Estimating the Global Burden of Low Back Pain Attributable to Combined Occupational Exposures

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Background *There is little information about the global burden of non-traumatic low back pain (LBP) attributable to the effects of physical and psychosocial occupational stressors.*
Methods *Based on a review of the epidemiological evidence, occupation-specific relative risks were used to compute attributable proportions by age, gender, and geographical sub-region for the economically active population aged 15 and older. The reference group was professional/administrative workers; other risk categories were Low, clerical and sales; Moderate, operators (production workers) and service; and High, farmers.*
Results *Worldwide, 37% of LBP was attributed to occupation, with twofold variation across regions. The attributable proportion was higher for men than women, because of higher participation in the labor force and in occupations with heavy lifting or whole-body vibration. Work-related LBP was estimated to cause 818,000 disability-adjusted life years lost annually.*
Conclusions *Occupational exposures to ergonomic stressors represent a substantial source of preventable back pain. Specific research on children is needed to quantify the global burden of disease due to child labor.* Am. J. Ind. Med. 48:459–469, 2005.
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KEY WORDS: back pain; ergonomics; global burden of disease; human factors; musculoskeletal disorders; psychosocial; risk assessment; risk factors; work-related disease

INTRODUCTION

Pain in the soft tissues of the back is extremely common among adults. In the United States, the National Arthritis Data Workgroup reviewed national survey data showing that each year some 15% of adults report frequent back pain or pain lasting more than 2 weeks [Lawrence et al., 1998]. Back pain is widespread in many countries, and is associated with substantial financial costs and loss of quality of life. In Canada, Finland, and the United States, more people are disabled from working as a result of musculoskeletal disorders (MSDs), especially back pain, than from any other group of diseases [Badley et al., 1994; Riihimäki, 1995; Battié and Videman, 1997; Bernard, 1997]. MSDs constitute

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a major proportion of all registered and/or compensable work-related diseases in many countries, representing a third or more of all registered occupational diseases in North America, the Nordic countries, and Japan.

The physical ergonomic features of work that are most frequently cited as MSD risk factors include rapid work pace and repetitive motion patterns; insufficient recovery time; heavy lifting and other forceful manual exertions; non-neutral body postures (either dynamic or static); mechanical pressure concentrations; vibration (both segmental and whole-body); and low temperature. Many reviewers from the United States, Canada, Europe, and Asia have reached similar conclusions regarding the etiologic importance of these exposures for low back disorders [Hulshof and Veldhuijzen van Zanten, 1987; Jensen, 1988; Johanning et al., 1991; Riihimäki, 1991, 1995; Garg, 1992; Hagberg et al., 1993, 1995; Wikström et al., 1994; Frank et al., 1996; Hales and Bernard, 1996; ICOH et al., 1996; Bernard, 1997; Burdorf and Sorock, 1997; Viikari-Juntura, 1997; Gordon and Weinstein, 1998; Lagerström et al., 1998; Hoogendorn et al., 1999; Nachemson, 1999; Jin et al., 2000; National Research Council, the Institute of Medicine, 2001]. Psychosocial factors may also play a role, although the evidence for these is less conclusive to date. Despite this extensive literature, some still dispute, the evidence for physical workload, especially in relation to non-occupational causes [e.g., Battié and Bigos, 1991; Waddell, 1991; Nachemson, 1999]. Reasons for the continuing controversy have been discussed elsewhere [Frank et al., 1995, 1996; Viikari-Juntura and Riihimäki, 1999; National Research Council, the Institute of Medicine, 2001; Punnett and Wegman, 2004].

Low back pain was identified by the Pan American Health Organization as one of the top three occupational health problems to be targeted by surveillance within the WHO Region of the Americas [Choi et al., 2001]. To prioritize prevention efforts appropriately worldwide, information on the burden caused by occupational exposure to physical and psychosocial stressors would be useful. Guo et al. [1995] estimated that 65% of low back pain cases in the United States are attributable to the combined effects of the occupational exposures listed above. To date, no other estimates of the fraction of back pain in the total population that is occupationally induced have been identified. Thus, the analyses described here sought to quantify the global burden of work-related low back disorders. Two companion studies in this issue address the costs and benefits of interventions to reduce ergonomic stressors at work [Lahiri et al., 2005a,b].

