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The Global Burden Due to Occupational Injury

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Background *Occupational injuries are a public health problem, estimated to kill more than 300,000 workers worldwide every year and to cause many more cases of disability. We estimate the global burden of fatal and non-fatal unintentional occupational injuries for the year 2000.*

Methods *The economically active population (EAP) of about 2.9 billion workers was used as a surrogate of the population at risk for occupational injuries. Occupational unintentional injury fatality rates for insured workers, by country, were used to estimate WHO regional rates. These were applied to regional EAP to estimate the number of deaths. In addition to mortality, the disability-adjusted life years (DALYs) lost, which measure both morbidity and mortality, were calculated for 14 WHO regions.*

Results *Worldwide, hazardous conditions in the workplace were responsible for a minimum of 312,000 fatal unintentional occupational injuries. Together, fatal and non-fatal occupational injuries resulted in about 10.5 million DALYs; that is, about 3.5 years of healthy life are lost per 1,000 workers every year globally. Occupational risk factors are responsible for 8.8% of the global burden of mortality due to unintentional injuries and 8.1% of DALYs due to this outcome.*

Conclusions *Occupational injuries constitute a substantial global burden. However, our findings greatly underestimate the impact of occupational risk factors leading to injuries in the overall burden of disease. Our estimates could not include intentional injuries at work, or commuting injuries, due to lack of global data. Additional factors contributing to grave underestimation of occupational injuries include limited insurance coverage of workers and substantial under-reporting of fatal injuries in record-keeping systems globally. About 113,000 deaths were probably missed in our analyses due to under-reporting alone. It is clear that known prevention strategies need to be implemented widely to diminish the avoidable burden of injuries in the workplace.* Am. J. Ind. Med. 48:470–481, 2005.

KEY WORDS: occupational injuries; global injury burden; occupational health; occupational accident; fatalities at work; injury surveillance; injury disability

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INTRODUCTION

Occupational injuries are a public health problem, estimated to kill more than 300,000 workers worldwide every year and to cause many more cases of disability [Takala, 1998]. Mortality due to injuries tends to be higher in developing countries, where workers experience a greater number and variety of hazards that lead to injury, and where fewer resources for injury prevention, treatment, and rehabilitation exist. In this study, we estimate the burden of fatal and non-fatal unintentional occupational injuries globally in two ways: using mortality, and a single measure of both mortality and morbidity, the disability-adjusted life year (DALY) [Murray et al., 2001].

MATERIALS AND METHODS

Literature Review

Extensive literature sources were searched, including biomedical sources (Medline), occupational health reports (NIOSHTIC), country web sites, country reports, and personal contacts. Studies examined were restricted to those that included fatal and/or non-fatal injuries at work. Systematic reviews showed that many reports were not indexed in the biomedical databases. Most of the studies focused on mortality and hospitalization, or were surveys applicable only to specific injuries or specific economic sectors. A detailed description of the limitations of the literature in the field is provided by Beahler et al. [2000].

A review of the available information indicates that injury death rates vary by sex and age group; males account for more than 90% of the deaths [International Labor Organization (ILO), 2002a,b]; and a steady rise in the mortality risk from the youngest age groups to about 64 years is usually observed [Corvalan et al., 1993; National Institute for Occupational Safety and Health (NIOSH), 2000]. Within the category of unintentional injury fatalities, motor vehicle accidents are by far the most common occupational fatality in both developed and developing countries. Data collection about fatal intentional injuries at work (homicides) occurs only in a few developed countries [National Institute for Occupational Safety and Health (NIOSH), 1996; Feyer et al., 2001b].

Mortality

Databases of the International Labor Organization (ILO) and publications of the Pan American Health Organization (PAHO) provided key data sources used to estimate the frequency and types of mortality due to occupational injuries. ILO develops its statistics describing occupational injury fatalities from information supplied by national organizations in response to specific questionnaires, and from national and international publications and websites, and other official documents [International Labor Organization (ILO), 2000, 2002a,b]. The Project on Systematizing Basic Data on Workers Health in the countries of the Americas is the source of the Latin American rates [Pan American Health Organization/World Health Organization (PAHO/WHO), 1998].

Differences in capture methods, reporting, coding criteria, and occupational mortality definitions hampered comparability among studies. In many developing countries, increasing trends of mortality due to injuries at work are reported; whereas, developed countries show declining death rates [Feyer et al., 2001a; Marsh and Layne, 2001]. Differences in types of industries, occupational activities, employment characteristics, and implementation of safety measures also explain mortality variability across countries. Table I summarizes country-specific fatality rates due to occupational injuries among insured workers. We used these rates among insured workers in our study, because occupational fatalities among uninsured workers are not reported widely in developing regions of the world.

