

COMPARATIVE ANALYSIS OF THE BURDEN OF INJURY AND ILLNESS AT WORK IN SELECTED COUNTRIES AND REGIONS

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ABSTRACT

Developed countries have made tremendous progress in Workplace Safety and Health in terms of reducing the burden of occupational injuries caused by accidents. Developing countries and transition economies experience both high injury and illness risks at work. There is a clear need to look more carefully at the long latency diseases and disorders caused by work. In order to have a baseline for priority setting and future work, a better picture of the burden caused by work is needed. Data on both fatalities and non-fatal outcomes, attributable fractions based on the exposure-outcome relationship, Labour Force Surveys including ad hoc modules on workplace injuries and ill-health and data from several comparable countries have been obtained, modified, adapted, and used. Comparisons between countries are not straightforward but an effort has been made to compare numbers and rates. Globally there were 2.3 million work-related deaths in 2011. While cancers (666,000 deaths) and cardiovascular diseases (827,000 deaths) kill much more workers than injuries (353,000 deaths), the number of Years of Lives Lost to work-related injuries is still very high as those injured were much younger than, for example, those who died from work-related cancers. Various estimates indicated that largely comparable numbers exist for work-related cancer, while other work-related diseases, disorders and injuries were less comparable due to non-coverage of some and poor coverage of others. For major countries and regions, China had 173,000 work-related cancer deaths while the European Union (EU28) had 103,000. China's workforce is around three times bigger but also younger than that of EU28. China had an estimated 99,000 injury deaths at work while EU28 had 4,700 such deaths. For smaller comparable countries, Hungary had 96 fatal

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Received: 1st June 2017

Accepted: 14th June 2017

occupational injuries, 3,986 work-related disease deaths, totalling 4,082 deaths. Singapore had 115 fatal occupational injuries based on compensation records, and an estimated one work-related suicide and 1,323 fatal work-related diseases totalling 1,439 fatal work-related injuries and illnesses. Hungarian and Singaporean burden and fatal work-related disease cases and rates of work-related diseases were comparable taken the size of workforce. Fatal injury rates in these countries are at the same level than in most Western European countries and Japan and are among the 20 safest countries globally. Of individual factors causing deaths asbestos appears to be the most significant one with an estimated 237,000 (184,000 – 290,000) work-related deaths. In workers' self-reported surveys carried out in 2007-2008, Hungarian and Singaporean non-fatal injury rates were also comparable. Later surveys showed increasing non-fatal trends and compensation sources indicated lower fatality trends. Background data for calculations and comparative tables are presented in separately available datasets by WHO regions and country and based on the 2014 ILO study. The authors concluded that health disorders at work are much less comparable than fatal injuries across countries and regions. Future studies can improve the estimates but there is no reason to wait for further research to start taking action to reduce both injuries and illnesses. Many work-related diseases, such as occupational cancers can be eliminated by reducing the exposures. Applying a mindset of Vision Zero and Zero Harm at work is needed for eliminating or radically reducing the burden of injuries and illnesses from work.

KEY WORDS: work-related diseases and deaths, workplace injuries and ill-health, cancer, mesothelioma, occupational injuries, asbestos, DALY

INTRODUCTION

Over the years, developed countries have done well to reduce occupational injuries (Hämäläinen et al., 2005; Hämäläinen et al., 2009), despite having an increasingly complex environment.

As seen in many developed countries, the health component of workplace safety and health is rapidly increasing in importance compared to the safety component. The relatively higher importance of health is caused by improvements in safety and by reduction of the number of workers in hazardous industries. In developed countries, another major component in reducing accidents has been the shift in economic structures. Hazardous and labour intensive workplaces, such as those in manufacturing have decreased in developed countries and much of such work takes place in other locations, in particular, in Asia. It is common that in developed countries more than two thirds of all workers are already working in service occupations. The processes of mechanization, automation and prefabrication are also foreseen to contribute to jobs less exposed to injuries. However, a majority of the population is exposed to “new and emerging” work risks related to long-term health effects, such as psychosocial factors.

This paper reviews latest global and country numbers of occupational accidents and work-related illnesses in 2014 and spin-off data of selected countries and regions.

The objectives of this paper include:

- a) Create a better understanding of short and long-term health risks caused by work and of the expected serious consequences;
- b) Based on recent estimates compare data from available sources to understand the magnitude of various occupational problems and disorders, based on indicators commonly used. Analysis of existing estimates from different countries and regions and differences between countries and estimates would provide a roadmap for setting priorities;
- c) Identify the main targets for the elimination and reduction of exposures to negative workplace factors causing long-term serious outcomes and deaths related to work, and
- d) Provide facts and evidence for priority action related to WSH policies, strategies, regulatory measures, enforcement, engagement and building of a mindset and culture of total workplace health and well-being at work.

MATERIALS AND METHODS*

Sources of data on the burden of injuries and illnesses at work

We reviewed employment figures, mortality rates, occupational burden of diseases and injuries, reported accidents, surveys on self-reported occupational illnesses and injuries, attributable fractions, economic cost estimates of work related injuries and ill-health, and the most recent information on the problems from published papers, documents, and electronic data sources of international and regional organizations, in particular ILO, WHO, EU and ASEAN, institutions, agencies, and public websites.

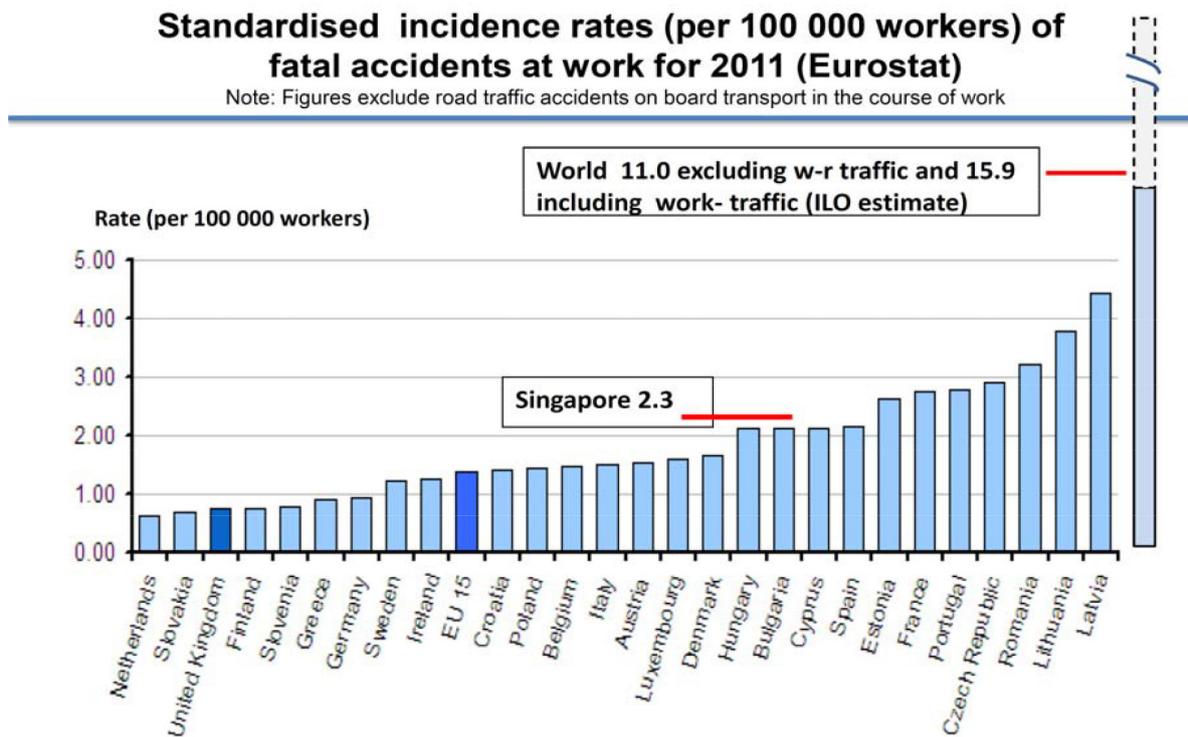
Occupational injuries and work-related illnesses

