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Global Estimates of Fatal Work-Related Diseases

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Background *Work-related mortality is a relatively new concept which aims to widen occupational health and safety; to take into account not only recognized fatal occupational accidents and diseases but also other work-related deaths. Few countries in the world have a register for work-related diseases.*

Methods *Estimates are calculated using baseline world mortality scenarios of all diseases for the year 2000 and attributable fractions made for work-related diseases in Finland, as adjusted.*

Results *It is estimated that about 2 million work-related deaths take place annually. Men suffer two thirds of those deaths. The biggest groups of work-related diseases are cancers, circulatory diseases and communicable diseases.*

Conclusions *Information about work-related diseases is needed for prevention, as people in developed countries are working longer, and the age of retirement is being raised in many countries. As a result, workers are being exposed to different kinds of substances and working conditions for a longer time. In developing countries, work exposures may already start in infancy. Due to industrialization, workers in developing countries are facing new conditions with a lack of relevant knowledge and skills. With the help of information, nations can direct resources and skills for appropriate purposes such as regulatory measures on health and safety at work.* Am. J. Ind. Med. 50:28–41, 2007.

KEY WORDS: work-related diseases; global estimates; mortality; developing country; developed country

INTRODUCTION

Occupational diseases are defined as diseases that result from exposure to risk factors during a work activity [An ILO Codes and Practice, 1996]. Work-related disease is a wider concept: it covers diseases that have been shown to have an association with work, for example: work-related cancer, musculoskeletal disorders, and psycho-social problems, circulatory diseases [Zahm and Blair, 2003; Punnett et al., 2005; Driscoll et al., 2005a]. The International Labour Office (ILO), other safety and health organizations, and many governments—particularly in industrialized countries—have kept records of occupational injuries. While records might have been kept for occupational diseases, very few countries have been kept records of work-related diseases. Relation to work can be assessed through an attributable factor—the proportion of the total burden of a disease that is related to a given risk factor in a population—in this case, related to work. It is the fraction of the disease that would not have occurred if the risk factor had not existed. [Nurminen and Karjalainen, 2001; Steenland et al., 2003; Nelson et al., 2005; Driscoll et al., 2005a, 2005b]. The Harvard School of Public Health published estimates of the global burden of disease [Murray and Lopez, 1996]. The data covers not only occupational diseases, but all diseases. ILO estimated in 1999 that the incidence of work-related diseases is 160 million per year, and predicts that altogether 1.2 million people will die due to occupational accidents and work-related diseases every year [Takala, 1999]. ILO has also

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estimated that the total cost of these accidents represent 4% of the gross national product (GNP) [Safety in numbers, 2003]. Leigh et al. [1997] have estimated that total costs of work-related injuries and illnesses represent 3% of the gross domestic product (GDP) in the USA. This covers both mortality and morbidity costs.

Work-related diseases are increasing and the proportion of traditional occupational accidents from all work-related hazards is decreasing in more developed countries where workers are working and living longer [Punnett et al., 2005; Driscoll et al., 2005a]. At the same time, the number of occupational accidents and work-related diseases is growing in developing countries [Hämäläinen et al., 2006]. Today, developing countries are encountering work-related hazards more frequently than developed countries did at the time of their industrialization, which took place over a relatively long time period. Work-related diseases will grow in relative significance in the future as a component of the morbidity and mortality of society as a whole [Steenland et al., 2003; Eijkemans and Takala, 2005].

Work-related morbidity and mortality cannot be easily calculated [Driscoll et al., 2005a]. Reasons include a lack of reliable information and records, and cultural and structural differences between countries [Concha-Barrientos et al., 2005; Nelson et al., 2005; Hämäläinen et al., 2006]. Also, many work-related diseases have multiple potential causes making it difficult to determine whether the condition is work-related [Leigh et al., 1999; Driscoll et al., 2005a]. However, work does have a heavy impact on health, and work-related morbidity and mortality affect not only the worker and his or her family, but also increase costs for society [Leigh et al., 1999; Eijkemans and Takala, 2005; Nelson et al., 2005]. As a result, work-related morbidity and mortality rates are usually estimated. These estimations are needed to better understand, and more importantly, to prevent work-related diseases and injuries.

Traditional factors that are well known causes of work-related diseases, and have been seen to have a major effect on the incidence and mortality of work-related diseases, include: hazardous substances (e.g., asbestos, silica dusts, pesticides, radon), ionizing radiation, non-ionizing radiation, noise, and other physical factors [e.g., Zahm and Blair, 2003; Nelson et al., 2005; Driscoll et al., 2005b]. Some well-known factors that further affect and contribute to the number of work-related diseases include: age, sex, shift work, overwork and stress, communicable diseases at work, violence at work, and child labor [Eijkemans and Takala, 2005; Nakata et al., 2006)]. Also, worker lifestyle may contribute to the later occurrence of work-related disease [Leigh et al., 1999; Driscoll et al., 2005a].

Shift, overwork and work-related stress are increasingly causing work-related diseases in the world [Caruso et al., 2004; Trinkoff et al., 2006]. They may lead to sleeping disorders, which in turn, become a risk factor for high blood pressure, obesity, type II diabetes, and coronary heart disease [Härmä et al., 2006]. They may also be linked to the misuse of alcohol and drugs, as wells as work place violence [Kalia, 2002; Drug and alcohol abuse, 2003]. Violence at work has been identified as a serious problem in the member states of the European Union, in the USA, and in many other countries around the world. In the workplace, violent acts may include: physical assault, threat of violence, bullying and harassment. These acts cause not only suffering for the individuals involved, but also account for economic losses [Violence in the workplace, 1996; Saarela, 2002].

Men perform a large majority of the hazardous jobs, and therefore suffer some 80% of the deaths [Safety in numbers, 2003]. This is partially the result of a higher participation by men in the labor force and especially in occupations with heavy physical workload [Punnett et al., 2005]. In the future, the potential for work-related diseases among women will increase due to the increased participation of women in the workforce [Zahm and Blair, 2003]. It is estimated that 250 million children aged 5–18 are working, and approximately 120 million of those are working full-time. Most child laborers work in their communities alongside their parents and siblings. [Estrella-Gust, 2002]. However, many of them are in hazardous and exploitative jobs away from home. Work hazards affect children more seriously than adults, resulting in both physical and psychological consequences [Caesar-Leo, 1999].