Estimating the Population at Risk

The economically active population (EAP) includes all persons of either sex who furnish the supply of labor for the production of goods and services. The EAP includes people in paid employment, the self-employed, people who work to produce goods and services for their own household consumption, and the unemployed [International Labour Organization (ILO), 2002]. The EAP was used as a surrogate of the population at risk for occupational injuries. This approach to risk estimation does not address the different levels of risk for injuries that exist among the various economic sectors and job categories. Data in developed countries permit estimation of differential risks for injury by occupational category, being highest in agriculture and production, less in sales and service, and lowest in professional, administrative, and clerical sectors. Unfortunately, there are not adequate data on work-related injuries in developing countries by occupation or economic sector to make it possible to generate plausible relative risks for economic sectors by age, sex, and WHO region.[1] Estimation of the population at risk is described by Nelson et al. [2005]. Table II lists the EAP by gender, age, and WHO region. About 2.9 billion workers constitute the global EAP. Male's account for about 56% of the EAP in developed nations and about 60% of the EAP in developing nations.

[1] WHO member states are divided into six geographical regions (Africa–AFR, Americas–AMR, Europe–EUR, Eastern Mediterranean–EMR, Southeast Asia–SEAR, Western Pacific–WPR) and into five mortality strata (A–E) according to the levels of mortality under 5 years of age and of 15–59 year old males, resulting in 14 epidemiological regions.

TABLE I. Fatality Rates Due to Occupational Injuries (per 100,000 Insured Workers) by Country and Year

Country	Year(s)	Fatality rate per 100,000	Source
Australia	1982–1984	8.06	Harrison et al. [1989]
	1998–1999	4.0	National Occupational Health and Safety Commission (NOHSC), Australia [2001]
Austria	1998	5.3	International Labor Organization (ILO) [2002a,b]
Bolivia	1995	3.7	PAHO-WHO (OPS-OMS) [1998]
Brazil	1995	13.3	PAHO-WHO (OPS-OMS) [1998]
	1998	13.5	Takala [1998]
Canada	1970–1997	8.79	Human Resources Development Canada, Surveys [2002a,b]
China	1991–1997	9.1	Xia et al. [2000]
Costa Rica	1996	10.5	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
Cuba	1996	4.2	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
Czech Republic	1999	4.2	International Labor Organization (ILO) [2002a,b]
Denmark	1999	2	International Labor Organization (ILO) [2002a,b]
Dominican Republic	1996	6.3	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
El Salvador	1996	4.7	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
European Union	1998	5.03	Dupre [2001]
Finland	1997	3.1	International Labor Organization (ILO) [2002a,b]
Ireland	1999	4.21	International Labor Organization (ILO) [2002a,b]
Jamaica	1996	11.8	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
Jordan	1980–1993	25.5	Atallah et al. [1998]
México	1996	10.4	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
Namibia	1998/1999	25	Amweelo [2000]
New Zealand	1985–1994	5.03	Feyer et al. [2001a]
Panama	1996	14.5	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
Peru	1996	190	Pan American Health Organization/World Health Organization (PAHO/WHO) [1998]
Philippines	1999	11	National Statistics Office Philippines [2000]
Poland	1999	5.5	International Labor Organization (ILO) [2002a,b]
Russia	1999	14.4	International Labor Organization (ILO) [2001]
Slovenia	1998	4	International Labor Organization (ILO) [2002a,b]
Singapore	2000	10.8	Singapore Ministry of Manpower Statistics [2002]
South Africa	1995	14.2	Loewenson [1999]
Spain	2000	9.2	Ministerio del Trabajo y Asuntos Sociales de España: Estadísticas [2002]
Sweden	1998	1.7	International Labor Organization (ILO) [2002a,b]
Thailand	1999	11.48	International Labor Organization (ILO) [2002a,b]
United Kingdom	1998	0.8	International Labor Organization (ILO) [2002a,b]
United States	1980–1995	4.25	National Institute for Occupational Safety and Health (NIOSH) [2000]
Venezuela	1997	0.58	International Labor Organization (ILO) [2002a,b]

Outcomes Assessed

In this study, the outcome selected was unintentional injuries, as a single group, because data were too sparse globally to allow us to estimate individual types of injuries at work. Unintentional injuries include motor vehicle injuries, poisonings, falls, fires, drowning, and ''other'' injuries that correspond to exposure to inanimate mechanical forces, exposure to electric current, radiation, extreme ambient air temperature and pressure, and accidental exposure to other unspecified factors [World Health Organization (WHO), 1992].

Estimating Mortality

In this study, deaths due to unintentional occupational injuries were defined[2] as any potentially avoidable death due to an external cause resulting from an exposure related to the

[2] Fatal and non-fatal injuries have different definitions in different countries, but all have in common that the individual must be engaged in a work activity at the moment of the event. The most frequent definition of occupational injuries corresponds to ''those that are employment-related and are the result of a traumatic event while a person is on duty.'' This definition, depending on the country, may or may not include injury during commuting; however, commuting injuries were excluded in this study.