MATERIALS AND METHODS

Basic Methodology and Population

This comparative risk assessment (CRA) exposure assessment was conducted using the overall methodology developed estimating the global burden of occupational disease and injury [Concha-Barrientos et al., 2004; Nelson et al., 2005]. The age- and gender-specific distribution of the workforce aged 15 or older in each occupational group, as compiled by the International Labour Organization and the World Bank, was categorized by sub-region and adjusted by the economic activity rate (EAR) to generate the denominator for these analyses [see Nelson et al., 2005].

In the absence of data on worldwide prevalence of all relevant physical and psychosocial exposures, we used broad occupational category as a proxy for exposure to the combined stressors that produce excess risk of low back pain. Estimates of relative risk by age, sex, region, and exposure category were applied to compute stratum-specific attributable proportions; multiplying these by persons at risk gave numbers of cases, which could then be summed across strata for estimation of the global attributable proportion. The same fractions for each age-sex-region stratum were applied to the total of disability-adjusted life years (DALYs) caused by low back pain.

Definition of Outcome

Low back pain (LBP) was defined as any ‘‘non-traumatic musculoskeletal disorder affecting the low back.’’ It included all back pain, regardless of diagnosis, that was not secondary to another disease or injury cause (e.g., cancer or motor vehicle accident). It included lumbar disk problems (displacement, rupture) and sciatica but excluded cervical spine problems, such as neck pain or neck torsion problems.

Exposure Categories

Reviews of low back pain epidemiology have implicated an overlapping set of occupational exposures such as lifting, forceful movements, awkward postures, whole-body vibration, and perhaps psychosocial stressors. However, such exposures are rarely assessed in surveillance activities on a large scale, and thus data are not available for risk assessment calculations at the global level. An alternative strategy was applied for this assessment, using occupation as a proxy for specific combinations of physical and psychosocial stressors.

The reference group (background risk) was comprised of professional and administrative workers. The other risk categories were defined as follows:

Low exposure, clerical and sales workers;

Moderate exposure, operators (production workers) and service workers;

High exposure, farmers.

This method thus required the assumption that the distribution of the combined individual risk factors (psychosocial as well as physical exposures) is similar within each occupational group across geographical regions. It also assumed that the relative risks among occupational groups

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were stable across studies, although this assumption could be examined directly in available published reports (see below).

For low back pain, ''theoretical minimum risk'' was considered to represent the level of disease that would occur in the population if all excessive physical workload were abated by effective implementation of ergonomic control measures. This would be equivalent to the achievement of relative risks of 1.0 in each occupational group.

Relative Risk of LBP by Exposure Category: Data sources

Electronic literature searches were conducted in MEDLINE and the WHO Regional libraries, and published statistics of national occupational health and safety institutes were consulted. Epidemiologic studies published between 1985 and 2001 were sought that compared the risk of low back pain among the occupational groups specified above (by odds ratio, prevalence ratio, or incidence ratio) and comprehensively enough to cover the range of occupations within each group. Smaller, more specific studies limited to relatively narrow occupational groups (e.g., nurses, dockers, drivers) were checked for consistency with the more comprehensive data sets. Studies where the reference groups were engaged in substantial physical activity (e.g., house painters) were excluded. In addition, reviews and studies were identified that might provide evidence to support or contest the selected approach.

Statistical Analysis

Occupation-specific estimates of relative risk for LBP were applied to compute stratum-specific attributable fractions, for each WHO subregion, age group, and gender. These were weighted by population to determine the regional attributable proportion. Applying the same attributable fractions for each age-sex category to the disability-adjusted life years (DALYs) for LBP experienced by that category yielded estimates of attributable DALYs for each sub-region.

Unlike the global burden analyses of other conditions, the effect of occupational turnover was not utilized in estimating the numbers of workers exposed to ergonomic stressors, as the latent effects could not be quantified (see Discussion).