This article is based on a research project carried out during the years 2001–2002. The aim of the study is to estimate global fatal work-related diseases, categorized by region, gender and age. This project consists of two parts: the study of global estimate of occupational accidents [Hämäläinen et al., 2006] and the study of global estimate of work-related diseases. This article concentrates on the global estimate of fatal work-related diseases.

MATERIALS AND METHODS

Work-related diseases can be either communicable or non-communicable. Communicable diseases usually have a short incubation time or latent period. Non-communicable diseases might be acute or have a long latent period (e.g., cancers). The aim of the study was to develop a model for global estimation of fatal work-related diseases. Figure 1 shows the progress of the study.

Initial Data: Estimates of Deaths

This study of global estimates of fatal work-related diseases used mainly two sources of information: The global burden of disease (GBD) [Murray and Lopez, 1996], and the epidemiologic estimate of the proportion of fatalities related to occupational fraction in Finland [Nurminen and Karjalainen, 2001]. GBD was selected because it provides

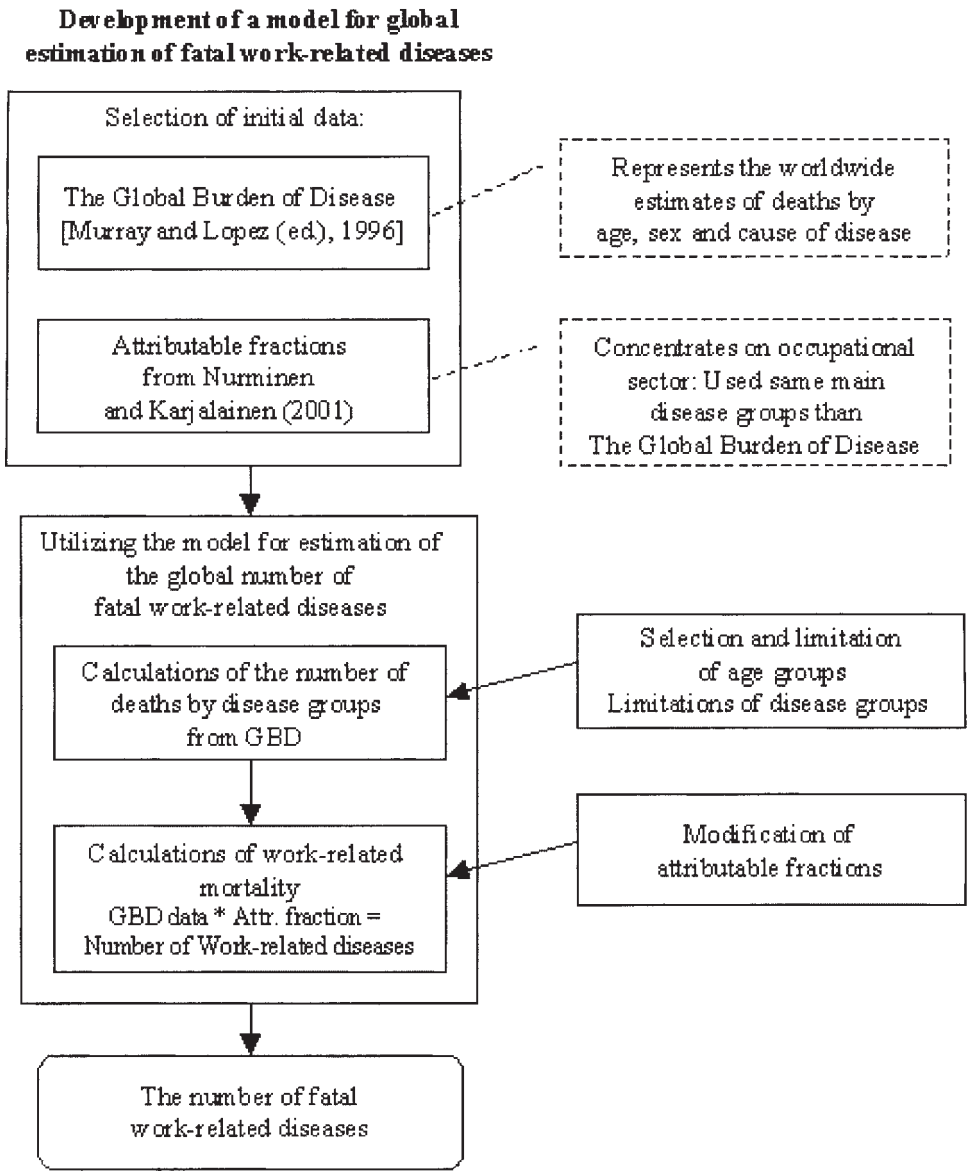

FIGURE 1. Progress of the study.

worldwide estimates of deaths categorized by age, sex, and causes of disease; and was found to be only source, which covers the entire world. GBD figures include not only occupational diseases, but all diseases and deaths [Murray and Lopez, 1996].

Estimates were made according regions and by the groups of diseases used in GBD. The regions used in this study are the same as are used by the World Bank [The World Bank group, 2001], namely:

- Established Market Economies (EME),
- Formerly Socialist Economies of Europe (FSE),
- India (IND),
- China (CHN),
- Other Asia and Islands (OAI),
- Sub-Saharan Africa (SSA),
- Latin America and the Caribbean (LAC) and
- Middle Eastern Crescent (MEC)

In GBD, diseases were categorized by disease, which were further divided into more specific disease groups. For this study, only the seven main disease categories were used: communicable diseases, malignant neoplasms, respiratory system diseases, circulatory system diseases,

neuro-psychiatric conditions, digestive system diseases, and genitourinary system diseases.

Initial Data: Attributable Fractions

The attributable fractions for the project were mainly taken from Nurminen and Karjalainen as attributable fractions were formed for the same disease categories as for GBD; attributable fractions are based on large literary review (although mainly from industrial countries); and the fractions were newest ones could be found. The attributable fractions given are based on exposure estimates, the known exposure-disease relationship of different work-related diseases, and from figures registered by Statistics Finland [Nurminen and Karjalainen, 2001].