While it is difficult to compare national data related to occupational injuries due to differences in legal and compensation criteria, the comparison between the number of fatal injuries (accidents) is easier and, although not completely, it is relatively comparable when the recording criteria, denominators and economic structures are well documented. Usually fatal injuries are expressed per 100,000 employed population in national statistics, or per 1 million working hours which may be converted to 100,000 full time employed.

Some international and regional organizations collect such data, notably the International Labour Organization (ILO), the World Health Organization (WHO) and the European Union (EU). In addition, research mechanisms and published scientific papers complement these sources. Data collection systems for these still vary so their comparability has limitations. Using a combination of these sources, a selection of such data is presented in *Figures 1 and 2*. For example, Singapore had 2.3 fatal injuries per 100,000 employed in 2010. These numbers exclude fatal commuting injuries between home and work and injuries that took place in work-related traffic on public roads and other public traffic according to Health and Safety Executive

**The data bases used for this paper are accessible on the homepage of the Central European Journal of Occupational and Environmental Medicine (www.omfi.hu/cejoem/)*

report (HSE, 2014) based on EU's Eurostat numbers. The after removal of fatalities arising from work-related traffic injuries enables comparison. The best countries included major countries such as United Kingdom with 0.74 fatal injuries per 100,000 employed and Germany 0.9 per 100,000. Hungary was slightly safer than Singapore, when using numbers from the WSH Institute regular reports. Comparative global outcomes are based also on ILO estimates (ILO, 2014) as sources for global data. Data including work-related traffic will significantly increase the rates (up to double of those presented).



Note: Singapore and World rates not standardised

Figure 1. Standardized incidence rates (per 100,000 workers) of fatal accidents at work for 2011 (Eurostat 2014), Singapore and World rates are not standardized by economic structures.

The standardized numbers in *Figure 1*. included adjustments based on average industry structures in the EU. Countries that have a relatively high level of activity in high-risk industries or construction work would otherwise show much higher rates as compared to those with a high service industry component even though within each economic sector, their safety levels and rates would be equal to those in another country. Singapore's rate and ILO global rates are not standardized and reflect a different level of more hazardous economic activities. Fatal injury rates in industrialized countries are gradually going down partly due to a shift in the countries' economic structure from dangerous sectors to less risky ones, such as the service sector, and partly due to better leadership, management and efforts in safety and health, see *Figure 1*. *Figure 2* from Singapore illustrates the trend in many industrialized countries where fatal occupational injuries have become gradually a smaller problem.

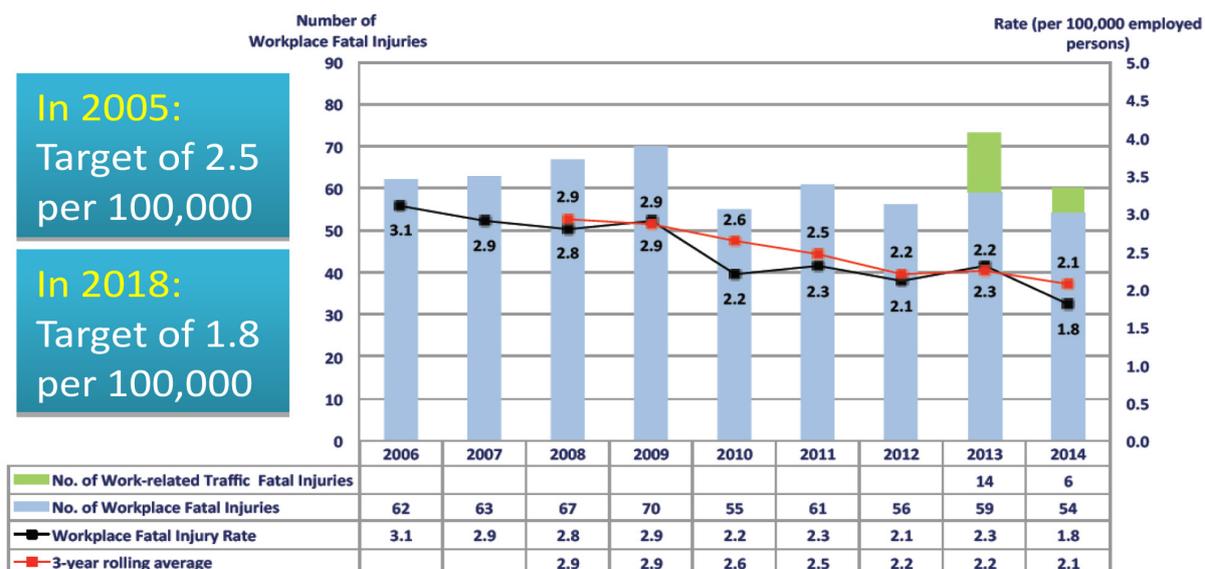


Figure 2. Singapore Fatal Injury Rate Performance

Occupational disease is usually understood to be a disorder or illness included in the designated list of diseases at work where employment injury compensation is legally defined. Inclusion in such list is influenced by both evidence of work-relatedness and by administrative, financial and political arguments by the government or region concerned. In reality, the number of illnesses covered depends on the countries' development, political commitment and financial capacity. A disease, such as stress or musculoskeletal disorder may be included in a list of occupational diseases in a country while not included in a list of another country. The concept of occupational injuries is usually much better defined as compared to occupational diseases.

Work-relatedness is a gradual component that may vary between obvious and commonly agreed to barely detectable. Often the work-relatedness is measured by the population attributable fraction (AF).

Past studies on work-related illnesses, and often including injuries, have been carried out in several countries, and globally. These have been based on the attributable fraction method and cover a varying number of illnesses and diseases. The AF method is well described by e.g. Nurminen and Karjalainen (Nurminen et al., 2001). Some attributable fractions were modified using values by Rushton (Rushton et al., 2012).

