 904	59 081
3 103/416	2 183/446	7 543/1 570	1 793/284	4 927/675	708/43	12 020/1 941	49 397/8 926	58 323
786/344	181/81	762/223	406/121	1 386/282	231/101	1 110/259	8 769/2 719	11 488
114/202	50/240	134/295	1 009/925	7 413/6 004	12/65	804/995	42 600/49 269	91 869
NA/3	NA/83	NA/47	NA/397	NA/3 354	NA/1	NA/290	NA/8 814	8 814
33/33	287/262	64/57	734/506	8 762/9 725	14/13	2 112/1 879	27 432/26 726	54 158
73/44	170/118	191/129	154/128	718/594	53/31	1 343/1 161	3 533/2 871	6 404
0/0	233/244	18/49	458/532	6 641/7 596	0/0	2 569/3 528	19 040/19 499	38 539
75/43	304/189	424/211	379/337	1 489/1 198	15/10	1 496/1 251	7 112/5 814	12 926
1/2	5/5	2/2	19/15	1 213/1 325	0/1	92/77	2 700/2 816	5 517
130/12	203/15	410/31	577/39	2 857/184	56/5	2 495/199	9 779/718	10 496
95/13	63/7	129/16	35/5	119/12	24/4	227/87	891/179	1 070
216/43	105/32	167/43	135/47	862/315	68/18	1 726/493	4 130/1 224	5 354
21/11	18/12	21/14	26/19	111/78	9/5	146/110	485/333	818
117/47	92/50	136/92	219/185	799/303	26/22	735/365	2 788/1 362	4 151
0/0	8/5	106/59	356/156	2 341/1 759	0/0	2 028/791	6 356/4 105	10 461
61/175	72/158	132/205	42/56	1 079/2 340	29/96	888/1 158	2 934/5 302	8 235

Note: The table shows the estimated mortality and disease burden for each risk factor considered individually. These risks act in part through other risks and act jointly with other risks. Consequently, the burden due to groups of risk factors will usually be less than the sum of individual risks (see chapter 27).

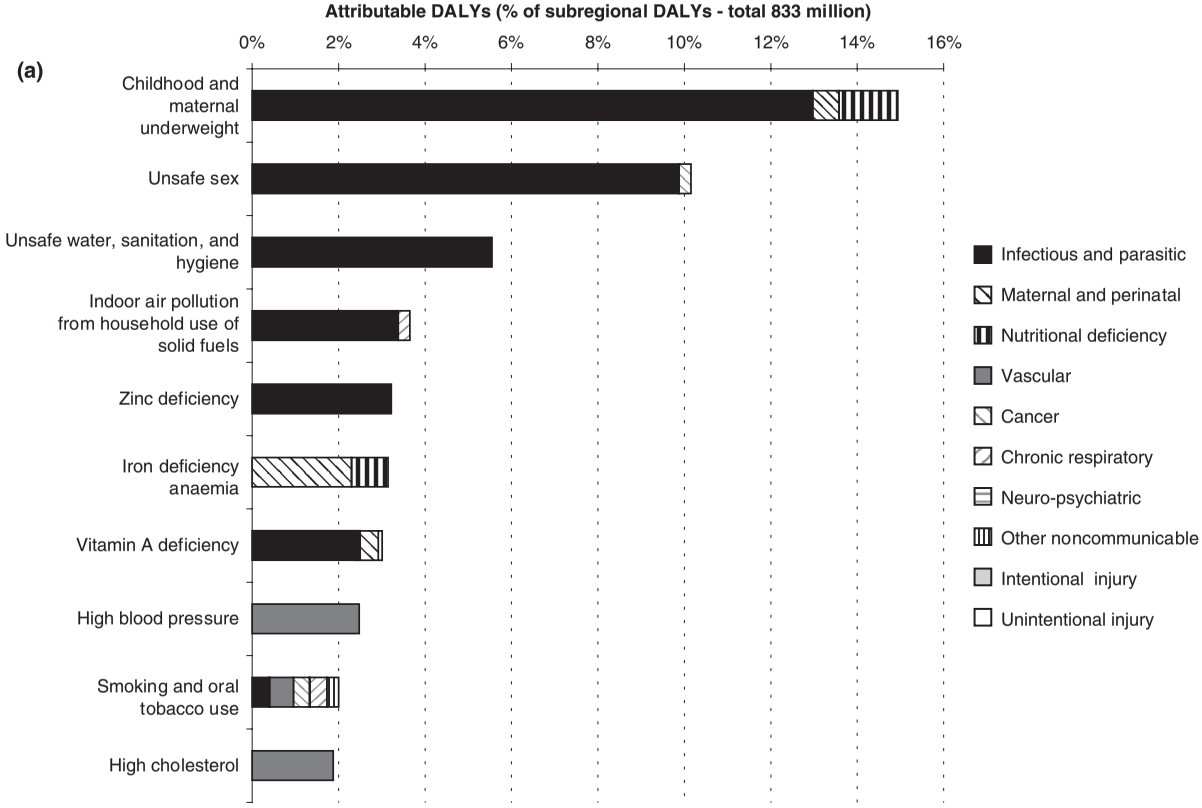
Figure 26.1 (a) Mortality and (b) burden of disease due to leading global risk factors