TABLE II. Economically Active Population (EAP) by Sex, Age Group and WHO Region (in Thousands)

Sex	Region	15–29	30–44	45–59	60–69	70–79	80+	ALL
Males	AFR-D	31,606	21,663	11,188	3,593	1,279	150	69,479
Females	AFR-D	20,211	13,701	7,658	2,311	669	91	44,641
Males	AFR-E	37,360	25,298	13,049	4,047	1,356	145	81,255
Females	AFR-E	30,684	18,891	10,160	3,001	961	127	63,824
Males	AMR-A	23,499	36,198	25,734	5,613	1,042	225	92,311
Females	AMR-A	20,739	31,025	21,466	3,960	732	241	78,163
Males	AMR-B	47,472	42,674	22,439	5,998	1,597	240	120,421
Females	AMR-B	27,776	24,249	10,536	2,097	439	81	65,177
Males	AMR-D	7,322	6,015	3,256	1,108	391	55	18,147
Females	AMR-D	3,879	3,096	1,410	411	129	21	8,947
Males	EMR-B	13,553	12,773	7,290	1,784	486	60	35,946
Females	EMR-B	6,474	4,293	1,686	413	104	14	12,983
Males	EMR-D	34,791	28,924	15,648	4,437	1,160	144	85,103
Females	EMR-D	16,848	12,373	6,084	1,568	364	44	37,280
Males	EUR-A	27,184	46,146	32,648	6,953	653	117	113,702
Females	EUR-A	23,253	34,641	21,926	3,080	372	105	83,377
Males	EUR-B	21,150	21,949	12,076	2,858	831	96	58,959
Females	EUR-B	15,813	17,529	9,271	1,897	664	105	45,279
Males	EUR-C	20,205	26,449	17,547	2,976	537	58	67,772
Females	EUR-C	16,681	26,180	16,857	2,458	535	96	62,808
Males	SEAR-B	31,407	31,690	16,565	5,012	1,350	147	86,172
Females	SEAR-B	22,880	22,272	11,732	3,411	776	100	61,170
Males	SEAR-D	135,838	125,323	69,279	19,712	6,806	855	357,812
Females	SEAR-D	73,350	66,820	35,218	9,268	2,284	316	187,256
Males	WPR-A	10,898	15,249	15,702	5,556	1,473	265	49,143
Females	WPR-A	8,887	10,838	11,137	3,134	849	241	35,086
Males	WPR-B	163,139	184,773	105,772	26,955	6,137	687	487,462
Females	WPR-B	146,296	160,318	72,753	12,675	2,292	387	394,722
Total		1,039,196	1,071,348	606,088	146,285	36,264	5,213	2,904,395

International Labor Organization (ILO) [2002a,b]. Economically Active Population 1950–2010, Fourth Edition, Rev. 2, Geneva.

person's work. The definition excludes death during commuting to or from the workplace. Workers traveling for work purposes were included. To estimate mortality, fatality rates of work-related injuries were applied to the EAP of each WHO region. Fatality rates were taken from data for insured worker populations as shown in Table I; these were distributed into 11 WHO Regions, as shown below. For the three regions (AMR-D, EMR-D, and SEAR-D) where data were not found, data from a similar region were applied. Further details are provided by Nelson et al. [2005].

Assumptions of the estimation of regional fatality rates were: (a) countries of the same region shared epidemiological and environmental characteristics and had a similar mix of economic sectors; and (b) a region with no available information that also has poor epidemiological and socioeconomic conditions should have at least the same level of mortality as that of the region with better general conditions (D regions vs. B regions). Extrapolations of the estimates were:

- WHO region Africa D were used for WHO region Africa E. (Estimates of Africa D are based on Loewenson [1999], which reported a median fatality rate of 14.02 per 100,000 workers in South Africa).
- WHO region America A of 4.72 per 100,000 workers correspond to the weighted average of reported data from Canada, United States, and Cuba [Pan American Health Organization/World Health Organization (PAHO/WHO), 1998; Human Resources Development Canada, 2000; National Institute for Occupational Safety and Health (NIOSH), 2000].
- WHO region America B correspond to the mortality rate of 13.5 per 1,000 workers in Brazil, estimated by Takala [1998].

- WHO region America B was used for WHO region America D.
- WHO regions Eastern Mediterranean B and D of 25.5 per 100,000 are based on a study carried out by Atallah et al. [1998] in Jordan. No other estimates were obtained from any other Middle Eastern country.
- WHO region Europe A of 5.03 per 100,000 correspond to those published by the European Union in the EUROSTAT Statistics [Dupre, 2001].
- Europe B of 5.5 per 100,000 workers is based on Poland 1998 [International Labor Organization (ILO), 2001].
- WHO region Europe C of 14.4 per 100,000 workers are based on Russia 1999 [International Labor Organization (ILO), 2001].
- WHO South East Asia regions B and D of 11.48 per 100,000 are based on a country report from Thailand 1999 [International Labor Organization (ILO), 2002a,b].
- WHO Western Pacific Region A of 4.22 per 100,000 workers are based on the weighted average between Australia 2001 and New Zealand, 1985–1994-NOSHC [1998–1999]; Feyer et al. [2001a].
- WHO region Western Pacific B of 9.1 per 100,000 are based on China [Xia et al., 2000].