Methods and data sources for the estimates related to fatal outcomes

Methods used in collecting data for the ILO estimates were using sources in addition to ILO, from WHO and Global Burden of Disease (GBD) of the Institute of Health Metrics and Evaluation (IHME). The method and obtained results are explained elsewhere (Hämäläinen, 2010; Lim et al., 2012; Nenonen et al., 2014; Takala et al., 2014a; GBD, 2016). The denominator in fatal injury rates is usually the number of employed persons. However, in other cases, the full labour force or data on the total population by age groups had been used. In many developing

countries, the number of those formally employed is a small fraction of all who work in the country as self-employed, subsistence farmers, and those working in the informal sectors, and were usually not properly captured in the statistics. Globally, the labour force size may also be an underestimate in some countries as large numbers of those below 15 years of age work, starting from as young as under ten years, and a sizable number of those beyond any retirement age must work for survival. The same applies to collecting data on injury incidents.

TABLE I.**Summary of ILO method and data sources**

Estimates of work-related deaths	Methods/ Data Sources
a) Total number of deaths due to work injuries	<p>Number. of fatal injuries reported to the ILO and member States</p> <ul style="list-style-type: none"> - Included fatal injuries, injury rates, work-related traffic fatalities, - suicide, but excluded fatalities via commuting to work and back, - As ILO data includes data from a limited number of countries, those countries where no information was available were grouped in specific regions, such as WHO groups and sub-groups, and fatal injury rates per 100,000 employed of one or several countries that had produced injury rates, were used as proxy values, - To improve the accuracy, separate injury rates were used for 1) agriculture and fishing, 2) industry including construction, and 3) service sector. This balances the potential differences between reporting proxy countries and non-reporting countries.
b) Total number of deaths due to work-related diseases	<p>All-cause mortality data from the World Health Organization</p> <ul style="list-style-type: none"> - Breakdown by diseases and groups of diseases - Breakdown by gender and age groups <p>Applied disease-specific AFs to the all-cause mortality data in 2015.</p> <p>The AFs were largely referenced from the Nurminen (Nurminen et al., 2001) paper, with some replaced by more recent AFs. The reference epidemiological studies and their source industries and occupations to which the AFs were derived were also reviewed. When no systematic data existed from elsewhere on the number and share of exposed workers, figures for similar occupations from Nurminen were used. Certain conditions were applied to exclude non-work-related deaths. For instance, children were excluded by using only deaths between the specific age groups.</p>
c) Total number of intentional injuries due to work	Applied AF in Nurminen 2001 data complemented by that of Rushton (Rushton et al., 2012) to mortality data from WHO
d) Total number of suicides due to work	Applied AF in Nurminen 2001 data complemented by that of Rushton to mortality data from WHO

RESULTS

Overall

An estimated 2.3 million deaths occurred annually across the countries for reasons attributed to work according to ILO estimates. The biggest mortality burden came from work-related diseases, accounting for 2 million deaths whilst the remainders were due to occupational injuries.

The GBD 2015 Study reported 1,086,000 deaths, of which 204,000 from occupational injuries and 882,000 from diseases caused by selected occupational risks. The main reasons for the differences were that the GBD process does not yet count circulatory and cardiovascular, communicable, neuropsychiatric conditions, genitourinary system diseases at work.

Globally, cardiovascular (circulatory) diseases at 35% and cancers at 29% were the top illnesses responsible for 2/3 of deaths from work-related diseases, followed by occupational injuries at 15% and infectious diseases 10%. Occupational cancer counted for 666,000 deaths in 2011 in ILO estimates, and 489,000 by the GBD 2015. The main reason for the difference is that the GBD 2015 study covered selected IARC List 1 – confirmed carcinogens – only while the ILO estimates covered also IARC List 2A cancers – probable carcinogens. There is a slow but gradually increasing trend in the coverage of IARC Lists where probable carcinogens are moved into the confirmed carcinogens list when enough scientific evidence is gathered. For example, diesel exhaust was only recently added to the IARC List Class 1, while the exposures and related cancers had been there for decades earlier.

Industrialized countries (WHO High Income Region) had a higher burden from cancers, at 53% and a much smaller attribution from accidents and infectious conditions each at 3%. This reflects the average life expectancy in the High Income Economies, typically the share of cancers – and work-related cancers – will increase when life expectancy goes up. The African region of WHO had the highest relative share of work-related communicable diseases. The Western Pacific Region estimates are dominated by China and the South East Asian estimates are dominated by India. The European Union estimate for occupational cancer deaths is 103,000. The corresponding number of the GBD 2015 Study was 75,279 deaths based on selected carcinogens. The Dutch National Institute for Public Health and the Environment (RIVM) reported 80,000 deaths caused by chemical carcinogens, while neither covering UV and ionising radiation, specific work processes, shift work nor sedentary work (Jongeneel et al., 2016). Taken the missing components these results would be in the same magnitude as the ILO estimates. The ILO corresponding cancer number for EU28 caused by only hazardous substances in 2011 was 55,600. This was obtained through the EU28 share of all cancers caused by chemical carcinogens globally (ILO, 2014; Nenonen et al., 2014).

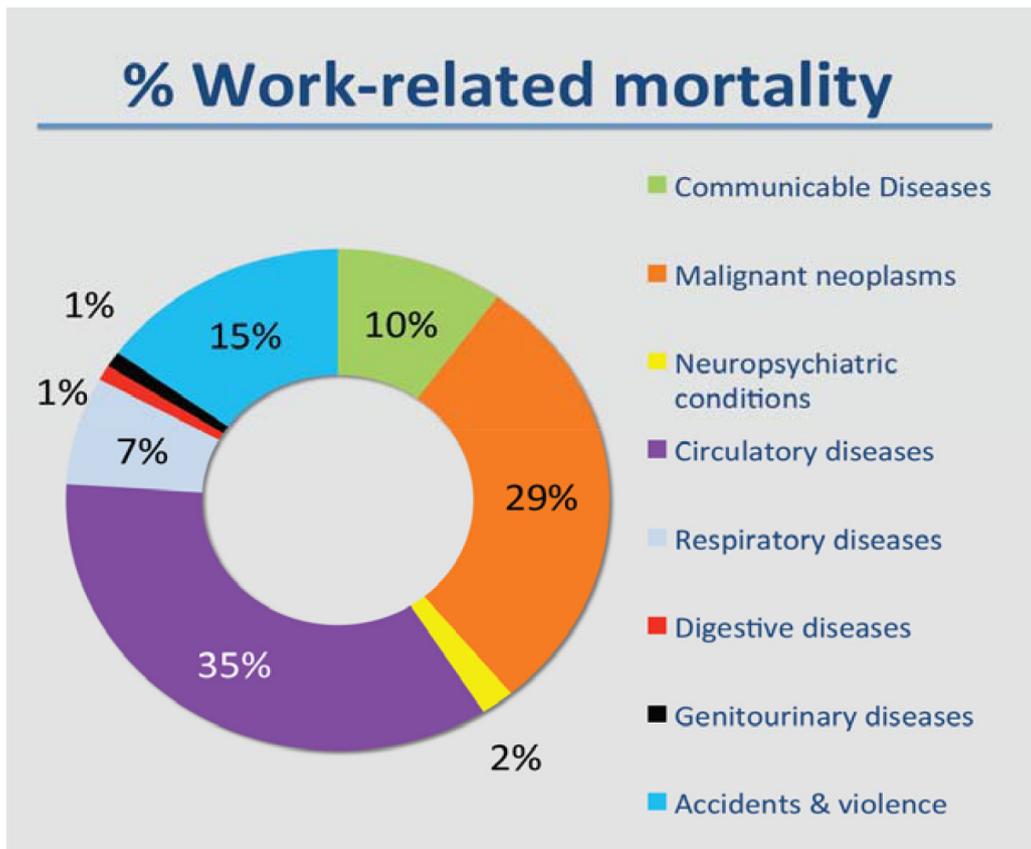


Figure 3. Work-related mortality of the 2014 study, data from years 2010 for injuries (ILO) and 2011 for work-related diseases (WHO)