RESULTS

Relative Risks of Low Back Pain by Occupational Group

Leigh and Sheetz [1989] measured low back pain on the basis of a national survey and a self-reported statement regarding ''trouble with back or pain during the last year.'' They estimated relative risks (RRs) by comparing the outcome frequency among occupational groups, using managers as a reference group (Table I). This study was relatively large (n = 1,404), covered a comprehensive sample of occupations, and involved statistical adjustment for numerous potential confounders (sex, race, height, smoking, etc.). Thus, despite some methodological limitations, it became the primary basis for the statistical computations of global burden. Its findings were checked for consistency with the body of evidence on work-related back pain and its values adapted slightly to reflect the overall evidence (see below). Operators and service workers had very similar estimated relative risks so these were averaged to form a ''moderate'' exposure category, even though intervention strategies would differ between these two occupational groups.

Within the limits of the available literature, the relative risks reported by Leigh and Sheetz [1989] appeared to be generally consistent with other reported values (Table II). The most comparable study (managers as the reference group, adjusted for confounders) was that by Leino-Arjas et al. [1998]. The values for office workers and for manual workers were quite similar; however, the relative risk for farmers was lower (2.13) than the value put forward by Leigh and Sheetz (5.17). To be conservative in the CRA, we used the average of these two values, or a relative risk of 3.65 (Table I).

Since many other studies used office workers or other sedentary occupations as the reference group, an additional computation was needed to compare their findings with those

TABLE I. Relative Risks of Low Back Pain for Broad Occupational Categories and for Final Exposure Categories Used in Comparative Risk Assessment (CRA)

Occupational category	Relative risk (95% CI)[a]	Exposure category used in CRA	Relative risk (95% CI)
Managers and professionals	1.00 (NA)	Background	1.00
Clerical or sales worker	1.38 (0.85–2.25)	Low	1.38
Operators	2.39 (1.09–5.25)	Moderate	2.53
Service workers	2.67 (1.26–5.69)		
Farmers	5.17 (1.57–17.0)	High	3.65

[a]Based on data from Leigh and Sheetz [1989].

TABLE II. Relative Risks of Occupational Groups by Occupational Category

Occupational category	Leigh and Sheetz [1989][a]	Astrand [1987]	Bongers et al. [1990]	Bovenzi and Betta [1994]	Burdorf et al. [1993]	Hildebrandt [1995]	Johanning [1991]; Johanning et al. [1991]	Magnusson et al. [1996]	Partridge and Duthie [1968]	Riihimäki et al. [1989]	Riihimäki et al. [1994]	Videman et al. [1990]	Burchfiel et al. [1992]	Ozguler et al. [2000]	Joshi et al. [2001]	Guo et al. [1995] (female only)[b]	Morken et al. [2000]	Leino-Arjas et al. [1998] (male only)[b]
	Source (first author and citation)																	
Managers and professionals	1.00/—																	1.00
Professionals													1.00					
Managers													1.80					
Teachers																(1.2)		
Clerical or sales workers	1.38/1.00																	
Office workers (sedentary)				1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	0.89	1.00	1.00		1.00	1.35
Clerks		1.00																
Air force officers			1.00															
Civil servants									1.00									
Sales													1.10					
Operators	2.39/1.73						3.90			1.0–1.5	1.40		1.10		1.83		1.80	
Construction laborers																2.10		
Manual workers		2.28										3.60	1.49					1.84
Pilots and aircrew			9.00															
Drivers (bus, truck, tractor)				1.83–5.49	2.51	1.32		1.55–2.10				2.90				2.00		
Crane operators					3.29													
Dockers									1.27									
Plumbers						1.32										1.70		
Carpenters											1.50					2.10		
Technicians													1.20		1.59			
Assembly, packing, food processing															1.73			
Automobile mechanics																1.80		
Maintenance															1.59	1.70		
Service workers	2.67/1.93												1.03					
Airport registration workers														0.86				
Hospital workers														1.13				
Warehouse workers														0.54				
Stock handlers baggers																1.70		
Janitors, cleaners																(2.0)		
Waitresses																(1.6)		
Nurses																(1.5)		
Farmers	5.17/3.75															1.80		2.13

[a]Relative risks by occupational category. The second set of relative risk values was estimated using clerical/sales jobs as the reference group, for comparison with other studies in which these also comprised the reference group.
[b]Compared to reference values for all male or all female workers.