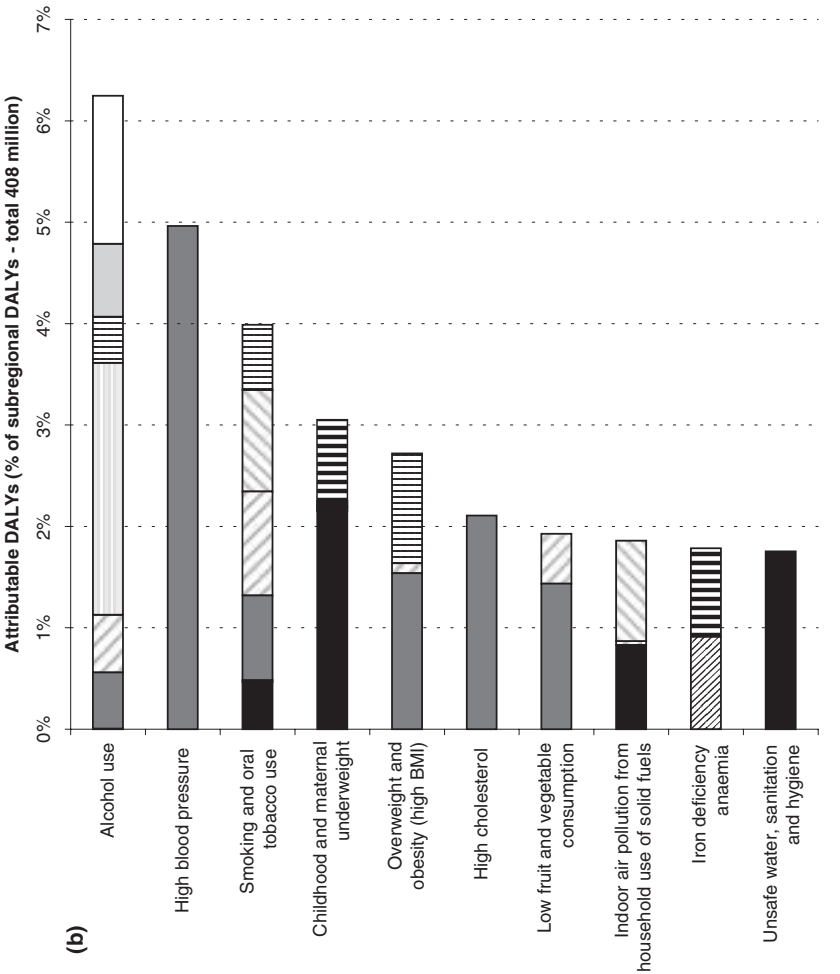




Note: High-mortality developing: AFR, AMR-D, EMR-D and SEAR-D subregions; low-mortality developing: AMR-B, EMR-B, SEAR-B and WPR-B; developed: AMR-A, EUR and WPR-A. The figure shows the estimated mortality and disease burden for each risk factor considered individually. These risks act in part through other risks and act jointly with other risks. Consequently, the burden due to groups of risk factors will usually be less than the sum of individual risks (see chapter 27).

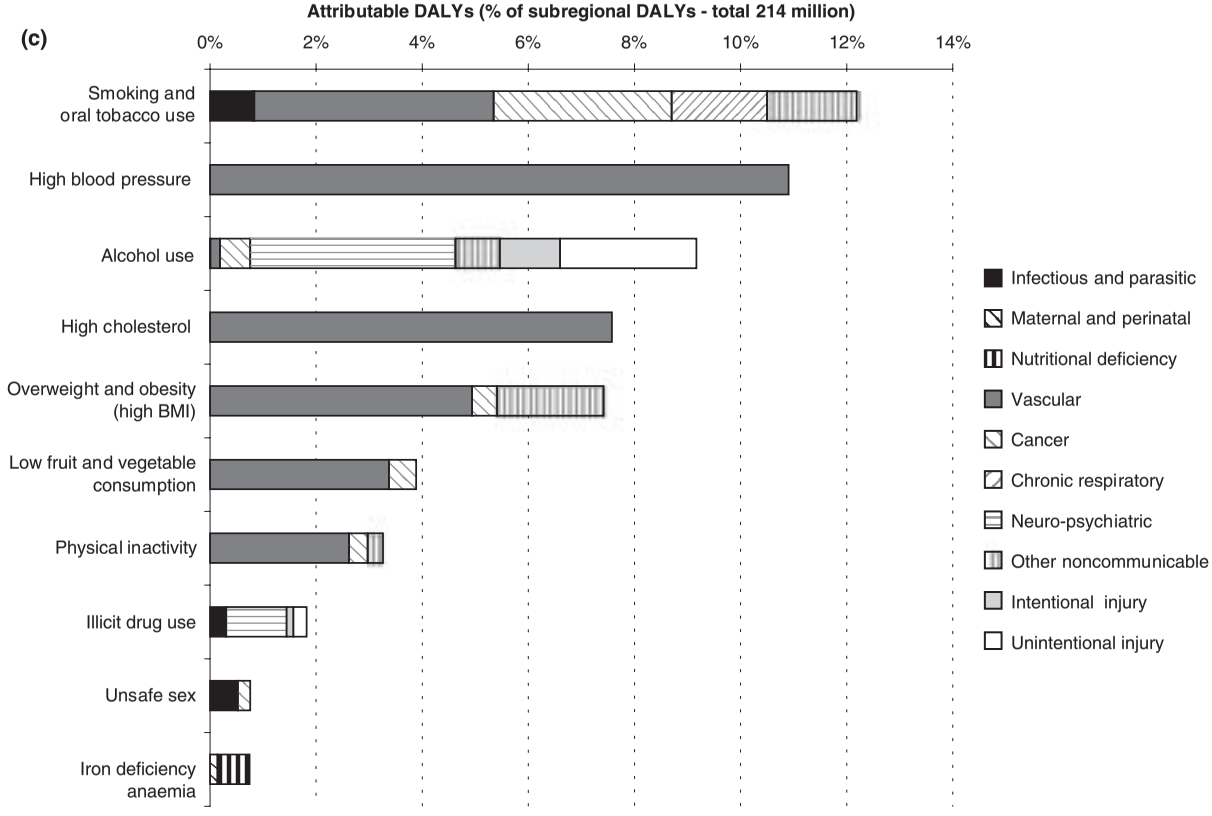
Figure 26.2 Burden of disease due to leading regional risk factors divided by disease type in (a) high-mortality developing, (b) low-mortality developing and (c) developed subregions