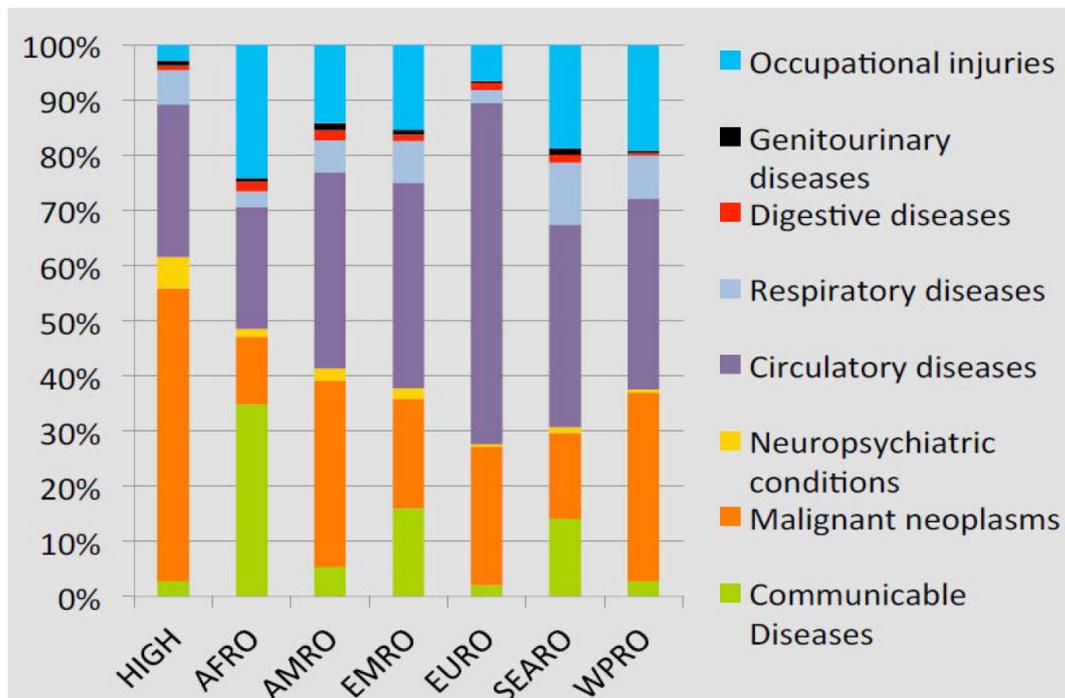


Figure 4. Work-related mortality by WHO regions in 2011

Table II.
Fatal injuries at work (occupational accidents) including and excluding those related to traffic
in selected countries and regions, absolute numbers (N*) and fatal injury rate (N*/100,000)

Year & Type/Area	Singapore ^a	Finland ^b	Germany ^c	Spain ^b	U.K. ^b	EU15 ^b	EU28 ^c	EU28/ ILOadd	China, Gvt 2013 ^d	China, IHME/ GBD 2013	China, ILO 2010 ^d	ILO/ World	GBD/ IHME ^e
Rate, 2011-13, excl. traffic@ work	2.3	0.75	0.94	2.16	0.74	1.39	2.0	2.15				11.0 ⁱ	5.0 ⁱ
N*, 2011 excl. traffic@work	61	26 ^f	194										
N*, 2010-11, incl. traffic@work	80 ^g	28	507	365	~650h	2,910	4,103	4,692	69,434	31,715	99,197	352,800 ⁱ	159,000 ⁱ

^a Singapore WSH Statistics, WSH Institute

^b EUROSTAT numbers referred by the Health and Safety Executive, U.K. web page: <http://www.hse.gov.uk/statistics/pdf/fatalinjuries.pdf> (accessed 11.9.2014), work-related traffic injuries excluded, rate for Finland in year 2013 including work-related traffic was 0.8/100,000 workers, in Singapore 1.8/100,00 in 2014.

^c EUROSTAT Fatal Accidents at Work by Economic Activity 18 July 2014, includes road traffic at work, web page http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Health_and_safety_at_work_statistics (accessed 11.9.2014)

^d See end note references referring to ILO Global Estimates 2014 (Takala et al. 2014; Nenonen et al., 2014), adjusted: includes all employed and road traffic at work, and

^e Government of China (Government of China, 2014) see http://www.stats.gov.cn/english/PressRelease/201402/t20140224_515103.html

^f Institute of Health Metrics, GBD Cause Patterns, Occupational Risks, Rate, Both sexes, Global, web page: <http://vizhub.healthdata.org/gbd-cause-patterns/> (accessed 18.09.2015)

^g Statistics Finland, Official Statistics of Finland (OSF): Occupational accident statistics [e-publication].

ISSN=1797-9544, 2011. Helsinki: Statistics Finland [referred: 11.9.2014].

Access method: http://www.stat.fi/til/itap/2011/2013-11-27_tie_001_en.html and http://www.stat.fi/til/itap/2011/itap_2011_2013-11-27_tau_001.fi.html

^h Work-related traffic fatalities included, seamen and other assigned workers' fatalities excluded, all injuries compensated was 115

ⁱ The Royal Society for the Prevention of Accidents: "Around one third of fatal and serious road crashes involve someone who was at work." In 2012: 1754 road fatalities

altogether; of which 1/3 is more than 500, web page: <http://www.rosipa.com/faqs/detail.aspx?faq=296> (accessed 11.9.2014)

^j For the Global Burden of illness and injuries the denominator is calculated for total population and converted to cover labour force in 2011 (3,200,509,548 million)

Occupational injuries

A more detailed comparison of the injury rates is presented in *Table II*. A wide difference exists in estimates between ILO (ILO, 2014), GBD (Lim et al., 2012) and Chinese Government's own reports (Government of China, 2014). While the numbers of GBD 2015 (GBD, 2015) have gone gradually up – 36,004 deaths in 2015 – it is still far from the Chinese Government's own reports, which are unlikely to be over-reported. It is understood that the Chinese reported deaths do not include the sizable number of subsistence farmers as the reference group, which could increase the number of deaths in China to beyond the ILO estimate.

However, the global number of deaths caused by injury risks or occupational risk factors was 481,429 deaths in GBD 2010, 159,000 in GBD 2013, and 203,677 in GBD 2015 within the global community at work. The ILO estimate has been in the range of 350,000 injury deaths, the latest release from 2014 was 352,769. The latest GBD number appears to be based on raw data from ILO occupational rates from ILO Statistics of which most rates are from industrialized and other “safer” countries due to lack of reporting from most countries – 85 % of the Member States – including the most populous countries in the world. The method on occupational injury estimates used in the GBD process is not easily verifiable and repeatable with present level of data transparency and lack of inclusion and reference population criteria that were used, while the numbers conflict with many officially reported numbers, such as those in China. The GBD 2015 Study would give a rate 2.76/100,000 of full population. This would mean that Portugal has a higher injury risk than India, Austria is riskier than China, and Ireland has a higher injury risk than the average world rate. None of those are likely to be true. Occupational injury risk in many developing countries and sectors is ten to twenty times of those in some of the high income economies.