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of Leigh and Sheetz [1989]. This involved dividing the Leigh relative risks for categories 3, 4, and 5 by 1.38 (the RR for clerical or sales work), in order to estimate the relative risk with clerical jobs as the reference group. The new values were 1.73, 1.93, and 3.75, respectively (Table II). Keeping in mind that these estimates represent the average values for the entire occupational category, it can be seen that the other studies cited fall within the CIs, with very few exceptions, and in fact generally have similar point estimates. For example, Morken et al. [2000] conducted a questionnaire survey of 5,654 people working at light aluminum smelting plants across Norway in 1998. Operators suffered more low back pain than office workers, with an odds ratio of 1.8 (95% confidence interval 1.5–2.1). A total of 18 studies (including Morken) compared specified types of operators to clerical workers; the average of 33 relative risks from these studies provided a RR of 1.9. This agreed rather closely with Leigh and Sheetz's estimate of 1.73 for operators compared with clerical or sales workers.

Also available were administrative statistics from three different countries on the annual number of cases of work-related back conditions. These were compiled from employer reports of work-related injuries in the United States (Bureau of Labor Statistics 2001), compensation statistics for the Australian workforce (National Occupational Health and Safety Commission 2001), and statistics for the German national workforce (Bundesverband der Betriebskrankenkassen 2001). These data could be used to estimate rates for certain occupational groups in comparison with Table III. LBP rates were consistently lowest for managers and professionals. The point estimates for other occupations varied somewhat. None of these frequency estimates could be adjusted for potential confounding variables. The rates were lower overall than those assessed by population surveys. The incidents assessed in the first two data sets were limited to cases recognized as work-related and resulting in absence from work or a claim for compensation. In contrast, the German study sought to assess the health status of the population more comprehensively and these data are, therefore, likely to be more comparable to those reported by Leigh and Sheetz. In fact, the values were relatively close to the final CRA values shown in Table I.

TABLE III. Relative Risks of Occupational Conditions Involving the Back, by Occupational Title, Compared to Managers and Professionals, From Three Sets of National Surveillance Data

Occupational group[a]	Relative risk for back conditions		
	USA[b]	Australia[c]	Germany[d]
Managers and professionals	1.0	1.0	1.0
Technical, sales, and administrative support	2.2	—[e]	—
Clerks	—	1.1	1.5
Sales and service workers	—	2.2	2.9
Service workers	7.4	—	—
Tradespersons	—	5.5	—
Operators and farmers	—	8.8	—
Operators	9.1	—	2.4
Farmers, fishermen, and forestry workers	4.3	—	3.6

[a]Owing to different classification systems among the countries, some rows (occupational groups) are subsets of other rows. In particular, the Australian term "tradesperson" likely includes occupations grouped elsewhere as operators, service, and possibly farmers.
[b]U.S. Bureau of Labor Statistics, 2001: Nonfatal occupational injuries and illnesses involving days away from work, for injuries involving the back.
[c]National Occupational Health and Safety Commission, 2001: Conditions affecting the upper and lower back.
[d]Bundesverband der Betriebskrankenkassen, 2001: Musculoskeletal illnesses of the lower back.
[e]No data available.

Attributable Proportion of Low Back Pain

Generally, men had higher exposure due to higher rates of participation in the labor force. The participation of women in the labor force was particularly low in eastern Mediterranean regions B and D. Exposures were higher in the less developed regions because of a higher proportion of workers in agriculture than in the developed regions. Over one-half of the working populations of African regions D and E and SEAR D worked in agriculture [Concha-Barrientos et al., 2004; Nelson et al., 2005]. In contrast, about one-third of the total American and European workforce was in production occupations ("operators") and another large fraction (40% or more) in professional, sales, and clerical jobs. More specifically, farmers were 54% of the male work force in SEAR D, 21% in Europe C, but only 5% in America A. In contrast, operators were 30% of male workers in SEAR D, 54% in Europe C, 30% and 42% in America A.