The ''theoretical minimum risk'' is a WHO convention used in the comparative risk assessment to represent the number of deaths from injury that would occur if all occupational injury hazards were controlled by effective preventive measures [Ezzati et al., 2004]. To estimate a lowest observed rate of fatalities at work, the broadest available and accurate data set was chosen. This corresponded to 16 years of data from the National Traumatic Occupational Fatalities surveillance system for the United States for the period 1980–1995. Over 93,000 deaths were used in the rate estimation, and rates were not calculated for categories with fewer than 3 deaths or with fewer than 20,000 employed [Marsh and Layne, 2001]. In this context, the lowest observed average annual rate (per 100,000 workers) was 0.1 in the age group 16–17 years and in the occupation category ''service.'' Thus, the theoretical minimum risk corresponds to 0.1 deaths per 100,000 exposed.

Demographic Distribution of Occupational Injuries

Sex

A review of ILO data describing injury deaths at work for 21 countries indicates that males accounted for between 91% and 99% of all deaths from injury at work in all countries, independently of the level of economic development of the country [International Labor Organization (ILO), 2000]. This is illustrated in Table III. Using this as a guide, the estimated total number of injury deaths was distributed using proportions of approximately 93:7.

TABLE III. Proportions of Deaths From Injury at Work by Sex and Country*

Country	Males	Females
Algeria	0.99	0.01
Australia	0.94	0.06
China	0.97	0.03
Denmark	0.93	0.07
El Salvador	0.93	0.07
European Union	0.94	0.06
France	0.94	0.06
Germany	0.91	0.09
Greece	0.96	0.04
Hungary	0.97	0.03
Italy	0.93	0.07
Jordan	0.98	0.02
Lithuania	0.93	0.07
Poland	0.94	0.06
Russian Federation	0.94	0.06
South Africa	0.97	0.03
Spain	0.97	0.03
Sweden	0.96	0.04
Ukraine	0.93	0.07
United Kingdom	0.98	0.03
United States	0.91	0.09

*Source: ILO [2000].

Age

Death rates from injuries at work vary by age. The most frequently observed pattern in our data corresponded to a steady rise from the youngest age groups to about 64 years. Only a few countries observed the highest risk in the youngest ages. For example, in the United States, workers aged $\geq$65 years had the highest age-specific death rates, whereas in Canada the highest risk was observed in the age group 16–24 years [Human Resources Development Canada, 2000; National Institute for Occupational Safety and Health (NIOSH), 2000]. Different causes have been attributed to the different patterns of risk, such as lack of experience in the workplace. We, however, cannot exclude the possibility that the observed variations are due to notification bias [Corvalan et al., 1993]. Due to limitations of data globally, the U.S. age distribution for unintentional injuries was chosen for the age group distribution used in our estimation. See Table IV [National Institute for Occupational Safety and Health (NIOSH), 2000].

TABLE IV. Percentage Distribution of Fatal Occupational Injuries by Age Group Among Workers in the United States*

Age (years)	Percentage distribution
15–29	0.27
30–44	0.35
45–59	0.24
≥60	0.14

*Source: National Institute for Occupational Safety and Health (NIOSH) [2000].

Estimating the Burden From Non-Fatal Unintentional Occupational Injuries

Due to lack of global data for non-fatal occupational injuries, WHO formulas were applied to calculate the burden in DALYs due to non-fatal occupational injuries, utilizing the distribution of unintentional occupational injury deaths by age and sex. For calculating years of life lost due to premature mortality (YLL), the standard expected years of life lost (SEYLL) method was used [Murray and Lopez, 1996]. This involves computation of the average age at death in each age interval (L) and of the standard life expectancies for these average ages at death, for each age-sex group, by interpolation between the standard life expectancies at exact ages of death given in either the full Model West or the abridged standard life tables. YLL for a given age and sex is the product of the average age of death and the number of deaths of each interval (YLL = N × L). With 3% discounting and uniform age weights:

$$\mathrm{YLL} = \frac{\mathrm{N}}{0.03}(1 - \mathrm{e}^{-0.03\mathrm{L}})$$

Years of life lost *due to disability* (YLD) is the disability component of DALYs. The formula for YLD is:

$$\mathrm{YLD} = \mathrm{I} \times \mathrm{DW} \times \mathrm{L}$$

where I is the number of incident cases in the reference period, DW is the disability weight (in the range 0–1), and L is the average duration of disability (measured in years). Further explanation about the calculations can be found in Mathers et al. [2002].