(b)
Attributable DALYs (% of subregional DALYs - total 408 million)
0%
1%
2%
3%
4%
5%
6%
7%
Alcohol use
High blood pressure
Smoking and oral tobacco use
Childhood and maternal underweight
Overweight and obesity (high BMI)
High cholesterol
Low fruit and vegetable consumption
Indoor air pollution from household use of solid fuels
Iron deficiency anaemia
Unsafe water, sanitation and hygiene
Infectious and parasitic
Maternal and perinatal
Nutritional deficiency
Vascular
Cancer
Chronic respiratory
Neuro-psychiatric
Other noncommunicable
Intentional injury
Unintentional injury

continued

Figure 26.2 Burden of disease due to leading regional risk factors divided by disease type in (a) high-mortalitydeveloping, (b) low-mortality developing and (c) developed subregions (*continued*)



contribution to disease burden) and the non-fatal effects (e.g. neuropsychological outcomes of alcohol).

Despite disaggregation into underweight and micronutrient deficiency (which are not additive; see chapter 27) and methodological changes, undernutrition has remained the single leading global cause of health loss with comparable contributions in 1990 (220 million DALYs, 16%, for malnutrition) (Murray and Lopez 1997) and 2000 (140 million DALYs, 9.5%, for underweight; 2.4%, 1.8%, 1.9% for iron, vitamin A and zinc deficiency respectively; 0.1% for iodine deficiency disorders). This is because while prevalence of underweight has decreased in most regions of the world in the past decade, it has increased in sub-Saharan Africa (de Onis et al. 2000) where its effects are disproportionately large due to simultaneous exposure to other childhood disease risk factors. A substantial part of the decrease in the burden of disease due to poor water, sanitation and hygiene (from 6.8% in 1990 to 3.7% in 2000) is due to a decline in global diarrhoeal disease mortality (from 2.9 million deaths in 1990 to 2.1 million in 2000), and partly a result of improved case management interventions, particularly oral rehydration therapy.

Leading causes of burden of disease in all high-mortality developing subregions were childhood and maternal undernutrition—including underweight (14.9%) and micronutrient deficiencies (3.1% for iron deficiency, 3.0% for vitamin A deficiency and 3.2% for zinc deficiency)—unsafe sex (10.2%), poor water, sanitation and hygiene (5.5%) and indoor smoke from solid fuels (3.6%). The relative contribution of unsafe sex was disproportionately larger (26%) in AFR-E, where HIV/AIDS prevalence is the highest, making it the leading cause of burden of disease in this subregion. The outcomes of these risk factors were mostly communicable, maternal, perinatal and nutritional conditions (Figure 26.2) which dominate the disease burden in high-mortality developing subregions. Despite the very large contribution of these diseases and their underlying risk factors, tobacco, blood pressure and cholesterol already resulted in significant loss of healthy life years in these subregions. For example, in SEAR-D (dominated by India in terms of population) the burden of disease attributable to tobacco, blood pressure and cholesterol was already of comparable magnitude to micronutrient deficiencies and is only marginally smaller than indoor smoke from solid fuels and poor water, sanitation and hygiene. In addition to their relative magnitude, the absolute size of the loss of healthy life years attributed to risk factors in high-mortality developing subregions was substantial. Childhood and maternal underweight and unsafe sex in these subregions alone (with 38% of global population) contributed as much (>200 million DALYs) to loss of healthy life as all diseases and injuries in developed countries (with 22% of global population).

Across developed subregions, tobacco (12.2%), high blood pressure (10.9%), alcohol (9.2%), high cholesterol (7.6%) and high BMI (7.4%) were consistently the leading causes of loss of healthy life, contributing

mainly to noncommunicable diseases and injuries. Tobacco was the leading cause of disease burden in all developed subregions, except EUR-C (dominated by Russia) where high blood pressure and alcohol resulted in slightly larger loss of healthy life. The increase in the disease burden due to blood pressure compared to 1990 (Murray and Lopez 1997) (from 3.9% in the established market economies and 5.9% in the formerly socialist economies) mainly reflects new evidence on hazard size after correction for regression dilution bias (MacMahon et al. 1990). The contributions of these risk factors are consistently larger than those of leading *diseases* of the developed subregions (i.e. ischaemic heart disease [9.4%], unipolar depressive disorders [7.2%], cerebrovascular disease [6.0%], etc.), which emphasizes the potential health gains from reducing risk factors.