Globally, 37% of low back pain was deemed attributable to occupational risk factors. The proportion varied somewhat among regions (21–41%) and was generally higher in those regions with lower overall health status, that is, groups B through E compared with A (Table IV and Fig. 1). The highest attributable fractions, around 40%, were reached in European regions B and C, South-East Asian regions B and D, and Western Pacific region B.

Differences by age groups were quite small. The attributable fraction in men (41%) was higher than in women (32%), because of men's higher participation in the labor force and in occupations with heavy physical workload, material handling, and whole-body vibration. The gender difference was most pronounced in the eastern Mediterranean region, where women's participation in the labor force is quite low, and in the less developed countries of the Americas. The attributable fraction was lower for men as

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TABLE IV. Attributable Fraction (%) of Low Back Pain Due to Occupational Ergonomic Stressors by Sex, Age Group, and WHO Sub-Region

	15–29		30–44		45–59		60–69		70–79		80+		Total		
Region	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**All**
Afr D	59	51	65	56	64	56	62	50	48	30	23	13	36	29	33
Afr E	59	56	65	59	64	58	62	52	48	35	24	15	36	31	33
Amr A	38	31	44	36	43	33	30	18	8	4	3	1	35	25	30
Amr B	51	34	56	37	54	30	47	18	25	6	10	2	41	23	33
Amr D	44	27	52	32	51	28	49	22	33	11	14	4	34	18	27
Emr B	43	22	52	24	51	18	45	13	27	5	11	2	31	12	22
Emr D	54	43	61	47	60	43	55	34	35	15	15	6	36	25	31
Eur A	36	29	45	34	42	28	23	9	3	1	1	0	34	22	29
Eur B	52	49	60	57	55	51	39	29	20	14	8	5	43	37	40
Eur C	51	44	58	55	56	49	30	18	11	5	4	2	45	36	41
Sear B	56	48	63	54	62	52	56	42	37	21	16	8	43	34	39
Sear D	60	51	65	57	65	54	58	43	43	22	20	9	43	34	38
Wpr A	38	32	47	37	46	36	38	23	17	7	6	3	38	27	33
Wpr B	58	55	62	58	61	51	51	31	27	10	11	3	44	38	41
World	55	47	59	52	58	46	47	30	25	10	9	3	41	32	37

well as women in EMR-B, reflecting regional variation in economic activity rates [Nelson et al., 2005].

Attributable Proportion of Disability

Low back pain does not directly produce premature mortality but causes substantial disability and has potentially severe societal consequences, particularly when workers suffer the outcomes at an early age. Combined occupational ergonomic stressors were estimated to cause 818,000 DALYs lost from LBP in the year 2000. Again, the estimates were about 50% higher for men than women (Table V and Fig. 2)

Among regions, the highest values were found in the South-East Asian regions, European regions B and C, and Western Pacific region B. Again, these values reflect the high proportions of the working population in the occupational categories of operator and, especially, farmer. In absolute terms, more DALYs were lost in South-East Asia and Western Pacific D, as these are by far the most populated regions. In per capita terms, the regions with highest loss of DALYs were the same as those with the highest attributable fractions.

DISCUSSION

Worldwide, 37% of low back pain was deemed attributable to occupational risk factors. The fraction varied somewhat among regions (21–41%) and was higher in areas