As all the diseases from GBD cannot be considered as work-related, some categories of diseases were disregarded for this study, including: childhood-cluster diseases, maternal and perinatal conditions, and nutritional deficiencies. Disease groups not included in Nurminen and Karjalainen [2001] were also excluded (rheumatic heart disease, inflammatory heart disease, and other cardiovascular diseases). In this study, circulatory system diseases included only ischaemic heart and cerebrovascular diseases.

In GBD, age groups were divided into seven different categories: 0–4, 5–14, 15–29, 30–44, 45–59, 60–69, and 70+. In this project, all age groups, except group from 0 to 14 years, were used. Also, group 70+ was used because the latency time of quite many diseases is long. Any error caused by disregarding the 0–14 years group was assumed to be quite small as both of the extreme age groups at least partially compensate for each other. It is well known that in some countries children under 15 years are working in very poor and hard conditions and are exposed to substances leading to diseases. On the other hand, people in their 70s are retired, but are still exposed to or affected by different substances having either long-lasting effects or a long latency time.

Model for Estimate Fatal Work-Related Diseases: Calculations of Deaths

The objective of the first phase of this study was to calculate the number of deaths according to the GBD disease groups (Appendix 1) [Murray and Lopez, 1996]. Some limitations were made for all age groups depending on the disease group as Nurminen and Karjalainen [2001] had divided the age groups differently. Their study excluded all deaths for people under 25 and over 74 years old. Their study also excluded groups over 65 years for two disease groups—communicable and digestive system diseases—but included persons over 65 in the other disease groups because of the long latency period of these diseases. For circulatory system diseases, the study included only 25% of cases in the oldest age group. These exclusions and selections have affected the calculation of age groups from GBD.

Communicable Diseases

For age groups 15–29, 30–44, and 45–59 all deaths were taken into account from GBD. For age group 60–69, only half of deaths (50%) were counted. For the over 70 years group, no deaths were calculated. Age group 15–29 was totally included because communicable diseases are usually quite infectious and spread easily. In most developing regions of the world, the average age for being economically active is close to 15 years, or even lower in the case of child labor (5–18 years).

Malignant Neoplasms

One third of GBD figures were taken into account for those aged 15–29. For age group 30–44 to 70+, all of the figures were included. As many cancers have quite a long latency period, the over 70 age group was also taken into account.

Respiratory System Diseases

One third of GBD figures were taken into account for those aged 15–29. For the age groups 30–44 to 70+, all the figures were included. Because of a long latency period, the over 70 age group was also calculated.

Circulatory System Diseases

Circulatory diseases are more complicated because GBD age groups differ from the age groups used by Nurminen and Karjalainen [2001] who divided age into ranges 60–65, 65–70, and 70–75. Respectively, 75%, 50%, and 25% of the deaths have been considered as work-related. To account for age range 60–65, one third of the deaths of those aged 60–69 in GBD have been counted. To account for age group 65–70, two thirds of the deaths of those aged 60–69 in GBD have been counted. For age group 60–65, only 75% of the deaths have been considered as work-related. In the same way, for age group 65–70, only 50% of the cases have been considered. Because the oldest age group in GBD is for over 70+, only 10% of these death figures have been used. Also, one third of the figures were taken into account for those aged 15–29 in GBD.

Neuro-Psychiatric Conditions

One third of the GBD figures were taken into account for age group 15–29. For age group 30 to 70+, all figures were

included. Because of the long latency period, age group over 70 was also calculated.

Digestive System Diseases

In this group of diseases, one third of the deaths are calculated for those aged 15–29 years. All of the deaths from ages 30 to 69 years are included. Age group 70+ is excluded totally.

Genitourinary System Diseases

In this disease group, only one third of the GBD death figures were taken into account for those aged 15–29 years. All figures were included for all of the other age groups.

Calculations of Work-Related Mortality

Work-related mortality was calculated by using either attributable or revised attributable fractions, depending on the region (Table I). Nurminen and Karjalainen's attributable fractions are based on extensive research material covering different disease groups. However, the attributable fractions of some regions (FSE, IND, and SSA) have been revised. In the GBD, the death ratio for each region (share of work-related deaths of all deaths) was calculated by comparing all deaths in the region: for EME the ratio is 2.2%; for FSE and India, 2.0%; and in SSA, 1.4% [Murray and Lopez, 1996]. In these regions, exposure to communicable diseases is higher than in other regions. This is especially true in SSA and India where the social structure, which is based on agriculture, differs remarkably from the structures in industrial countries. Communicable diseases receive more emphasis, as GBD does not account for infectious diseases at all in estimating the relation to work [Murray and Lopez, 1996]. The Equation 1 for communicable diseases in FSE and India is shown below

$$\text{Fraction}_{\text{rev}} = \text{Fraction}_{\text{N\&K}} \times \frac{\text{death ratio}_{\text{EME}}}{\text{death ratio}_{\text{FSE,IND}}} = 8.8 \times \frac{2.2}{2.0} = 9.68 \quad (1)$$

On the other hand, revised attributable fractions for non-communicable diseases were formulated as shown below (Eq. 2). The calculated example for malignant neoplasms in FSE and India is as presented. Thus, all non-communicable diseases have a lower emphasis in the equation

$$\text{Fraction}_{\text{rev}} = \text{Fraction}_{\text{N\&K}} \times \frac{\text{death ratio}_{\text{FSE,IND}}}{\text{death ratio}_{\text{EME}}} = 8.4 \times \frac{2.0}{2.2} = 7.64 \quad (2)$$

Attributable fractions for communicable diseases in FSE and India have been weighted using the ratio 2.2/2.0. The inverse has been used for non-communicable diseases. The same ratio for Sub-Saharan Africa is 2.2/1.4 for communicable diseases. For non-communicable diseases, the reverse is true. The ratio is in proportion to the ratio in EME because the attributable fractions are calculated for industrialized countries (Table I).