TABLE III.

Number of estimated deaths in Hungary and the European Union in 2011

Disease or disorder	European Union	Hungary * WHO EURO as reference
Work-related circulatory diseases	53,419	2,639
Work-related cancer	102,527	1,072
Work-related communicable diseases	5,000	86
Respiratory diseases	12,079	102
Other work-related disorders	14,467	87
All work-related diseases	187,492	3,986
Fatal occupational injuries	4,692	96
Total occupational mortality	192,184	4,082

If EU28 is used as a reference there would be 1808 occupational cancers

A full dataset of the study made for the ILO (International Labour Office, 2014) is separately available. Full methodology of the dataset and ILO study is explained in the past papers.

- j Year 2001, see reference (Nurminen et al., 2001), latest 2013 asbestos related 374+106, 16 fatal accidents by wage earners in 2013, 0.75/100,000 workers, includes work-related traffic (Statistics Finland)
- k Year 1997, see reference (Steenland, 2004)
- l Year 2004, see reference (García-Gomez, 2015)
- m 2012-2013, occupational cancer and chronic lung diseases
- n Year 2010 for fatal injuries and 2011 for fatal work-related diseases (ILO)
- o Year 2010 Singapore numbers are separate for resident employed population: 1.85 mill from total employed population 3.09 mill.
- p Year 2010 the road traffic fatalities were not yet officially recorded, hence 55 is excluding them, national data today includes these
- q Year 2010 based on Eurostat
- r Year 2010 Eurostat
- s Year 2013, GBD <http://vizhub.healthdata.org/gbd-compare/> (accessed 2016 11 10), ILO Year 2011. GBD World based on GBD 2015 data. Limited occupational risk factors covered by GBD.
- t Year 2010, denominator: resident employment (1.85 million) + foreign employment = total employment (3.09 million)
- u Year 2013, All tracheal, bronchus and lung cancer deaths attributable to occupational risks was 268 890, total occupational cancer deaths 304,000. Hungary see Table III for cancer deaths
- v Year 2013, All tracheal, bronchus and lung cancer deaths attributable to occupational risks was 268 890, total occupational cancer deaths 304,000. GBD 2015: 488,690 occupational cancer deaths
- w Year 2013, tentative estimate made by authors in 2015, GBD 2015 estimates cover Asbestos Related Lung Cancer (ARLC), Mesothelioma (Mes), All asbestos related occupational deaths (All)
- x Year 2005 USA CDC quoted by Center for Public Integrity, see http://www.icij.org/sites/icij/files/dangersinthedust_1.pdf (accessed 2014 09 15)
- y Year 2013. See reference (Takala, 2005a)
- z Old WHO – ILO estimates, present estimates in Table Vb enclosed, based on WHO and IARC studies.

Detailed comparison of selected work-related illnesses

A summary of the used attributable fractions has been earlier presented by Hämäläinen (2010). A table on “Examples of Attributable Fractions” of the reference paper (Takala et al., 2014a) is a good summary, not reproduced here but hyperlink included in the reference.

Table IV. includes a summary of selected studies and respective countries’ overall fatality data related to the corresponding results.

The estimates for Finland are based on Nurminen and Karjalainen (Nurminen et al., 2001) study. The ILO estimates contain more recent estimates also for Finland.

Singapore estimates have been made by Takala and Yong in 2014 based on 2011 data on fatal occupational injuries and data from 2010 on fatal work related illnesses (Takala and Yong, 2014). There were 115 fatal injuries including compensated work-related traffic ones and those caused for seafarers, but excluding commuting accidents. There were an estimated 1,323 fatal work-related diseases, of which 47% caused by cancer, 33 % by cardiovascular diseases, 7 % by work-related communicable diseases and 6.5% by non-communicable respiratory diseases. Data was obtained from the Ministry of Manpower for injuries and Ministry of Health for diseases (Takala and Yong, 2014b).

United States’ values had been estimated by Steenland (2004). He estimated 19,000 deaths attributable to occupational carcinogens in 1997. His estimate of “all deaths attributable to all occupational hazards” was 55,200 (49,000 due to disease, 6,200 due to injury). Cancer accounted for 39% of occupational disease fatalities.

Spanish estimates were made by Garcia (Garcia et al., 2004) for the year 2004 resulting in 16,000 deaths attributed to work (14,000 men and 2,000 women). The authors noted that due to the lack of proper exposure data in Spain, the attributable fractions (AF) from the Finnish Job Exposure Matrix were used. They stated that it was likely that the Spanish exposures to factors causing work-related illnesses were higher than those in Finland since at the time of the estimation, in 2004, the Finnish fatal injury rate was 1.9 per 100,000 employed and was 3.7 per 100,000 employed in Spain, which reflected the exposure differences for the risks to occupational injuries in both countries.

Estimates for New Zealand have been made by ‘t Mannelje and Pearce (2005) and was based on the year 1999. They used two alternative sets of AFs due to the lack of specific exposure data or a Job Exposure Matrix for New Zealand. The total estimate was between 700 to 1,000 deaths while the authors believed it was an underestimate due to missing data.

The Global Burden of Injury and Illness, GBD’s visualisation provided by the IHME, of the University of Washington is based on the data collected from various sources including WHO, while WHO reports different numbers. However as a whole, the process undertaken for estimating the GBD is documented by a number of high profile publications starting from classic co-publication by the WHO, World Bank and Harvard University of two volumes of the Global Burden of Disease by C. Murray and A. Lopez (Murray et al., 1996). The GBD and the user-friendly presentations by the Institute of Health Metrics and Evaluation, IHME, have provided major steps forward in estimating the overall magnitude for a number of risk factors including a few selected occupational risk factors. The results were reasonably close for selected disease categories and for selected risks when compared to the ILO estimates (ILO, 2014).

While the traditional fatal injury rate per 100,000 employed persons is used by authorities

around the world and by the ILO, it would be more appropriate to use the full labour force numbers in calculating the global rates of health disorders collected using the WHO methodology. Diseases with long latencies may cause deaths well beyond the usual working careers, such as asbestos caused mesothelioma or lung cancer, which may cause a death more than 20 years after the worker retired. This will modify the denominator population from which the deaths are obtained and counted. However, the real population size and the fraction exposed has been much smaller when the actual exposures took place, say 20 to 50 years earlier, due to population growth all over the world. The rate/100,000 population may provide reasonably relevant data for comparative analysis and are better than absolute numbers. In some cases the reference population is the total population.

The GBD-IHME visualisations have listed a limited number of health risk factors causing deaths: key risks are occupational carcinogens, asthmagens, injuries and particulates. The Disability Adjusted Life Years (DALYs) cover a selected number of further risks at work, in particular ergonomic risk factors consisting of low back and neck pain. Many job exposures are still missing, such as further carcinogens, in particular, IARC List 2A Probable carcinogens, and cancer sites, all circulatory diseases at work, psychosocial factors at work and communicable diseases at work. Furthermore, working children, self-employed and subsistence farmers/fishermen are not covered or cannot be identified.