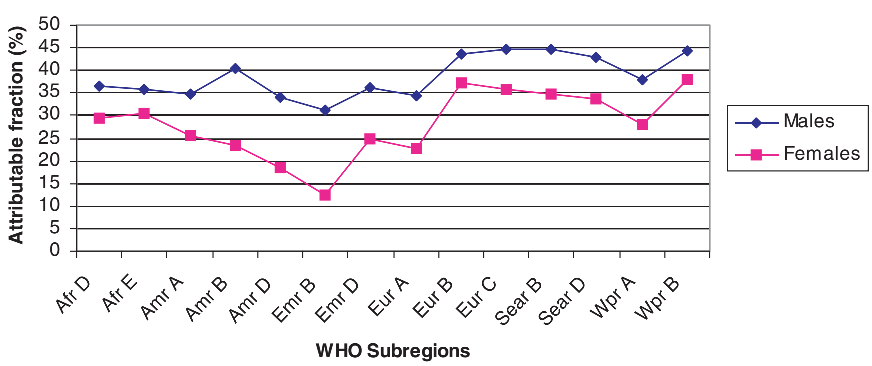

FIGURE 1. Attributable fractions (%) of LBP due to ergonomic stressors, by region[a] and gender. [a]AFR, Africa; AMR, Americas; EMR, Eastern Mediterranean; EUR, Europe; SEAR, South-East Asia; WPR, Western Pacific. **A**: Very low child, very low adult mortality; (**B**) Low child, low adult mortality; (**C**) Low child, high adult mortality; (**D**) High child, high adult mortality; (**E**) High child, very high adult mortality.

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TABLE V. Attributable DALYS* (in Thousands) of Low Back Pain Due to Occupational Ergonomic Stressors by Sex, Age Group, and WHO Sub-Region

	15–29		30–44		45–59		60–69		70–79		80+		Total		
Region	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**All**
Afr D	9	6	6	6	4	3	1	1	0	0	0	0	21	16	37
Afr E	11	8	8	8	5	4	1	1	0	0	D	0	25	20	45
Amr A	3	2	8	4	5	3	1	0	0	0	0	0	17	10	27
Amr B	11	5	14	7	6	3	1	0	0	0	0	0	32	15	47
Amr D	2	1	2	1	1	0	0	0	0	0	D	0	4	2	6
Emr B	3	1	3	1	2	1	0	0	0	0	0	0	9	3	12
Emr D	10	6	8	G	6	3	1	1	0	0	0	0	25	16	41
Eur A	4	2	10	5	6	4	1	0	0	0	0	0	21	11	32
Eur B	5	3	8	5	4	3	1	1	0	0	0	0	18	12	30
Eur C	5	3	10	6	5	4	1	1	0	0	0	0	21	14	34
Sear B	9	6	9	6	6	4	1	1	0	0	0	0	26	19	46
Sear D	41	23	37	33	26	18	5	4	1	1	0	0	111	78	189
Wpr A	2	1	3	2	3	2	1	0	0	0	0	0	9	5	14
Wpr B	45	29	53	51	39	26	8	4	1	0	0	0	146	110	256
World	162	95	179	143	117	80	23	14	4	2	0	0	485	333	818

*Disability-adjusted life years.

with lower health status in general. Regional differences were driven by the labor force participation rate and the population distribution of occupations, especially the proportion of farmers. In each region, the attributable risk fraction was higher for men than for women, largely because of men's higher participation in the labor force and in occupations with heavy lifting and whole-body vibration. Low back pain does not directly produce premature mortality but causes substantial disability and has potentially severe societal consequences. Combined occupational ergonomic stressors were estimated to cause 818,000 DALYs lost annually from LBP.

Although the present analysis was limited to low back pain, the evidence on MSDs caused by occupational ergonomic stressors is broader. MSDs affecting the neck and the upper and lower limbs result from the same risk factors as are implicated in low back pain [Hagberg et al., 1995; Hales and Bernard, 1996; Bernard, 1997; Malchaire et al., 2001; National Research Council, the Institute of Medicine, 2001]. Also excluded here are other