Estimating DALYs

DALYs are computed as the sum of the years of life lost due to premature mortality (YLL) in the population and the equivalent 'healthy' years lost due to disability (YLD) for incident cases of the health condition [Mathers et al., 2002]:

$$\mathrm{DALY} = \mathrm{YLL} + \mathrm{YLD}$$

Estimating Attributable Fraction

The *Mortality Attributable Fraction* (%) was calculated as the number of deaths due to unintentional injuries at work compared to the total worldwide number of deaths due to all unintentional injuries, including occupational injuries. Similarly, the *Attributable Fraction due to both mortality and morbidity* (%) was calculated as the number of DALYs due to unintentional occupational injuries compared to the total number of DALYS due to all unintentional injuries [Mathers et al., 2002].

RESULTS

Worldwide, about 312,000 deaths due to unintentional occupational injuries occurred in the year 2000 among 2.9 billion workers. (See Table V). Table VI provides the total number of occupational unintentional injury fatalities by WHO subregion, age group, and sex, illustrating that the mortality burden differs by age and sex. Males experience unintentional occupational injuries at a higher rate in every region of the world; overall, fatal occupational injuries occur in males about fifteen times more often than among females.

The *combined burden of both mortality and morbidity* in DALYs is shown in Table VII, by age group, sex, and WHO region. Unintentional occupational injuries account for 10,531,000 DALYs, with 9,798,000 among males and 733,000 among women. Thus, among the EAP of 2.9 billion workers, about 3.5 years of healthy life are lost per 1,000 workers worldwide due to injury risks found in workplaces.

Unintentional occupational injuries account for 8.8% of the mortality worldwide due to unintentional injuries: 12.9% in males versus 1.5% in females. The *mortality attributable fractions* ranged from 6.4% to 15.7% among the regions (Table VIII). The highest attributable burden of mortality due to injuries is found in the Eastern Mediterranean region and in the less developed countries in the Americas. Overall, these high mortality attributable fractions reflect not only the hazardous conditions in workplace, but also the limited implementation of prevention strategies in the workplace.

The attributable fraction expressed in DALYs is the proportion of the global burden due to *both mortality and morbidity.* Table IX provides the distribution of attributable fraction (%) in DALYs by age, sex, and WHO region that is due to unintentional occupational injuries. Overall, unintentional occupational injuries account for 8.1% of the worldwide burden of death and disability due to unintentional

TABLE V. Total Number of Injury Fatalities at Work in the Economically Active Population (EAP), by WHO Subregion

Subregion	EAP	Fatality rate	Total number of deaths	Lowest number of deaths (theoretical minimum)	Total number of deaths minus theoretical minimum
AFR-D	114,119,178	14.02	16,000	114	15,886
AFR-E	145,078,996	14.02	20,340	145	20,195
AMR-A	170,474,649	4.72	8,046	170	7,876
AMR-B	185,597,686	13.5	25,056	186	24,870
AMR-D	27,093,435	13.5	3,658	27	3,631
EMR-B	48,929,025	25.5	12,477	49	12,428
EMR-D	122,382,843	25.5	31,208	122	31,086
EUR-A	197,079,187	5.03	9,913	197	9,716
EUR-B	104,238,611	5.5	5,733	104	5,629
EUR-C	130,579,473	14.4	18,803	131	18,672
SEAR-B	147,342,192	11.48	16,915	147	16,768
SEAR-D	545,067,213	11.48	62,574	545	62,029
WPR-A	84,228,855	4.22	3,554	84	3,470
WPRB	882,183,384	9.1	80,279	882	79,397
Total	2,904,394,727	10.8	314,555	2,903	311,652

injuries, with 11.8% among males and 1.5% among females. Attributable fractions range from 5.9% to 13.1% among the regions.

DISCUSSION

Measures of Burden

This is the first study to estimate the attributable fraction for fatal and non-fatal unintentional injuries at work globally, using the measure of the overall burden of disability-adjusted life years (DALYs). We estimate that occupational risks for injuries are responsible for about 10.5 million DALYs, or about 8.1% of the global burden of both mortality and morbidity that is due to unintentional injuries. The mortality attributable fraction is 8.8% worldwide. Our estimation of about 312,000 deaths due to occupational injury risks is similar to the total of 334,870 estimated by ILO [Takala, 1998]. The similarity of the fatality estimate is due, in part, to the use of a similar methodology and the utilization of the

TABLE VI. Distribution of Occupational Injury Fatalities (in thousands) at Work by Age Group, Sex, and WHO Subregion*