In EME, China, OAI, LAC, and MEC, the same attributable fractions have been used as by Nurminen and Karjalainen [2001] in their calculations for Finland. The results for established market economies give a good estimate of mortality as the attributable fractions are based on epidemiological research done in industrialized countries. For China, Other Asia and Islands, Latin America and the Caribbean, as well as the Middle Eastern Crescent the estimated figures are likely to be higher, as these regions are undergoing enormous changes. Industrialization, urbanization, and the construction of infrastructure have increased the

TABLE I. Attributable Fraction

	Total			Men			Women		
Causes	EME, CHN, OAI, LAC, MEC[a]	FSE, IND[b]	SSA[b]	EME, CHN, OAI, LAC, MEC[a]	FSE, IND[b]	SSA[b]	EME, CHN, OAI, LAC, MEC[a]	FSE, IND[b]	SSA[b]
Communicable diseases	8.8	9.68	13.80	4.8	5.28	7.54	32.5	35.75	51.07
Malignant neoplasms	8.4	7.64	5.35	13.8	12.55	8.78	2.2	2.00	1.40
Respiratory system diseases	4.1	3.73	2.61	6.8	6.18	4.33	1.1	1.00	0.70
Circulatory system diseases	12.4	11.27	7.89	14.4	13.09	9.16	6.7	6.09	4.26
Neuro-psychiatric conditions[c]	3.4	3.09	2.16	6.6	6.00	4.20	1.8	1.64	1.15
Digestive system diseases	2.1	1.91	1.34	2.3	2.09	1.46	1.5	1.36	0.95
Genitourinary system diseass	1.3	1.18	0.83	3.0	2.73	1.91	0.4	0.36	0.25

[a]Attributable fraction from Nurminen and Karjalainen.
[b]Revised attributable fraction.
[c]Revised attributable fraction for neuro-psychiatric condition.

number of employees who face new, dangerous, and hazardous situations. Agriculture is increasingly mechanized and uses high amounts of agrochemicals. Frequently, employers and workers alike are facing new situations and are quite unaware of the dangers of the work.

The attributable fractions for neuro-psychiatric conditions have also been revised because Murray and Lopez [1996] have categorized this disease group differently than have Nurminen and Karjalainen [2001]. They calculated separate attributable fractions for mental disorders and nervous system diseases. In this study, the revised attributable fraction was calculated using the proportion of attributable fractions compared to the total number of deaths that occur in Finland. Equation 3 for the revised attributable fraction (Fr) for neuro-psychiatric conditions is calculated as follows:

$$\mathrm{Fr}_{\mathrm{np}} = \frac{\mathrm{fr}_{\text{mental disorder}} \times \mathrm{deaths}_{\text{mental disorder}} + \mathrm{fr}_{\text{nervous system disease}} \times \mathrm{deaths}_{\text{nervous system disease}}}{\mathrm{deaths}_{\mathrm{all}}} = \frac{3.5 * 2673 + 3.1 * 1249}{3922} \approx 3.4 \quad (3)$$

The same calculations were made for attributable fractions for both men and women. When the attributable fraction is known, the number of work-related deaths can be calculated by multiplying all selected deaths gathered from GBD with these attributable fractions. Appendix 1 represents as an example, the total number of deaths as categorized in GBD by region, age and sex in EME. The same attributable fractions are used for all age groups, because Nurminen and Karjalainen [2001] have used only one factor for all age groups. Because GBD have represented the number of deaths by age groups, the number of work-related diseases are also presented by age, and the different age groups can be compared.

To obtain the total work-related mortality in regions, the selected age group estimates and work-related mortality by men and women have been summarized. These two total estimates differ from each other because the attributable fractions were based on work-related mortality in Finland. However, age and gender distributions of work-related diseases differ in different countries. In industrial countries, for example, women's proportion of the workforce is much higher than in developing countries.

RESULTS

The results indicate that approximately two (2) million work-related deaths take place annually (Table II). Traditionally, countries have calculated only their occupational accidents and occupational diseases as defined by a national compensation system that represents only a small proportion of all work-related mortality. Very rarely are there calculations of proportions that try to take into account all or even most of the diseases caused by work. However, it is obvious that the proportion of work-related diseases is greater than has been assumed before.

Work-related mortality is shown in Figure 2. The two main groups are malignant neoplasms (32%) and circulatory system diseases (26%). The proportion of occupational

TABLE II. Work-Related Mortality by Region and Cause

Causes	EME	FSE	India	China	OAI	SSA	LAC	MEC	Work-related mortality
Communicable diseases	11,176	2,856	97,865	11,044	27,456	139,890	20,284	9,900	320,471
Malignant neoplasms	164,581	61,273	50,898	172,746	70,190	27,729	38,186	24,074	609,678
Respiratory system diseases	16,716	9,970	13,029	77,437	7,597	6,802	6,642	7,983	146,175
Circulatory system diseases	76,595	66,493	93,237	116,324	50,319	26,076	38,564	51,646	519,255
Neuro-psychiatric conditions	7,572	2,163	2,552	2,754	2,142	676	1,316	1,166	20,341
Digestive system diseases	2,892	1,522	3,323	4,864	4,689	1,294	2,190	1,791	22,566
Genitourinary system diseases	1,833	563	988	1,477	1,278	564	715	1,061	8,478
Accidents and violence[a]	16,170	21,425	48,176	73,615	83,048	54,705	29,594	18,986	345,719
Total mortality	297,534	166,265	310,067	460,260	246,720	257,738	137,789	116,607	1,992,684

EME, established market economies; FSE, formerly socialist economies; IND, India; CHN, China; OAI, other Asia and Islands; SSA, Sub-Saharan Africa; LAC, Latin America and the Caribbean; MEC, Middle Eastern Crescent.

[a]Number of accidents and violence have been taken from the study of Hämäläinen et al. [2006].