The low-mortality developing subregions present possibly the most striking mixture of leading risk factors. The leading risk factors in these subregions (40% of global population) include those from both developed and high-mortality developing subregions with comparable magnitudes (e.g. underweight [3.1%] and high BMI [2.7%] had comparable contributions to the burden of disease. See also Monteiro et al. 2002). In addition, the decline in the share of burden of disease due to the risk factors in low-mortality developing subregions was less marked than that in high-mortality developing and developed subregions (e.g. the ratio of 1st to 10th leading risk factors was smaller). This lower clustering of risk factor burden further emphasizes the role of a more extended and mixed group of risk factors in low-mortality developing subregions. Alcohol was the leading cause of burden of disease in low-mortality developing subregions as a whole (6.2%) and in AMR-B and WPR-B, but made a relatively low contribution to the burden of disease in EMR-B. In general, AMR-B and EMR-B had risk factor profiles similar to the developed subregions (tobacco, blood pressure, cholesterol, BMI and alcohol), while SEAR-B and WPR-B had a more mixed risk factor profile (with the leading five risks being underweight, blood pressure, tobacco, unsafe sex and alcohol in SEAR-B; alcohol, blood pressure, tobacco, underweight and indoor smoke from solid fuels in WPR-B).

An important finding of this analysis is the key role of nutrition in health worldwide. Approximately 13% of the global disease burden can be attributed to the joint effects of childhood and maternal underweight or micronutrient deficiencies. In addition, almost as much as 7% (16% for those aged 30 years and above) can be attributed to risk factors that have substantial dietary determinants—high blood pressure, high cholesterol, high BMI and low fruit and vegetable intake. These patterns are not uniform within subregions, however, and in some countries the transition has been healthier than in others (Lee et al. 2000; Popkin et al. 2001). Further, the major nutritional risk factors show interregional heterogeneity (e.g. the relative contributions of blood pressure, cholesterol and BMI were different in AMR-A, SEAR-D and WPR-B). This het-

erogeneity further illustrates the importance of concurrent and comparable quantification of distal and proximal risk factors to provide a more complete picture of the role of various distal and proximal risk factors in reducing disease.

This analysis also provides the first quantitative evidence of the public health consequences of a number of risk factors including indoor smoke from solid fuels (2.6% of global disease burden), high BMI (2.3%) and zinc deficiency (1.9%). On the other hand, the burden of disease due to some risks (e.g. physical inactivity) was lower than expected if the methodology and results from the limited number of industrialized countries had been extrapolated (Powell and Blair 1994). This is partially because of difficulties in measuring exposure to this risk factor. A categorical exposure variable with a conservative baseline of "sufficient" (vs vigorous) activity was used. In part, it also reflects the inclusion of occupational and transportation domains of activity (that are common among rural populations of developing countries) in this analysis, above and beyond leisure-time activity which is more relevant to developed countries and urban populations (Jacobs et al. 1993; Levine et al. 2001).

2. Distributions of risk factor-attributable disease burden

An important feature of risk assessment, with implications for broad prevention policies and specific interventions and programmes, is the distribution of disease burden among population subgroups. These subgroups may be defined by factors such as age, sex, socioeconomic status or the current level of exposure to a risk factor, if exposures are defined in multiple categories or continuously. For example, reducing the large disease burden due to road traffic accidents among young adult males, largely associated with binge alcohol consumption, would require designing interventions that focus on this population subgroup and their specific drinking behaviours. On the other hand, the majority of effects from risk factors such as blood pressure have been found to occur among those at moderately elevated levels, suggesting the need for interventions beyond those intended for clinical hypertension (Cook et al. 1995; Murray et al. 2003; Rodgers et al. 2000). While the distribution of health effects by age and by exposure level has been studied in specific cohorts and for specific risk factors (Peto et al. 1992; Rodgers and MacMahon 1999; Rose 1992), there are no such estimates at the global level and for multiple risks.

The distributions of mortality and disease burden attributable to the risk factors included in this book by age and sex is shown in Table 26.2. The estimated disease burden from childhood and maternal undernutrition, unsafe water, sanitation and hygiene, and global climate change (much of whose estimated effects are mediated through nutritional and water variables) was almost exclusively among children aged <5 years.

Table 26.2 The distribution of risk factor-attributable mortality and burden of disease by age and sex

	Mortality (%)						*Disease burden (%)*					
	0–4	*5–14*	*15–59*	*≥60*	*Males*	*Females*	*0–4*	*5–14*	*15–59*	*≥60*	*Males*	*Females*
Childhood and maternal undernutrition												
Childhood and maternal underweight	100	0	0	0	51	49	100	0	0	0	51	49
Iron deficiency anaemia	72	1	22	4	45	55	62	6	30	2	45	55
Vitamin A deficiency	85	1	14	0	43	57	86	1	12	0	44	56
Zinc deficiency	100	0	0	0	51	49	100	0	0	0	51	49
Other nutrition-related risk factors and physical inactivity												
High blood pressure	0	0	19	81	49	51	0	0	43	57	54	46
High cholesterol	0	0	22	78	48	52	0	0	50	50	55	45
Overweight and obesity (high BMI)	0	0	26	74	45	55	0	0	57	43	47	53
Low fruit and vegetable consumption	0	0	23	77	53	47	0	0	49	51	57	43
Physical inactivity	0	0	21	79	50	50	0	0	48	52	53	47
Addictive substances												
Smoking and oral tobacco use	0	0	30	70	79	21	0	0	61	39	82	18
Alcohol use	1	1	65	33	91	9	1	3	87	9	85	15
Illicit drugs use	0	0	100	0	80	20	0	2	98	0	77	23
Sexual and reproductive health												
Unsafe sex	16	1	77	6	47	53	18	1	79	2	46	54
Non-use and use of ineffective methods of contraception	0	0	100	0	0	100	0	0	100	0	0	100
Environmental risk factors												
Unsafe water, sanitation and hygiene	68	5	13	14	52	48	77	8	13	3	51	49
Urban air pollution	3	0	16	81	51	49	12	0	40	49	56	44
Indoor air pollution from household use of solid fuels	56	0	5	38	41	59	83	0	8	9	49	51
Lead exposure	0	0	41	57	66	34	75	0	16	8	55	45
Global climate change	86	3	6	5	49	51	88	5	6	1	49	51
Selected occupational risk factors												
Risk factors for injuries	0	0	85	14	94	6	0	0	95	5	93	7
Carcinogens	0	0	28	72	85	15	0	0	51	49	83	17
Airborne particulates	0	0	17	83	74	26	0	0	65	35	77	23
Ergonomic stressors	0	0	0	0	0	0	0	0	95	5	59	41
Noise	0	0	0	0	0	0	0	0	89	11	67	33
Other selected risk factors												
Contaminated injections in health care settings	10	2	53	35	63	37	16	3	67	13	61	39
Child sexual abuse	0	0	81	22	48	52	0	0	96	4	36	64