The figures for deaths caused by occupational carcinogens presented in the GBD IHME visualisations in 2015, was reasonably close with those estimates made elsewhere. The ILO global estimate for occupational cancer was 666,000 deaths while the GBD 2015 outcome was 488,691 for the IARC 1 listed carcinogens and in essence largely coming by asbestos related cancer deaths. United States had 32,828 occupational cancer deaths and the United Kingdom, highest in Europe, had 18,326 occupational cancer deaths. The European Union 28 countries (EU28) had altogether 75,279 deaths in GBD 2015 Study, while the ILO estimate was 103,000 and the relatively new RIVM Institute Report on chemical carcinogens only came to 79,700 deaths. A comprehensive 2001 study in Finland resulted in 839 occupational cancer deaths while the IHME latest estimate in 2015 had 649 caused almost exclusively by asbestos. The Finnish Cancer Registry reports that there has been an increasing number of manifestations of mesothelioma, in 2013 there were 106 deaths, and 95 cases in average for some 10 years in a working population of 2.45 million workers in 2007-2011 (Santonen et al., 2014). Some 85% of mesothelioma cases have been compensated while some 65% of all asbestos related diseases have been compensated. In effect, asbestos related lung cancer has a fairly low level of compensation even in developed countries as it is difficult to show that asbestos has been the main cause. Lung cancer forms the biggest component of occupational cancers in practically any country, more than 50% of all occupational cancer cases and deaths were related to lung cancer. Underreporting of the work-relatedness is also expected to be high. Latest information from McCormack et al. (2013) report that chrysotile – the most commonly used asbestos today – causes as many as 6.1 lung cancers in average (a range of 3.6 – 10.5) against one mesothelioma when mesothelioma cases were used as a proxy for asbestos exposure.

Globally, the WHO estimated in the past that there are 107,000 deaths related to occupational exposure to asbestos (WHO, 2014) and the EU/ILO had estimated roughly the same or 112,000 deaths. All lately reported numbers are considerably higher and continue to rise. The GBD 2013 burden data for occupational cancer – mainly caused by asbestos – was 304,000 deaths (Forouzanfar et al., 2013) and the GBD 2015 was 489,000.

The difference between GBD and ILO numbers concerning occupational cancer was most likely caused by

- 1) asbestos related mesothelioma numbers are under-estimated based on latest reports from all reporting countries and WHO data, non-reporting country estimates need thorough reconsideration based on asbestos consumption;
- 2) Asbestos-related lung cancer deaths are still under-estimated when mesothelioma is used as a proxy for asbestos exposure;
- 3) A selected set of carcinogens have been so far used by IHME/GBD, a larger number of further carcinogens, agents such as radon, or carcinogenic processes and jobs, such as welding, need to be covered;
- 4) A selected number of cancer sites and target organs have been used.

Taking these factors into account the two estimates are relatively close. Using the recent global estimate in Tables *VA* and *VB* of 38,400 annual global asbestos-related mesothelioma deaths (Chimed-Ochir et al., 2016) of which 36,400 are work-related based on Rushton's $AF=0.949$ (Rushton et al., 2012), and an estimated 6.77 times the number of mesothelioma deaths for lung cancer deaths or 177,400 asbestos related lung cancer (ARLC) deaths at work. Together ARLC, mesothelioma, ovary and larynx cancers, and asbestosis cause annually between 258,078 (lower estimate using GBD data) and 304,841 deaths (*Table VB* high estimate). Of these some 183,800 – 289,600 are work-related globally, (*Table VB*). Other cancers, such as stomach, colorectal and pharynx cancers may add to the toll.

A full dataset of the study made for the ILO (ILO, 2014) is separately available. Full methodology of the dataset and ILO study is explained in the past papers. (Nenonen et al. 2014; Takala et al, 2014a; Takala, 2005; Hämäläinen et al., 2006; 2007; 2009; Driscoll et al., 2005).

TABLE VA.

Estimated Global Mesothelioma Deaths (Annual N*), based on WHO data

Extrapolation method	Reported Global	Non-reported, adjusted Global	China / EU28
(1) Best estimate, asbestos consumption, adjusted	15,011*	23,377	
(2) Estimates based on asbestos use			
All GBD 2015 and best estimates	32,373 (IHME)	- 38,400 (new)	China: 4,512 (GBD/IHME 2015 all)
Work AFmeso.work=94.9%, (Rush-ton et al., 2012)	22,822 (IHME)	- 36,400 (new)	EU28: 11,404 (GBD/IHME 2015 all)
(3) Reported/Estimated by continent, employment and asbestos adjusted, other EU estimates, all	15,011	21,247 – 23,377	EU: 8,363 (Odgerel, Takahashi et al., 2016), all EU: 10,368 (Takala, 2015), all

* Reported N in 59 countries, estimated M in 172 countries, (Takahashi et al., 2015, Chimed-Ochir et al., 2016)

TABLE VB.

Asbestos related lung cancer and other asbestos related deaths (Takala)

Methods of estimated lung cancer death using mesothelioma as a proxy for asbestos use	Lung cancer / mesothelioma rate	Asbestos related lung, other cancer (and other asbestosis) deaths	
		World	China/EU28
McCormack, Peto et al. (2013) average estimate using chrysotile, lung cancer, all, GBD 2015 Study	6.1	197,475	
McCormack, Peto et al. (2013), low – high estimates, lung cancer, all, GBD	2.0 – 10.0	64,746 – 323,730	
Nurminen, Karjalainen (2001) using mixed fibres, asbestos exposure verified by lung tissue fibre counting, lung cancer, all, GBD	3,525	137,475	
GBD based rate on global asbestos-related lung cancer and mesothelioma at work: 154,601/22,822 = 6.77436, GBD, (2015)	6.77	177,423 _{work} – 283,221 _{work}	based on GBD/IHME 2015 _{work} Area meso/ARLC/Ova/Lary EU28 9,664/56,461/335/440 China 2,477/24,405/294/199 Earth 22,822/154,601/1397/1405
Ovary and larynx cancers, GBD, (2015)		2,802 _{work}	
Asbestosis, GBD, (2015)		3,597 _{work}	
	Global asbestos death, work:	183,822 – 289,621;	Mid-point 236,700
	All asbestos exposed, global:	258,078 – 304,841;	Mid-point 281,500

Asbestos is the cause of some 54-85% of lung cancer globally and lung cancer in turn counts for 54-75 % of all occupational cancer cases. Many of the cancers are hitting predominantly males while breast and ovary cancers at work cause a particular burden to women.

The picture of the burden at work becomes more gender balanced if not just deaths are counted but rather work-related Years of Lost Life (YLL_{work}) and Years Lived with Disability (YLD_{work}). Long term disabilities caused by musculoskeletal and mental disorders are expected to affect the female population (GBD, 2017) more seriously.