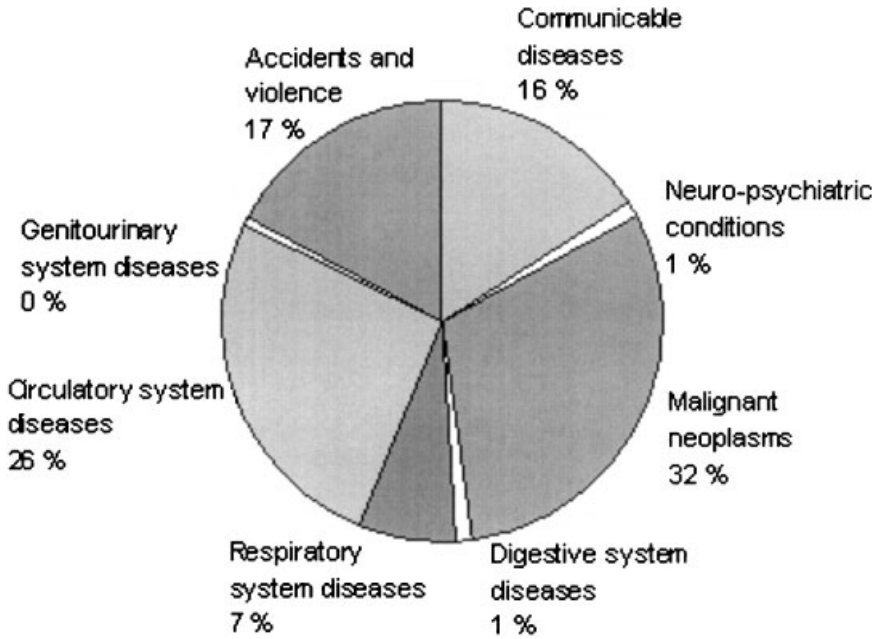

FIGURE 2. Global estimated work-related mortality, by cause.

accidents is 17% of all work-related deaths, and this varies in each region. It is lowest in EME (5%) and the highest in OAI (34%).

The largest groups of work-related diseases worldwide are cancers, circulatory diseases and communicable diseases. Figure 3 shows work-related mortality according to region. It can be seen that in all regions except for Sub-Saharan Africa, the proportion of diseases follows the proportions for the world in general. In SSA and India, communicable diseases caused the most work-related deaths.

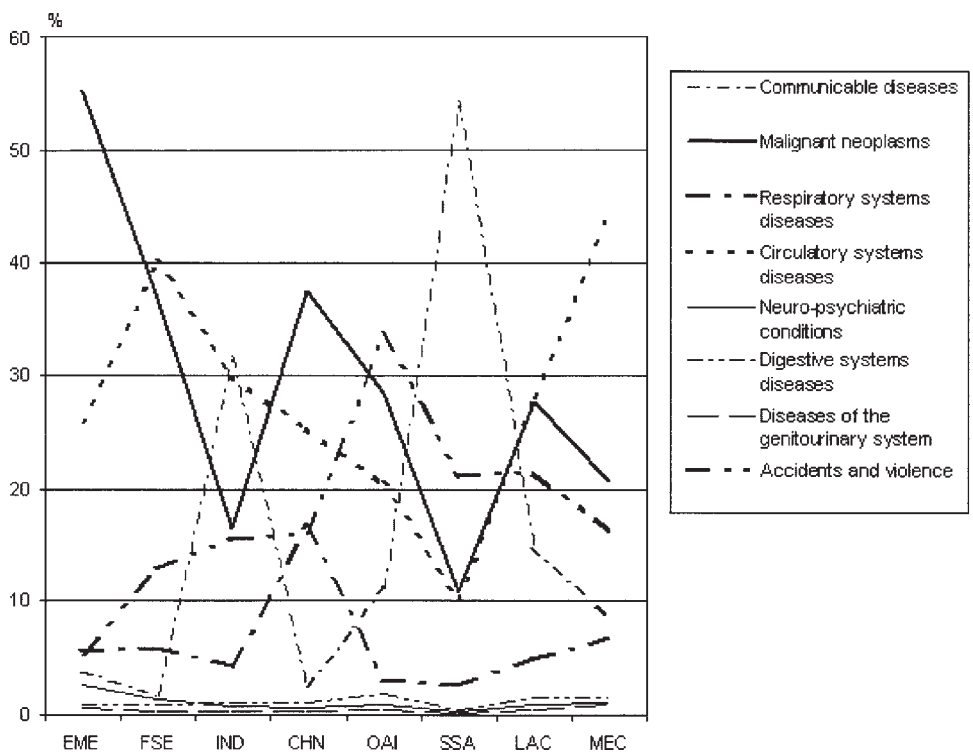

FIGURE 3. Proportion of mortality for work-related diseases in each region.

The proportion of malignant neoplasms and circulatory system diseases is significant in almost all regions, and it might still grow in the future because the proportion of communicable diseases is expected to diminish. The proportion of neuro-psychiatric conditions is very low in all regions, varying between almost 0% and 3%, even though it seem that the number of mental disorders is growing. The likely reason is that these disorders are causing high rates of disability, but not very high mortality. Violence and suicides are usually separately classified as accidents/injuries.

In EME, the annual number of work-related diseases is approximately 300,000. The largest disease group, malignant neoplasms, represents over half of all diseases. This is clearly a different situation than in the other regions. In FSE, both malignant neoplasms and circulatory system diseases represent nearly 40% of all work-related diseases. In India, the proportion of communicable and circulatory system diseases is for each approximately 30% of all work-related diseases. In China, respiratory system diseases represent 20% of all work-related mortality. One explanation for this could be that the mining industry employs many workers in China. In OAI, malignant neoplasms and circulatory system diseases also represent the main disease group. At nearly 20%, the proportion of communicable diseases is also still quite high. Sub-Saharan Africa differs from most other areas. There, communicable diseases are the main disease group, resulting in almost 55% of deaths. This estimate is probably too high due to attributable fraction for Finnish workers. In Finland communicable diseases are uncommon and almost always work-related. In LAC, circulatory system diseases and cancers are the main work-related problems. They account for approximately 28% of the total work-related mortality. Circulatory system diseases are the main problem in MEC. They represent up to 44% of total mortality. In this region, the proportion of communicable diseases is quite low, even though some parts of the region may have similar environmental conditions to India, SSA and OAI.