For these risks, more than 85% of the total attributable burden occurred in this age group, with the exception of iron deficiency where 30% of burden was borne by women of childbearing age. The disease burden from other diet-related risks, tobacco and occupational risks (except injuries and back pain) was almost equally distributed among adults above and below the age of 60 years. For example, 43% and 61% of disease burden due to high blood pressure and tobacco respectively, occurred from adverse events in the 15–59-year age group.

More than 90% of disease burden attributable to lack of contraception, illicit drugs, occupational ergonomic stressors and risk factors for injury and child sexual abuse occurred in adults below the age of 60 years. About three-quarters (77–80%) of disease burden for alcohol, unsafe sex and contaminated injections in health care settings occurred between the ages of 15 and 59 years. Most of the risks whose burden is concentrated in younger adults are those with outcomes that include HIV/AIDS, maternal conditions, neuropsychiatric diseases and injuries. Moreover, with the exception of alcohol, which has a global presence, the majority of disease burden from these risks is concentrated in developing countries (Figures 26.1 and 26.2). This illustrates the large, and at times neglected disease burden from risks that affect young adults in developing countries, with important consequences for economic development.

Only a small fraction of disease burden from the risk factors considered occurred among 5–14-year olds. This was because some of the leading causes of ill-health of this age group (e.g. motor vehicle accidents and other injuries, depression) have complex causes that could not easily be included in the current risk-based framework. For other leading diseases at these ages (e.g. diarrhoea and lower respiratory infections), most epidemiological studies have focused on children aged <5 years and do not provide hazard estimates for older children.

The disease burden attributable to underweight and micronutrient deficiencies in children was equally distributed among males and females, but the total all-age disease burden from iron and vitamin A deficiencies was slightly greater in females due to effects on maternal conditions. Other diet-related risks, physical inactivity, environmental risks and unsafe sex contributed almost equally to disease burden in males and females. Approximately 80% of disease burden from addictive substances and 60–90% from various occupational risks occurred among men. The former reflects the social, behavioural and economic forces that have so far made addictive substances more widely used by men, especially in developing countries. The latter was partially due to the inclusion of formal employment only and partially because men tend to make up most of the workforce engaged in heavy industrial jobs and formal agriculture. Women suffered an estimated two-thirds of disease burden from childhood sexual abuse and the entire burden caused by non-use and use of ineffective methods of contraception, as defined in chapter 15.

The distributions of disease burden attributable to risk factors by exposure levels are shown in Table 26.3 for those risks quantified using categorical variables, and in Figure 26.3 for those with continuous variables. For most of these risks a substantial proportion of attributable burden occurred among those with modest elevation of risk. For example, only 35% of the disease burden from underweight, the leading global risk, occurred in severely underweight children (<–3 SD from referent group median); the rest was among those in the 1–3 SD below the median range. The large majority of the burden of disease from unsafe water, sanitation and hygiene was approximately equally distributed among three of the five exposure scenarios. This reflects the fact that the exposure categories were defined as the presence of water and sanitation technology-based interventions, and during decades of water and sanitation projects, many countries have "clustered" in a limited number of technology groups. However, there is likely to be large heterogeneity of exposure within each scenario (Curtis et al. 2000).

Figure 26.3(a) shows the distribution of the estimated cardiovascular (CVD) burden of disease (in DALYs) attributable to four major continuous risk factors, by exposure levels. Half the attributable burden occurs to the left of the solid vertical line and half occurs to the right. The dashed vertical lines indicate commonly used thresholds—140 or 160 mmHg for hypertension, 6.5 mmol/l for hypercholesterolaemia, and 30 kg/m^2 for obesity (the cut-off for hypertension is shown at 150 mmHg, between the two commonly used values of 140 and 160 mmHg). Figure 26.3(b) shows the cumulative percentage of attributable burden by exposure levels. In reality, a modest rightward skew (not modelled here) of distributions would lead to slightly more events occurring in those who were hypertensive, hypercholesterolaemic or obese.