	15–29		30–44		45–59		60–69		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	4	0	5	0	4	0	2	0	15	1	16
AFR-E	5	0	7	0	5	0	3	0	19	1	20
AMR-A	2	0	3	0	2	0	1	0	7	0	8
AMR-B	6	0	8	1	6	0	3	0	23	1	25
AMR-D	1	0	1	0	1	0	0	0	3	0	4
EMR-B	3	0	4	0	3	0	2	0	12	1	12
EMR-D	8	1	10	1	7	0	4	0	29	2	31
EUR-A	2	0	3	0	2	0	1	0	9	1	10
EUR-B	1	0	2	0	1	0	1	0	5	0	6
EUR-C	5	0	6	0	4	0	2	0	18	1	19
SEAR-B	4	0	5	0	4	0	2	0	16	1	17
SEAR-D	16	1	20	1	14	1	8	1	58	4	62
WPR-A	1	0	1	0	1	0	0	0	3	0	3
WPR-B	20	1	26	2	18	1	11	1	75	5	79
World	80	5	101	6	70	4	42	3	293	19	312

Differences in totals are due to rounding.

TABLE VII. Total Number of DALYs (in Thousands) Due to Occupational Injuries, by Age Group, Sex, and WHO Subregion

	15–29		30–44		45–59		60–69		Total		
Subregion	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**All**
AFR-D	225	19	181	14	74	6	23	2	503	40	543
AFR-E	276	22	217	17	92	7	30	2	615	49	663
AMR-A	93	7	83	6	38	3	13	1	226	17	244
AMR-B	359	31	307	26	130	10	42	3	837	71	908
AMR-D	49	4	40	3	17	1	5	0	111	9	120
EMR-B	163	12	140	10	58	4	17	1	378	28	406
EMR-D	460	30	382	28	146	11	48	3	1,036	73	1,109
EUR-A	126	11	117	11	49	4	16	1	308	28	335
EUR-B	97	7	73	6	31	2	10	1	211	15	226
EUR-C	214	17	173	13	76	5	27	2	489	36	525
SEAR-B	202	14	171	12	72	5	24	2	469	31	501
SEAR-D	988	55	731	53	288	20	96	7	2,103	135	2,239
WPR-A	52	5	46	4	17	1	5	0	121	11	131
WPR-B	1,008	91	898	64	368	27	117	9	2,391	190	2,581
World	4,312	324	3,559	267	1,455	107	473	35	9,798	733	10,531

ILO Database of EAPs [International Labour Organization (ILO), 2002]. However, our countries fatality rates and regions differ from those used by ILO.

Analysis of the full contribution of injuries at work within the overall global burden of injuries is served well by an indicator such as the DALY, which measures not only the burden from mortality but also from years lived with disability. In countries and regions with constant or slight decreasing mortality patterns, the contribution of mortality is no longer sufficient to measure risk factors at work leading to injuries. It has been observed in some countries that the decline in mortality is balanced by an increase in severity of injuries and morbidity, especially in long-lasting or permanent disabilities [Guerrero et al., 1994; Centers for Disease Control and Prevention (CDC), 2001].

Our estimation of mortality is subject to uncertainty for several reasons. Data from one region were extrapolated to other regions under assumptions about their similarity. However, different regions usually have different cultural, socio-economic, and geographical population distributions.

TABLE VIII. Attributable Fraction (%) of Unintentional Injury Mortality Due to Occupational Risk Factors, by Age Group, Sex, and Subregion

	15–29		30–44		45–59		60–69		Total		
Subregion	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**All**
AFR-D	14.6	2.6	21.6	3.7	19.9	3.3	21.8	2.7	10.4	1.3	7.4
AFR-E	16.2	2.8	21.7	3.9	20.2	3.7	27.7	3.6	11.7	1.3	8.0
AMR-A	12.1	2.4	14.1	2.6	13.1	2.2	18.7	2.2	9.9	1.1	6.7
AMR-B	15.9	5.7	24.1	9.4	26.1	8.1	34.2	6.8	17.7	3.9	14.6
AMR-D	11.3	2.7	16.9	6.2	16.2	4.6	20.4	4.3	10.7	1.9	8.3
EMR-B	17.1	4.5	30.2	9.2	24.4	7.8	28.6	5.9	17.6	3.7	14.4
EMR-D	26.7	3.8	43.8	7.4	38.0	5.8	47.3	4.7	23.3	2.6	15.7
EUR-A	14.7	3.9	20.8	5.7	15.6	3.2	13.4	2.0	10.8	1.0	6.8
EUR-B	10.7	3.0	12.5	3.9	10.7	2.2	12.9	2.1	9.2	1.5	7.1
EUR-C	10.9	3.5	8.7	3.0	6.3	1.6	9.1	1.5	7.7	1.7	6.4
SEAR-B	10.1	1.4	13.8	1.9	14.7	1.5	22.4	1.7	11.0	1.2	7.3
SEAR-D	15.0	1.0	17.4	2.0	14.4	1.5	19.3	1.4	11.9	0.9	6.9
WPR-A	21.7	5.2	34.5	8.3	14.4	2.8	9.5	1.6	10.7	1.2	7.3
WPR-B	16.4	4.2	23.3	3.4	20.3	2.8	23.5	3.1	14.9	1.9	10.5
World	15.2	2.3	19.5	3.3	16.7	2.5	21.1	2.4	12.9	1.5	8.8