Accidents and violence represent one third of all deaths in OAI. In SSA and LAC, accidents and violence represent 21% of all deaths, and is the second largest disease group in SSA. In India, China and MEC, the proportion of accidents and violence is also a significant reason for work-related mortality (16%). The latest data show that accidents in China are growing [Decent Work—Safe Work, 2005].

Work-Related Diseases by Age

When work-related diseases are considered by age, the latency period is emphasized. As shown, communicable diseases have a short latency period (Table III). Most deaths occur in workers aged between 15 and 59, even though immunity is usually lower in older people. Malignant neoplasms and respiratory system diseases have a long latency period, so most of these deaths occur in older workers.

Work-Related Diseases by Gender

When the results are considered by gender, approximately 2.3 million work-related deaths take place annually (Table IV). The figure is higher than the figure obtained by age calculations, because the attributable fractions are largely based on work-related mortality in Finland, and the distribution of work-related diseases differ in different countries. While the results are higher, they do indicate a difference between men and women. The real figure might also be nearer to 2.3 than 2 million. Men suffer two thirds of these deaths. About 80% of communicable diseases occur in women, particularly in developing countries such as in India and especially in SSA. Women are working in jobs (agriculture, nursing, food processing, etc.) where the risk of infection is greater than for men.

Figure 4 presents work-related mortality by gender. It shows that almost all work-related cancers are diagnosed for men and most communicable diseases for women. Otherwise, the work-related mortality curve for diseases by men and women is almost identical.

DISCUSSION

New estimates of work-related accidents and diseases show that work is much more prone to risk than has been previously understood. New estimates show that more work-related accidents and diseases take place yearly than were estimated earlier. Annually 2–2.3 million workers die because of an occupational accident or a work-related disease. Thus, 5,000–6,000 workers die every day (the earlier estimated figure was 3,000). Malignant neoplasms (32%) and circulatory system diseases (26%) are the most common reason for work-related deaths in the world. But in some regions, occupational accidents (Asia) and communicable diseases (Africa) are the main groups. Worldwide both groups represent nearly 16% of all work-related deaths.

Leigh et al. [1997] have estimated that in the USA, 66,822 work-related deaths from diseases and injuries occur annually. This represents over 20% of all diseases estimated for EME. Another study from the USA estimates that 55,254 occupational diseases and injuries occur annually. Altogether, occupational injury and diseases are the eighth leading cause of death in the USA [Steenland et al., 2003]. In Finland, approximately 1,810 deaths happen each year related to work [Nurminen and Karjalainen, 2001]. Driscoll et al. [2004] estimated that 1,054 deaths per year

TABLE III. Work-Related Mortality in Regions by Age and Cause

Causes by region		15–29	30–44	45–59	60–69	70+	Total mortality
Communicable diseases							
	EME	1,672	5,280	3,080	1,144		11,176
	FSE	290	581	1,355	629		2,856
	IND	20,038	29,814	35,622	12,390		97,865
	CHN	792	2,288	5,016	2,948		11,044
	OAI	5,896	8,360	8,712	4,488		27,456
	SSA	55,873	49,373	26,692	7,952		139,890
	LAC	7,304	7,040	4,400	1,540		20,284
	MEC	2,376	2,200	3,168	2,156		9,900
Malignant neoplasms							
	EME	277	5,460	27,888	36,876	94,080	164,581
	FSE	229	2,827	17,648	16,350	24,219	61,273
	IND	856	4,508	18,107	11,766	15,662	50,898
	CHN	1,134	17,808	50,904	49,980	52,920	172,746
	OAI	638	7,224	18,564	19,572	24,192	70,190
	SSA	337	2,889	8,293	7,276	8,935	27,729
	LAC	302	3,528	9,576	9,072	15,708	38,186
	MEC	386	277	7,560	6,300	7,056	24,074
Respiratory systems diseases							
	EME	29	205	984	2,378	13,120	16,716
	FSE	11	112	1,268	1,790	6,789	9,970
	IND	86	448	2,275	3,506	6,714	13,029
	CHN	70	1,066	7,011	16,277	53,013	77,437
	OAI	53	287	779	1,435	5,043	7,597
	SSA	68	574	1,383	1,462	3,315	6,802
	LAC	41	328	902	1,189	4,182	6,642
	MEC	70	369	1,353	1,640	4,551	7,983
Circulatory systems diseases							
	EME	124	3,844	23,064	22,630	26,933	76,595
	FSE	79	3,719	25,696	19,396	17,604	66,493
	IND	192	4,057	34,035	41,395	13,558	93,237
	CHN	409	8,680	45,632	41,676	19,927	116,324
	OAI	322	6,572	17,856	16,827	8,742	50,319
	SSA	316	3,866	11,204	7,653	2,959	26,076
	LAC	211	5,084	16,368	10,738	6,163	38,564
	MEC	446	5,828	21,080	15,686	8,606	51,646
Neuro-psychiatric conditions							
	EME	58	374	612	680	5,848	7,572
	FSE	31	155	278	278	1,421	2,163
	IND	80	340	371	618	1,143	2,552
	CHN	136	544	374	374	1,326	2,754
	OAI	68	306	408	374	986	2,142
	SSA	28	130	130	130	259	676
	LAC	58	340	306	170	442	1,316
	MEC	78	170	238	170	510	1,166
Digestive systems diseases							
	EME	15	357	1,281	1,239		2,892
	FSE	13	172	726	611		1,522

TABLE III. (*Continued*)

Causes by region		15–29	30–44	45–59	60–69	70+	Total mortality
	IND	115	688	1,700	821		3,323
	CHN	55	861	2,058	1,890		4,864
	OAI	48	819	2,121	1,701		4,689
	SSA	48	322	523	402		1,294
	LAC	27	504	987	672		2,190
	MEC	48	315	840	588		1,791
Genitourinary system diseases							
	EME		26	91	156	1,560	1,833
	FSE	8	35	106	106	307	563
	IND	20	71	201	260	437	988
	CHN	34	208	273	312	650	1,477
	OAI	17	117	234	273	637	1,278
	SSA	17	83	141	125	199	564
	LAC	13	65	117	117	403	715
	MEC	34	143	273	195	416	1,061

from work-related diseases and injuries occur in New Zealand. The estimated number of deaths that occurred each year in Australia from occupational exposure to hazardous substances was 2,290 [Morrell et al., 1998]. However, this does not cover all work-related hazards in Australia.