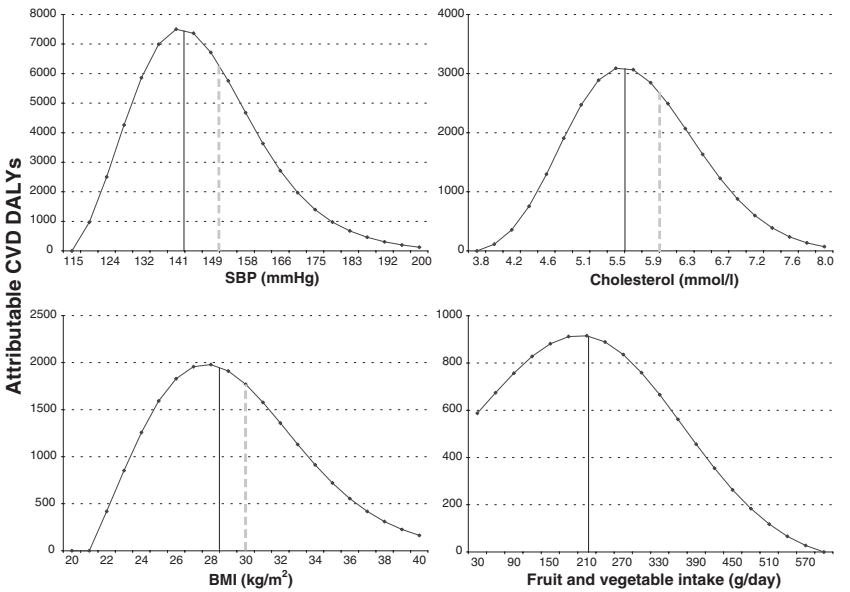
Figure 26.3 shows that a substantial proportion of the disease burden attributable to high blood pressure, cholesterol and body mass index (BMI) and inadequate fruit and vegetable intake occurred in the "mid-range" exposures. For example, the 2nd and 3rd quartiles (i.e. half of attributable burden) occurred between SBP of approximately 130 and 150 mmHg, cholesterol of 5.0 and 6.1 mmol/l and BMI of 25–32 kg/m^2 and fruit and vegetable intake of 150–300 g/day. This was similar to or greater than the amount of burden occurring among individuals with risk factor levels above the commonly used (but arbitrary) thresholds of hypertension, hypercholesterolaemia and obesity, as shown in Figure 26.3.

The distribution by levels of demographic and economic development suggest that the burden of disease due to risks such as undernutrition and unsafe water, sanitation and hygiene occurred virtually entirely in the high-mortality developing subregions of the world, whereas other risks, such as tobacco, alcohol and dietary risks had global effects (Figure 26.1). Categorization based on economic and demographic development was also a key modifier of the age distribution patterns. Most notably,

Table 26.3 Distribution by exposure level of attributable burden due to selected categorical risk factors

Risk factor	*Referent category*	*Exposure categories*				
Childhood and maternal underweight	Same fraction of children <–1 SD weight-for-age as the international reference group	<–1 to <–2 SD below the international reference group median	<–2 to <–3 SD below the international reference group median	<–3 SD below the international reference group median		
Proportion of total attributable disease burden	0	0.20	0.46	0.35		
Physical inactivity	All having at least 2.5 hours per week of moderate-intensity activity or equivalent (400 kJ/week)	Some but less than 2.5 hours per week of moderate-intensity activity	Little or no physical activity			
Proportion of total attributable disease burden	0	0.49	0.51			
Unsafe water, sanitation and hygiene	Absence of transmission of diarrhoeal disease through water, sanitation and hygiene	Regulated water supply and full sanitation coverage, with partial treatment for sewage	Improved water supply, basic sanitation, improved access to drinking water, improved personal hygiene and water disinfected at point of use	Improved water supply and basic sanitation	Basic sanitation but no improved water supply	No improved water supply and no basic sanitation
Proportion of total attributable disease burden	0	0	0.39	0.03	0.28	0.30
Child sexual abuse	No sexual abuse	Non-contact abuse	Contact abuse	Intercourse		
Proportion of total attributable disease burden	0	0.08	0.44	0.48		

Figure 26.3 Distribution by exposure level of cardiovascular disease (CVD) burden attributable to selected continuous risk factors



Note: For blood pressure and cholesterol, the plots represent the estimated usual levels (MacMahon et al. 1990), which tend to be closer to population means than levels based on one-off measurements commonly used in population surveys. For example, the distribution of usual blood pressure is approximately half as wide as the distribution of one-off blood pressure measures and so less people would be classified as hypertensive if classifications were based on usual rather than one-off blood pressure. Thus, with a population mean systolic blood pressure (SBP) of 134 mmHg, the SD of one-off measures might be 17 mmHg (with about 18% of the population having one-off SBP over 150 mmHg) and the SD of usual SBP 9 mmHg (hence about 5% of the population would have usual SBP over 150 mmHg).

disease burden due to many major risks for chronic diseases occurred in younger ages in developing regions compared to developed regions. For example, in high-mortality developing subregions, 69% of disease burden attributable to tobacco occurred in people aged 15–59 years, whereas this share was 63% for low-mortality developing subregions and 55% for developed subregions. The different age structures across major world regions, together with exposure differences, resulted in different distributions of attributable burden by region. For example, Figure 26.4 shows that disease burden attributable to elevated blood pressure, cholesterol and BMI occurred at lower levels in developing regions compared to developed regions, mainly because of lower age-specific exposure levels in those populations (see chapters 6–8).