TABLE IX. Attributable Fractions (%) in DALYs of Global Burden of Morbidity and Mortality for Unintentional Injuries Due to Occupational Risk Factors, by Age Group, Sex, and WHO Subregion

	15–29		30–44		45–59		60–69		Total		
Subregion	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**All**
AFR-D	14.6	2.6	21.6	3.7	19.9	3.3	21.8	2.7	8.6	1.2	5.9
AFR-E	16.2	2.8	21.7	3.9	20.2	3.7	27.7	3.6	9.3	1.1	6.1
AMR-A	12.1	2.4	14.1	2.6	13.1	2.2	18.7	2.2	10.9	1.7	7.9
AMR-B	15.9	5.7	24.1	9.4	26.1	8.1	34.2	6.8	15.0	4.1	12.4
AMR-D	11.3	2.7	16.9	6.2	16.2	4.6	20.4	4.3	9.1	1.8	7.1
EMR-B	17.1	4.5	30.2	9.2	24.4	7.8	28.6	5.9	15.3	3.4	12.4
EMR-D	26.7	3.8	43.8	7.4	38.0	5.8	47.3	4.7	18.5	2.2	12.4
EUR-A	14.7	3.9	20.8	5.7	15.6	3.2	13.4	2.0	14.0	2.8	10.5
EUR-B	10.7	3.0	12.5	3.9	10.7	2.2	12.9	2.1	8.2	1.9	6.7
EUR-C	10.9	3.5	8.7	3.0	6.3	1.6	9.1	1.5	8.0	2.1	6.7
SEAR-B	10.1	1.4	13.8	1.9	14.7	1.5	22.4	1.7	10.0	1.1	6.7
SEAR-D	15.0	1.0	17.4	2.0	14.4	1.5	19.3	1.4	10.6	0.8	6.1
WPR-A	21.7	5.2	34.5	8.3	14.4	2.8	9.5	1.6	17.7	3.3	13.1
WPR-B	16.4	4.2	23.3	3.4	20.3	2.8	23.5	3.1	13.7	2.1	9.7
World	15.4	2.5	20.0	3.4	17.0	2.6	21.1	2.4	11.8	1.5	8.1

In the absence of adequate data, we could not establish these differences or address their impact in the estimation. There was considerable variation between regions in the estimates of attributable fraction, whether based on deaths or DALYs. These attributable fractions are influenced by the numbers in both the numerator and the denominator of the attributable fraction. The numerator is likely to be primarily influenced by the industry mix in the workforce, since different industries have different risks of injury, and the industry mix is known to vary considerably between countries and regions. The denominator reflects the total number of injuries (both occupational and non-occupational), which is influenced by a variety of factors, including extent of industrialization.

Data from developed countries such as Australia, the European Union countries, and the United States are more accurate than data reported from developing countries. This asymmetry of information among countries may have two impacts on the estimation: (a) the accuracy and validity of the estimation is greater in developed countries than in developing ones, and (b) the variability of socio-economic conditions in developing countries may hide their interplay with the development of injuries at work. Moreover, the degree to which socio-economic conditions mediate the relationship between the risk exposure and the outcome is not measurable and estimates as to the true effect can be little more than speculation at this stage.

Underestimation of Injury Burden

Our findings underestimate the impact of the occupational risk factors leading to injuries in the overall burden of disease due to injuries, especially in developing countries. Some countries count commuting deaths to or from work as occupational deaths [International Labor Organization (ILO), 2002a,b], but we did not. The degree of undercounting due to this omission depends on the frequency of road crashes, which varies between countries, but commuting deaths were in the order of 25% of all work-related deaths of workers, and 20% of all work-related deaths if bystanders were included, in a recent Australian study. Bystander deaths were also not included in the current analysis, and the same Australian study found that the undercounting due to this omission was in the order of 25% [Driscoll et al., 2001].

In this study, we did not estimate the injury mortality due to intentional injuries, such as homicides in the workplace, because of the lack of data in developing countries. However, current evidence shows that intentional injuries must be present in such countries; therefore, the lack of estimation of deaths due to this cause exacerbates the degree of underestimation of the number of deaths of workers due to workplace injuries by approximately 4–6%, if we take Australia and New Zealand as reference [Driscoll et al., 2001; Feyer et al., 2001b].