There are many clear reasons for the increases compared to the earlier ILO estimates, but they do not explain it all: work-related communicable diseases were not counted in the earlier estimates. This is especially true in India (32%) and the region of Sub-Saharan Africa (55%) where communicable diseases comprised a large proportional of all diseases. Work-related cancer and circulatory diseases are higher than earlier estimated. This is caused by the fact that some age groups not covered before are now taken into account. For example, they did not taken into account the ages between 60 and 70 years for some disease categories, because the workers may have already retired. This can now be justified by taking into account the long latency periods of these diseases. It has been found, for example, that shift workers linked to work-related stress and strain, although already retired, die more often than others from circulatory diseases [Åkerstedt et al., 2004, 2002; Costa, 2005; Tse et al., 2006]. Also, the exposure/disease link is better established than before, so the attributable fractions related to occupation are better known, and slightly higher.

TABLE IV. Work-Related Mortality by Gender

Causes	Men	Women	Total mortality
Communicable diseases	108,256	517,404	625,660
Malignant neoplasms	570,008	64,975	634,984
Respiratory system diseases	127,226	17,562	144,788
Circulatory system diseases	337,129	112,214	449,343
Neuro-psychiatric conditions	18,827	5,384	24,212
Digestive system diseases	16,307	4,959	21,266
Genitourinary system diseases	9,163	1,200	10,362
Total mortality	1,186,917	723,699	2,256,335

The world population and the number of workers have increased mainly because the figures for year 2000 were used instead of the previous 1990 figures. In many parts of the world, non-communicable diseases are increasing rapidly, while deaths from communicable diseases are lower (except for Africa). People are more likely to die from work-related reasons rather than from childhood or infectious diseases. The increase can also be explained by the use of more accurate calculations based on attributable fractions used for individual and separate diseases.

Figure 3 clearly presents the proportion of work-related mortality in each region. Accidents and violence take up a great part of all work-related mortality in all areas except EME. The proportion of all diseases in EME is remarkably high, even if the work is less labor intensive. One explanation for this is a longer life expectancy, which emphasizes mortality caused by non-communicable diseases such as cancer and circulatory diseases. However, it also indicates that other regions are developing in the same direction. Accidents are a major factor in developing countries. The peak in accident figures in OAI is mainly explained through industrialization. Therefore, it is likely that accidents and work-related diseases in China are going to increase: China is

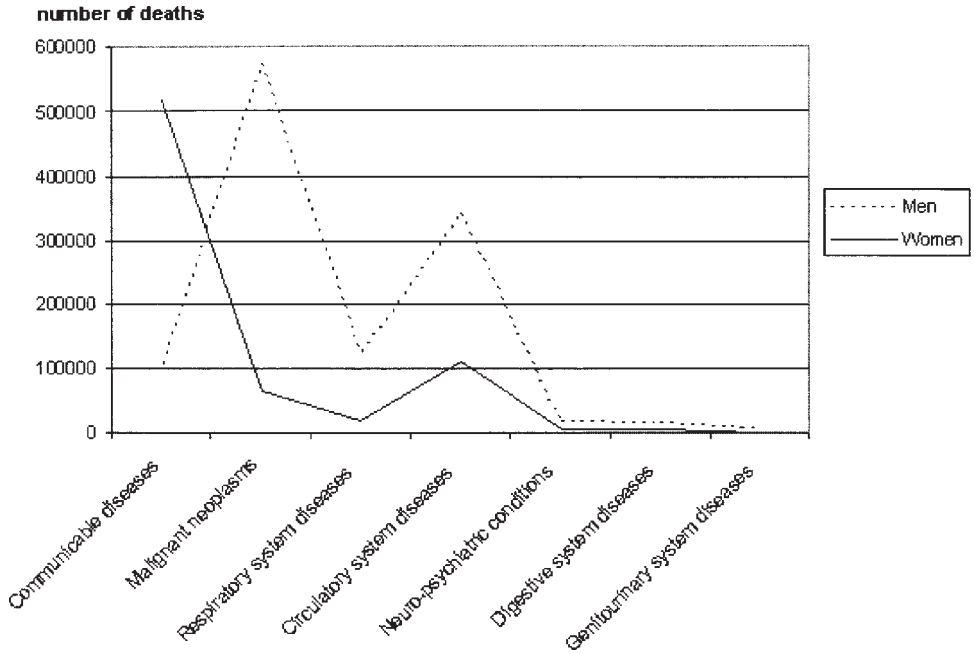

FIGURE 4. Work-related mortality for diseases, by gender and cause.

industrializing, and construction and urbanization are on the rise. A lot of people work in the fields of mining and agriculture, which are known risk sectors. Although work-related cancers and circulatory diseases were higher than before, the proportion of malignant neoplasms and circulatory diseases will increase in the future. Actually, the proportion of circulatory system diseases was quite low in many regions, with the exception of FSE and MEC. The level of circulatory diseases in MEC is surprisingly high. These estimates are based on GBD figures [Murray and Lopez, 1996]. Communicable diseases in SSA are likely to decrease, but other groups of diseases will take over.

There are many factors contributing to work-related diseases in the workplace, and they have combined effects. The proportion of mortality in neuro-psychiatric conditions is quite low when compared to other disease groups. However, work-related stressors may increasingly cause psychosocial disorders and other possible outcomes, including: burnout, alcohol abuse, unexplained physical symptoms, absenteeism, chronic fatigue and accidents, sick building syndrome, and repetitive strain injury [Hotopf and Wessely, 1997]. These factors may increase the mortality of neuro-psychiatric conditions or the outcomes may be included in other disease groups. Tennant [2001] asserts that psychological morbidity in the workplace will also continue to be a significant problem unless major changes occur in the structure of employment.