Non-fatal injuries and illnesses at work

A common method to identify non-fatal injuries is to use an additional module as a part of labour force surveys carried out regularly in many countries and regions. Based on such surveys where data is obtained through interview surveys or self-reporting households can be also used to estimate the level of under-reporting of official statistics. Countries where the reported rate of non-fatal injuries is high have usually much more minor injuries reported. The results from such surveys on non-fatal injuries and illnesses at work can be summarized as follows:

TABLE VI.

Injuries caused by occupational accidents in selected countries including one day or longer absence (Eurostat, 2009)

Country/Region	Injuries by occupational accidents (% of the workforce)	Work-related ill-health (% of the workforce)
Finland	6.3	24.5
Sweden	5.1	14.3
Denmark	4.9	12.9
France	5.4	-
EU average	3.2	8.6
Hungary	1.0	5.8
Singapore	5.4	10.0

The rate may also be obtained for compensable injuries, which in many countries includes accidents that cause an absence of work for 4 days or more.

The relationship between serious and less serious outcomes of occupational injuries and illnesses

Drawing a combined picture of both lives lost and burden of disabilities needs an accurate picture of the severity distribution of the injury and illness burden. *Figure 5* shows the two pyramids for both injuries (accidents) and illnesses at work.

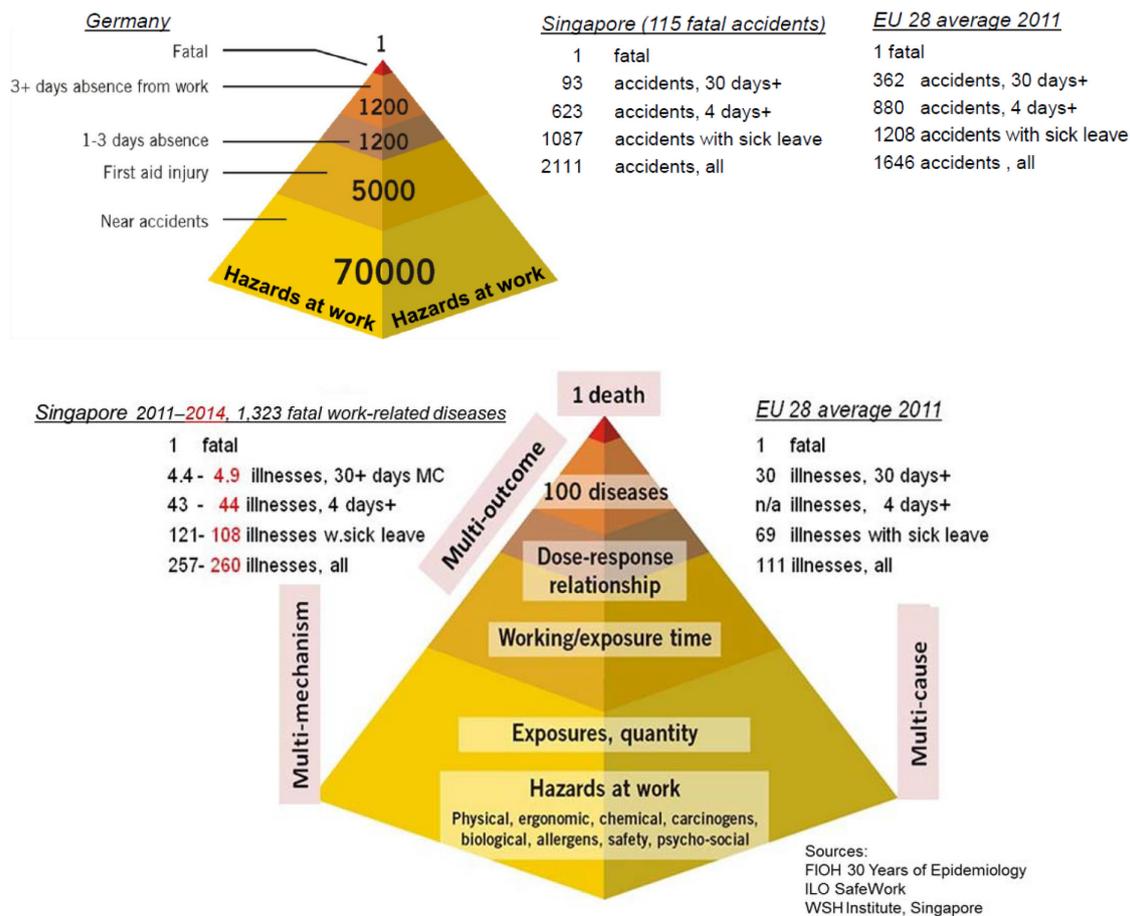


Figure 5. Division of fatal and non-fatal injuries and illnesses in relation to one fatal case in Singapore and selected reference populations, smaller pyramid illustrates occupational injuries and the larger one illnesses.

DISCUSSION

The figures presented may not be the exact true verifiable figures. There are notable differences in various estimates. The GBD 2015 release estimates from the year 2015 exercise point out to generally lower estimates compared to those of the International Labour Office. The most important reasons are the selected coverage of various diseases and disorders. The latest GBD global estimate was 488,000 occupational cancer deaths and 1,086,000 for all selected occupational risks. This is lower than that of 666,000 reported by the ILO on occupational cancer and about a half of all risks identified by the ILO. Major occupational risks remain unreported by the GBD estimate, or reported under risks other than occupational risks, in particular, heart and other circulatory diseases caused by work-related factors, selected cancers, communicable diseases, and work-related fractions of a large number of other diseases. Examples of missing occupational risk factors include shift work, mineral oils, solar radiation, painting, chemical exposures, long working hours, second-hand (environmental) tobacco smoke and engine exhaust for circulatory diseases. Furthermore, most AFs are largely based on data in 2001 when e.g. only 28 of the presently known some 50 cancers were taken into account. IARC lists have been expanded as well. COPD AFs are today known to be clearly higher.

All of these figures point to limited compensation criteria and practices in reporting countries and to under-reporting situations and limited understanding of work-relatedness, especially to deaths due to work-related illnesses in the baseline national data. Fatal injuries are clearly better recognized and reported in developed countries as compared to work-related illnesses. The estimates presented in our tables are influenced by the assumptions taken and limited by the availability and quality of data and evidence available for the AFs used. For example, the lower than expected mesothelioma numbers in many parts of the world may be caused by

- a. Under-diagnosing, misdiagnosing and non-diagnosing of the disease. Without proper knowledge and investigation measures based on proper (Helsinki) criteria this is easy to misclassify. The symptoms may not be distinguished from those of lung cancer. Even many EU countries, such as Spain and Bulgaria have had a poor record of mesothelioma cases, 93-99% under-reporting so very few are reported/compensated (Garcia-Gomez et al., 2015; Vangelova et al., 2016).
- b. In the developing world asbestos use started late, clearly later than in Europe, USA and Japan. In Singapore the peak is expected to be some ten years later than in Western countries and Australia/New Zealand. As a result the diseases and deaths are just now appearing and increasing.
- c. Due to b) above practically all asbestos used has been chrysotile resulting into relatively less mesothelioma cases and consequently much higher number of lung cancers.
- d. Some exposed workers may have been moving from the country of exposure and may not be aware of the exposures earlier in their working life.

Another comparison related to occupational cancer could be made between selected countries, see *Table VII*.

TABLE VII.