Figure 26.4 Distribution by exposure level of attributable cardiovascular disease (CVD) burden due to selected risk factors, by age and subregional grouping (see Figure 26.3 for details)

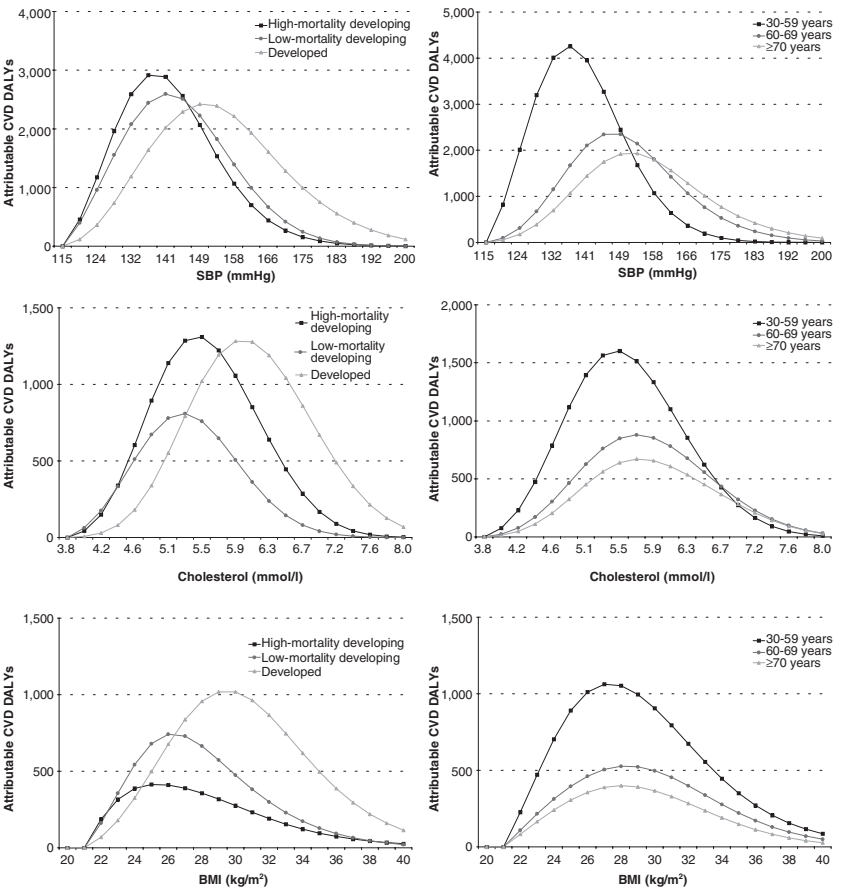


Figure 26.4 also shows that skewness of the distribution of disease burden was not substantially different across different age groups for BMI. This is because the comparatively larger relative risk per unit-BMI at younger ages (which leads to more right-hand skew) is counterbalanced by the comparatively lower BMI at younger ages (which leads to left-hand skew). This is in contrast to blood pressure, for which disease burden in younger age groups occurred at lower exposures because the age patterns of exposure and relative risk do not entirely compensate.

3. Sources of uncertainty

Broad sources of uncertainty in risk assessment were discussed in chapter 1 of this book. Uncertainty about disease causation (Evans 1978; Hill 1965) in practice was secondary to uncertainty about hazard size, because when causality was uncertain, estimates of hazard needed for risk assessment were also unknown or uncertain. For example, while there is uncertainty about whether climate change would increase incidence of certain diseases, or whether the relationships between occupational factors or physical inactivity and lower back pain are causal, in each case quantitative risk assessment would also require estimates of hazard magnitude. The collectivity of scientific knowledge from disciplines such as behavioural science, vector biology, physiology, biomechanics and epidemiology would confirm the possibility of a causal relationship in the above cases, but would shift the debate to hazard size. As a result, for some risk factors, only the contribution to a subset of disease outcomes could be quantified because epidemiological studies did not provide enough information for hazard quantification for all risk factor–disease pairs, even when the causal relationships were believed or suspected.

Estimates of hazard size in individual studies were as far as possible adjusted for confounding. Extrapolation of hazard from a limited number of studies to other populations on the other hand has received less attention. While the robustness of relative risk measures has been confirmed for more proximal factors in studies across populations (Eastern Stroke and Coronary Heart Disease Collaborative Research Group 1998; Horton 2000; Law et al. 1994), hazard extrapolation is an important source of uncertainty for more distal risks (e.g. child sexual abuse) or those whose effects are heterogeneous (e.g. alcohol and injuries vs alcohol and cancer).

Direct exposure data for many risk factors were limited due to difficulties both in their measurement and under-investment in risk factor surveillance, especially in developing countries. To allow maximum use of available data, such risk factors were represented using indirect or aggregate indicators (e.g. smoking impact ratio (*SIR*) for accumulated hazards of smoking, weight-for-age for childhood undernutrition and use of solid fuels for indoor air pollution). For some risks, multiple data sources allowed limiting the possible range of exposure estimates. For example, in the absence of alcohol surveys, total alcohol production, trade and unrecorded consumption provided upper bounds on the fraction of population that would be in the highest consumption category. Finally, some of the risk factors in this analysis were represented using continuous exposure variables (e.g. high blood pressure). Others have used categorical variables (e.g. indoor smoke from solid fuels, underweight and physical inactivity) even though the health effects occur along a continuum. This choice reflected the availability of exposure data and

hazard estimates for categories. In such cases, the contribution to disease within the categories may be under-estimated.

The findings of this work should, therefore, be considered within the context of limited available data and subject to uncertainty. This uncertainty varies across risk factors and geographical regions. Further discussion of sources and quantification of uncertainty has been provided in individual risk factor chapters.