Work-related stress is connected to increased absenteeism, violence, occupational accidents, alcohol and substance abuse, conflicts, etc. in the workplace. It has been shown that work-related stress increases the risk of cardiovascular disease as well as back and upper-extremity musculoskeletal disorders [Kalia, 2002]. Shift and night work have also been factors for increases in neuro-psychiatric and cardiovascular diseases, and to increased incidents leading to occupational accidents [Costa, 1996]. Circulatory system diseases represent over 20% of all diseases in all regions except SSA. These figures are expected to increase as demands for continuous growth of productivity increase.

From the age of 45 and beyond, work-related mortality increases for malignant neoplasms, respiratory system diseases, neuro-psychiatric conditions and genitourinary system diseases. It can be debated as to what extent this is due to work, and to what extent this is due to other non work-related factors—at least in the over 70 age group. Life expectancy is clearly lower for those workers who are exposed to various kinds of hazardous substances or situations in the workplaces.

Although global estimates of work-related mortality show that the problem of work-related diseases is growing, the calculations have some limitations. Most estimates are based on two independent major sources, which are themselves estimates. Inaccuracies in the GBD scenarios affect the figures for work-related estimates. Attributable fractions calculated for industrialized countries may cause errors to the figures for developing areas, even though the attributable fractions in some regions were adjusted. However, these calculations demonstrate the magnitude of the problem and the authors' estimation of 2–2.3 million

TABLE V. Example of Estimates of Work-Related Mortality Calculated by Using Two Different Sources in EME

		Attributable fraction		Work-related mortality	
Causes	Total deaths from GBD	by Nurminen and Karjalainen [2001]	Leigh et al. [1997]	Based on AF of Nurminen and Karjalainen	Based on AF of Leigh et al.
Malignant neoplasms	1,959,300	8.4	6–10	164,581	117,558–195,930
Respiratory systems diseases[a]	407,700	4.1	10	16,716	40,770
Circulatory systems diseases	617,700	12.4	5–10	76,595	30,885–61,770
Neuro-psychiatric conditions	222,700	3.4	1–3	7,572	2,227–6,681
Genitourinary system diseases[b]	141,000	1.3	1–3	1,833	1,410–4,230

AF is attributable fraction.
[a]Chronic respiratory disease in Leigh et al. study. Pneumoconioses are not included in this figure of Leigh et al.
[b]Renal disorders in Leigh et al. study.

work-related deaths may be nearer to the actual situation. In the future, country based estimates need to be calculated as accurate information from individual countries is needed.

Table V provides an example of estimates done for some disease groups in EME. Leigh et al. [1997] estimated the occupational disease mortality in the United States. As can be seen, the attributable fractions used by Leigh et al. [1997] are, for most disease groups, nearly the same as for Nurminen and Karjalainen [2001]. The main difference is in the respiratory systems disease category because of the different sun-categories used in the USA and Finland. Proportion of circulatory systems diseases is higher when attributable fraction of Nurminen and Karjalainen [2001] is used. It may be due to high mortality rates of this group in Finland. However, the range of fraction by Leigh et al. [1997] is considerable wide.

Many diseases caused by work and the work environment are presently recorded in groups other than those for work-related diseases as health care staff do not have enough information about the history, skills and knowledge to identify the causes of the disease. Many factors contribute to disease, including general environment and personal lifestyle factors. Some contributing factors are difficult to eliminate, such as genetic and inherited sensitivities. For that reason, these new estimates for work-related diseases might be still underestimated.

The distribution of causes in all regions follows the same pattern. While production processes are largely the same in all regions, some notable differences can be identified, in particular in estimating exposure levels:

1. Many production processes are considerably more labor intensive in developing countries than in industrialized countries: this tends to increase the number of exposed workers.
2. Temperatures and other climatic conditions are usually more demanding in developing countries, in particular in tropical regions. However, open production space, missing or limited walls and better natural ventilation in production facilities are more common in warmer, low-income countries.
3. Knowledge and awareness of hazards and consequently prevention levels are significantly lower in low-income countries.
4. Less sophisticated machinery and equipment using lower energy levels are used in developing countries.
5. Some minerals and chemicals have been used less in developing countries in the past (such as asbestos and industrial chemicals). While the pattern is changing, some others like pesticides are used more and without proper control measures.
6. Industrialized countries are more likely to have 24 hr production and services; this increases shift work and night work in high-income areas.
7. Communicable diseases at work (malaria, hepatitis, viral, and bacterial infections etc.) are considerably more prevalent in low-income countries than in middle- and high-income economies.
8. Due to shorter average life expectancy in developing countries, diseases that have a long latency period and appear later in working life or after retirement, such as work-related cancers and circulatory diseases, do not always have sufficient time to develop.

Work-related diseases are an increasing problem in the world. In developed countries occupational accidents have decreased and diseases with a long latency time have increased. In developing countries both occupational accidents and work-related diseases are a growing problem. Some factors that contribute to work-related diseases are also

increasing and might stop the positive trend of occupational accidents. Countries and organizations need more information about different work-related hazards and their effects on workers.

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Appendix 1. Deaths by Age, Sex and Cause in EME

Causes	15–29	30–44	45–59	60–69	70+	Total deaths	Total Attributable fraction	Total deaths of men	Attributable fraction, men	Total deaths of women	Attributable fraction, women
Communicable diseases	19,000	60,000	35,000	13,000		127,000	8.8	104,500	4.8	22,500	32.5
Malignant neoplasms	3,300	65,000	332,000	439,000	1,120 000	1,959,300	8.4	1,103,000	13.8	856,300	2.2
Respiratory systems diseases	700	5,000	24,000	58,000	320,000	407,700	4.1	242,300	6.8	165,300	1.1
Circulatory systems diseases	1,000	31,000	186,000	182,500	217,200	617,700	12.4	391,100	14.4	226,600	6.7
Neuro-psychiatric conditions	1,700	11,000	18,000	20,000	172,000	222,700	3.4	98,300	6.6	124,300	1.8
Digestive systems diseases	700	17,000	61,000	59,000		137,700	2.1	97,300	2.3	40,300	1.5
Genitourinary system diseases		2,000	7,000	12,000	120,000	141,000	1.3	65,000	3.0	76,000	0.4

Numbers of deaths have been gathered from the study of The Global Burden of Disease [Murray CJL, Lopez AD, editors, 1996].