Comparing countries and regions based on workforce and work-related cancer deaths

Country/Region	Workforce	Fatal occupational cancers (source)	
United Kingdom	31.4 million	8,010	(Rushton)
Finland	2.7 million	839	(Nurminen, Karjalainen)
Singapore	3.1 million	627	(Takala, Yong)
Hungary	4.3 million	1,072	(this paper)
EU28	247 million	103,000	(this paper)
China	821 million	173,392	(this paper)

No age adjustment has been carried out due to absolute numbers. This reduces comparability. Furthermore, there has been a smaller workforce in every country/region during past exposure periods. Workforce numbers are all from the year 2010, expecting that the occupational cancer deaths have not gone up in the U.K. and Finland while estimates are based on earlier and not exactly the same years. In reality, cancers and occupational cancers increase continuously due to ageing workforce, population growth and decreasing number of disease deaths from more acute and elementary sources, such as injuries and communicable diseases.

Detailed exposure data in the form of job exposure matrix (JEM) would definitely make the results more accurate and effort in this direction are being made in Singapore, in particular, for carcinogens in building and maritime sectors that are the major exposed groups. While details of exposures are not systematically available, it is expected that exposures are not radically different from equal jobs in other developed countries for most jobs. The processes, procedures, working methods, tools and machinery are evolving in parallel to other developed countries. Service occupations are not different in Singapore from those in Finland and the U.K.

The human metabolic reactions to exposures and related negative outcomes are unlikely to be different if jobs and exposures are comparable all over the world. The possible differences in estimating exposures and the number of exposed workers, however, include the size of various economic sectors, such as the construction sector. Furthermore climate makes a difference. More could also be done to obtain Asian-based epidemiological evidence for risk estimates of exposures and outcomes. The attributable fractions (AF) referenced, while commonly cited and used widely in related studies, could be confounded by their underlying research populations and reference economies. An example is the AF used for females in communicable diseases, at 32.5, which was influenced by a study on tuberculosis (TB) cases among healthcare professionals in Finland. As TB incidence in Finland is very much lower (at <10 per 100,000) than Singapore's 40.9 per 100,000 (Ministry of Health Singapore, 2012) the outcomes observed and inferences made in the Finnish study may point to occupational exposures, but the case may not be so clear for Singapore's healthcare professionals. Equally malaria cases in Finland are predominantly work-related due to Finnish worker population exposures in various jobs in endemic areas of developing countries. The exposure conditions in Singapore may be different.

As such, there lie opportunities for further regional epidemiological research, education and communication of "invisible deaths", and to advocate more strongly for prevention measures and actions to be taken to protect the occupational health of the workforce. Furthermore, reliable data is not available from most economies in the world, which makes also global comparisons difficult. As a result the estimates vary widely from each other. For example, the number of injuries has been announced in China by the Government and other estimates are given for comparison:

69,434 deaths reported by Chinese authorities for 2013 (Government of China, 2014) while the size of the reference population is not clear;

31,715 deaths by IHME in 2013, which appears to be based on the average reported sectoral ILO Statistics of deaths/100,000 (GBD, 2015b). The reporting countries are mostly industrialized ones and this number would indicate that China's fatal accident rate is at the same magnitude level as that of USA or Austria, see <http://www.ilo.org/ilostat> (accessed 15 Dec 2015);

99, 197 by the ILO in 2010, based on ILO Statistics, sectoral details and proxy accident rates, when no data provided by countries to ILO, see dataset separately available and references (Lim et al., 2014; Hämäläinen et al. 2014; ILO, 2014). It is likely that the difference between ILO estimates and the Chinese own statistics may be originated by the large rural agricultural labour force – often self-employed and self-sustaining

farmers – that has been taken into account in the ILO study, while not usually covered by compensation and statistics in most countries.

These deviations of different estimates are likely to be cross-cutting through many or most countries in the world. For example, the United Kingdom does not record occupational injuries in work-related road traffic, and such numbers need to be estimated. There are also a number of groups differently covered, such as defence forces (in peaceful jobs), uniformed workers, subsistence farmers, seamen and fishermen on-board ships and vessels, dispatched workers working for an enterprise or organization located in one country, but the actual workplace is located elsewhere in another country. Informal sector is not covered at all by definition and the size of grey economy varies widely.

For work-related illnesses there are also uncertainties. While the ad hoc household or self-reporting surveys should cover all groups uniformly, the understanding of work-relatedness by survey respondents is affected by the compensation criteria in a country, which in turn varies widely between the EU member States, and even more globally. Ideally, the household survey results could be validated by official records while that can be done only in a very limited number of countries reliably due to limited official records. The reference populations do not generally cover younger than 25 years and over 75 years age groups leaving out the more than hundred million child workers and those who have to work at advanced ages.

Better knowledge of recognising and diagnosing work-related diseases and placing emphasis on reporting, recording and registering occupational injuries and diseases would need a major effort in most countries globally.

While the attributable fractions are expected to be similar for many economic sectors and jobs, conditions are never the same even in the same country. The technological processes and human metabolism are not much different, but questions of open air production in tropical circumstances or winter conditions in temperate climate countries have an impact on outdoor exposure qualities and quantities. Salary level and, methods of payment, cultures of various groups, have favoured labour intensive processes in certain sectors instead of mechanization and prefabrication. The use of higher number of unskilled workers increases also the number of those exposed as compared to countries with high worker remuneration levels.

Nevertheless, we consider that such comparisons are useful for identifying the magnitude of exposures resulting in serious outcomes. The question is not whether the numbers presented are exactly correct or the number of deaths is 10-20% higher or lower, rather we should consider whether these identified problems are sufficiently big to start considering better methods to eliminate and reduce exposures to various hazards. Traditionally, injuries are more easily identified and their causes detected than illnesses. Long latency diseases and disorders make it difficult to link the original exposures and causes of the problems to the disease or disorder.

We also propose to start recording and calculating the Years of Lost Life at work (YLLwork), Years Lived with Disability (YLDwork) and Disability adjusted Life Years (DALYwork) at work

in addition to just counting the numbers of deaths, diseases and injuries. When concentrating only on serious and immediate problems, debilitating other problems may be poorly identified even though their prevalence could be high and consequences serious in terms of long absences from work, reduced workability, and early retirement due to disability. Back pain and other musculoskeletal problems and stress-related psychosocial factors are likely to be major burden to the workforce and the economy.

CONCLUSIONS

The number of deaths caused by work-related illnesses is more than ten times that of deaths caused by occupational injuries in most countries in the world. The scale of these numbers is nevertheless far too high and, moreover, preventable with present day methods. While this often reflects the historical exposures in the past, much remains to be done to further eliminate and reduce such exposures today. Better and more systematic exposure knowledge is the next step in that direction. Immediately, more emphasis on a level playing field is needed. Improved compensation and insurance systems will create interest and incentive to eliminate the risks, as that will place companies, organizations, economic sectors and countries on a more equal footing. Competent risk assessment would provide not just better data but is a key for risk prevention. Those companies and organizations creating high risks need to be held accountable for providing preventive measures and for covering the high compensation costs. A Vision Zero and Zero Harm mindset and a comprehensive view of creating and maintaining a healthy workforce in a safe workplace for the whole working life is the goal.

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