4. Discussion

Despite inherent uncertainties, the quantification of the burden of disease attributable to selected risk factors illustrates that the loss of health in the world is dominated by those risk factors that affect the poorest regions and populations, such as undernutrition, poor water, sanitation and hygiene and indoor smoke from solid fuels. Coupled with these are hazards such as alcohol, tobacco, high blood pressure and high cholesterol that in the year 2000—even compared to a decade earlier (Murray and Lopez 1997)—are widespread or are estimated to have large health impacts. Nowhere is this picture more apparent than in the low-mortality developing regions, which account for 48% of global population, and are affected by both groups of risk factors.

Comparing the burden attributable to risk factors across the three groupings of countries in this work (Figures 26.1 and 26.2) provides a cross-sectional picture of a "risk factor transition" in which the relative contribution of adult or noncommunicable disease risk factors increases as childhood and communicable disease risk factors decrease with economic development. Analysis of previous development-based transitions, such as changes in inequality or environment with economic development, has demonstrated the role of policy in inducing or delaying, and shaping the dynamics of the transition (Bowman 1997). Examples in public health include rapid control of vector-borne diseases (Chitsulo et al. 2000), high maternal mortality where contraception and abortions are not accessible for non-economic reasons, and potential HIV epidemics in some developed countries (MacLehose et al. 2002). At the same time, at least some risk factor transitions are confirmed by the increasing role of hazards such as tobacco and obesity *over time* (Ebbeling et al. 2002; Pelletier 1998; WHO 1997). The increase in the global burden of disease due to tobacco from 2.6% in 1990 to 4.1% in 2000, while partially due to new evidence on hazard size after correction for confounding (Thun et al. 2000), mostly reflects the increased accumulated hazards, and is most noticeable in developing countries. The cross-sectional comparison demonstrates that risk factors such as alcohol and high blood pressure and cholesterol, if not increasing in absolute terms (Popkin 2002; Reddy and Yusuf 1998), are important contributors to loss of health in all regions.

The large remaining burden from childhood disease and mortality risks such as undernutrition, poor water and sanitation, and indoor smoke from solid fuels shows the continued need for developing and delivering effective interventions. At the same time, four of the five leading causes of lost healthy life affect adults (Figure 26.1). Risk factors for both adult communicable and noncommunicable diseases already make substantial contributions even in regions with low income and high infant mortality. It is imperative therefore that health programmes and policy continually reassess the appropriate balance between interventions addressing childhood disease risk factors and those that affect adult health. Dynamic and systematic policy responses can mitigate the spread of such risk factors and their more distal causes to a large extent throughout the development process, such as a healthier nutritional or environmental transitions (Arrow et al. 1995; Lee et al. 2000). Also, as illustrated by the persistence of diseases such as malaria or the large increase in the disease burden due to HIV/AIDS and its risk factors since 1990 (e.g. unsafe sex from 3.5% to 6.3%), as well as the potential for generalized HIV/AIDS epidemics in some eastern European countries (MacLehose et al. 2002) or China (Kaufman and Jing 2002), important communicable disease risk factors also need dynamic monitoring and policy responses.

There are a number of reasons why risk factors that were not among the leading global causes of disease burden should not be neglected. Most obviously, this analysis could be expanded with other risk factors that are both prevalent and hazardous. Second, although smaller than other risks, many such risk factors make non-negligible contributions to burden of disease in specific populations. For example in WPR-B (dominated by China in terms of population), where there is considerable industrial activity based on coal, ambient air pollution and lead exposure have health effects comparable to poor water, sanitation and hygiene and some micronutrient deficiencies. Similarly, lack of contraception was among the 10 leading risk factors for female burden of disease in a number of subregions.

Some risk factors with comparatively low global disease burden are highly concentrated among sectors of society (e.g. occupational exposures among mine workers) and have implications for health inequalities. This concentration may also imply that risks can be targeted more easily. For other risk factors, such as child sexual abuse, ethical considerations may outweigh direct contributions to disease burden in policy debate. Finally, while the burden of disease due to a risk factor may be comparatively small, effective or cost-effective interventions may be available. Examples include reducing the number of unnecessary medical injections coupled with the use of sterile syringes and reduction in exposure to lead or ambient air pollution in industrialized countries in the second half of the 20th century which often also led to benefits such as energy saving.

Beyond their total magnitude, this study has also provided a picture of the distribution of risk factor-attributable disease burden by age, sex and exposure. Analysis in multiple age and exposure categories, or along a continuum of exposures, suggests that globally a considerable proportion of the disease burden attributable to many major risk factors occurred among those with only moderately raised levels, not the extremes (e.g. hypertension, obesity or severe malnutrition).

For acute exposures and outcomes, the underlying relationship is more complex. For example, while in many societies the majority of alcohol-attributable injury (e.g. traffic accidents) arises among people who on average drink moderately (Kreitman 1986), these people would be at the more extreme end of the distribution in a different dimension: volume of drinking *before* the injury. This finding suggests that the shapes of both exposure distributions and risk relationships are important determinants of the distribution of disease burden. If exposure to risk factors is clustered or the risk relationship does not follow a linear pattern, high exposure groups may indeed play a disproportionately important role (Lemmens 2001; Skog 1999). Further implications of these findings for research, and for policies and programmes aimed at improving population health, are discussed in chapter 29.

Note

1 See preface for an explanation of this term.

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