Another major factor contributing to underestimation was our use of data only from insured populations. Although we applied the fatality rates in insured populations to the entire EAP, some reports suggest that mortality can be greater in uninsured populations [Loewenson, 1998; Forastieri, 1999; Dror, 2001]. Few studies have been conducted in developing countries about the degree of insurance or Social Security coverage of workers. Empirical data suggest, however, that under-coverage is frequent in those countries

in which the informal sector is large, as well as in those that have a large agriculture sector where a sizeable number of farm workers are employed as seasonal workers [Hussmans and Mehran, 1991; Sethuraman, 1997; Loewenson, 1998, 1999; Forastieri, 1999; Amweelo, 2000; Tomei, 2000; Verdera, 2000; Ezenwa, 2001; Horsburgh et al., 2001]. A 1998 report from the Pan American Health Organization (PAHO), which retrieved data from different Latin America countries shows that the insured population ranges from 23.1% to 67.1% of the EAP [PAHO, 1998]. Atallah et al. [1998], in a descriptive study of fatal occupational injuries in Jordan, found that the actively insured employees were, on average, 71.9% of those employees who were required to be insured. The data from Latin America and Jordan indicate that more than 50% of the workers in the world do not have coverage by insurance or Social Security.

Under-reporting in all types of data systems is a key factor that contributes to the underestimation of occupational deaths due to injuries. Incomplete recording is characteristic of mortality registries, even for insured populations in developed nations. Data from the U.S. reveal that death registries identify between 67% and 90% of fatal injuries at work [Stout and Bell, 1991]. A similar under-reporting has been found in the regional Mortality Registry of Tuscany, Italy [Chellini et al., 2002]. Data from Lerer and Myers [1994] shows that 28% of occupational fatalities were not reported in terms of statutory regulations in Cape Town, South Africa. Moreover, the level of under-reporting increases up to 78–85% in rural areas [Schierhout et al., 1997]. Special registries also experience under-reporting, such as the National Fund for Occupational Diseases in Italy, which has a completeness of 56.4% [Chellini et al., 2002]. Workers' compensation systems have been found to underestimate deaths of all workers at work (i.e., excluding commuters and bystanders) in Australia by about 43% [Driscoll, 2001]. To improve the accuracy of the reporting of fatal injuries at work, many countries, such as the U.S., gather data from different data sources (deaths certificates, claims, data from insured companies, labor inspectorates, coroners files, and medical examiners files) [Centers for Disease Control and Prevention (CDC), 2001].

As noted above, under-reporting of occupational injury deaths ranges from 10% in the United States to 85% in rural Africa. We used a conservative approach to estimate the numbers of occupational injury fatalities that we may have missed in our analysis due to under-reporting alone. We assumed complete death ascertainment for the WHO A Regions, and we used for unreported deaths in the B–E Regions the estimation of Lerer and Myers [1994] of 28% under-reporting in South Africa. As shown in Table X, we conclude that at least 113,000 work-related injury fatalities were missed in our analysis solely due to under-reporting of occupational injury deaths in countries. This number does not include workplace homicides, commuter, and bystander fatalities. This means that our results in the WHO Comparative Risk Assessment, computed from existing global data for occupational fatalities, greatly underestimates the burden of total global mortality due to work-related injuries.

TABLE X. Occupational Injury Deaths by Region, Adjusted for Under-Reporting

Subregion	Total number of deaths	Number of unreported deaths	Number of deaths adjusted for under-reporting
AFR-D	15,886	6,178	22,064
AFR-E	20,195	7,854	28,049
AMR-A	7,876	NA	10,939
AMR-B	24,870	9,672	34,542
AMR-D	3,631	1,412	5,043
EMR-B	12,428	4,833	17,261
EMR-D	31,086	12,089	43,175
EUR-A	9,716	NA	13,494
EUR-B	5,629	2,189	7,818
EUR-C	18,672	7,261	25,933
SEAR-B	16,768	6,521	23,289
SEAR-D	62,029	24,122	86,151
WPR-A	3,470	NA	4,819
WPRB	79,397	30,877	110,274
Total	311,653	113,008	432,851

Method described in text.

CONCLUSION

Workplace fatal and non-fatal injuries produce a tremendous burden on workers, their families, and society. This analysis finds that occupational risk factors are responsible for 8.8% of global burden of mortality, and 8.1% of the combined burden of both mortality and morbidity due to injuries. We also conclude that our numbers constitute a grave underestimate of the full burden.

Injuries at work are largely preventable by improvements to make work safer and healthier. Improved engineering controls, administrative policies, health and safety information, and education to promote safety attitudes and behaviors are needed worldwide. Improved surveillance data must be developed to provide the basis for targeting prevention measures towards high-risk worker groups. Knowledge of the distribution of the burden by types of external cause of mortality has allowed the developed countries to focus on preventive actions at work, resulting in decrease of injury rates over time. Similar analysis and preventive actions in other nations can greatly reduce injuries in the workplace.

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