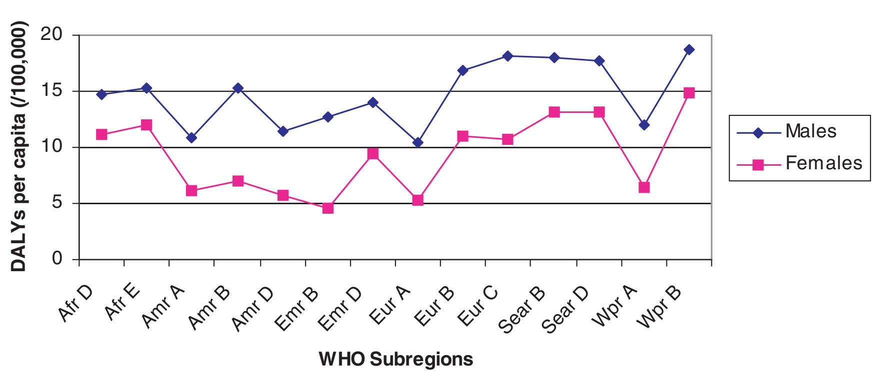

FIGURE 2. Disability-adjusted life years (DALYs) from LBP attributable to ergonomic stressors, per 100,000 people, by region[a] and gender. [a]AFR, Africa; AMR, Americas; EMR, Eastern Mediterranean; EUR, Europe; SEAR, South-East Asia; WPR, Western Pacific. **A**: Very low child, very low adult mortality; (**B**) Low child, low adult mortality; (**C**) Low child, high adult mortality; (**D**) High child, high adult mortality; (**E**) High child, very high adult mortality.

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types of health effect related to ergonomic stressors, such as acute workplace injuries, cardiovascular disease, mental health, and adverse reproductive effects [Punnett, 2002].

These results are derived from occupation-specific relative risks, in the context of substantial epidemiologic and experimental literature on the exposure-response relationships between LBP and specific occupational exposures. Similar exposures have been implicated across sectors of the economy and around the world, wherever the LBP problem has been studied. Internationally, there is broad (but not universal) agreement that among people occupationally exposed to ergonomic stressors, an important proportion of MSD morbidity results from those exposures.

This analysis may be subject to several sources of error, stemming both from the methods used and the available evidence on work-related back pain. Regarding the methodology, each occupation was taken to represent the combination of specific exposures typically found in that job setting. Although there is substantial evidence of inter-occupational differences in exposures, this approach is assumed to reflect the effects of average risks within each broad occupational category and is justified by similar relative risks being reported by numerous epidemiologic studies. This assumption may, however, introduce an error when transposing the risk values to the various geographical regions, as the risks within each occupational category may vary. In particular, different degrees of mechanization, general working conditions, or ergonomic interventions may vary across regions. The limited evidence available that allowed comparisons across regions did show some variations, but no general trend according to degree of development [Kuwashima et al., 1997; Volinn, 1997; Jin et al., 2000] (summary in Table VI). To the extent that there are unmeasured geographical differences in exposures within occupational category, it is most likely that physical workload is higher in less developed countries. Since the risk estimates were mostly derived from studies of developed countries, this would lead to an underestimate of attributable risk in a majority of geographical regions.

The distribution of workers into occupational categories was based on employment data in economic subsectors, which may also have introduced limited misclassification.

Several errors may have been introduced as a consequence of the nature of the epidemiologic literature on back pain. MSDs defined by self-report are not universally accepted as valid. Cases of back pain reported on interview often cannot be diagnosed on the basis of physical examination [e.g., Riihimäki et al., 1990; Punnett et al., 1991]. Furthermore, the definition of back pain may vary substantially across studies, and prevalence estimates can therefore vary substantially [Loney and Stratford, 1999]. However, such differences in definitions are not likely to affect the estimation of relative risks, as long as applied in a consistent manner within each study. This assertion is scientifically parsimonious and consistent with the very limited published data [Ozguler et al., 2000].

Regarding possible confounders, socio-economic status (SES) and gender have been reported as potential risk factors. However, to the extent that these factors are associated with and thus act through or are surrogates for working conditions [Behrens et al., 1994; Leino and Hänninen, 1995; Denton and Walters, 1999; Hollman et al., 1999; Marmot, 1999; Punnett and Herbert, 2000; MacDonald et al., 2001], adjusting for them would serve to obscure the role of those exposures. Relative risks for occupational exposures have often not reported separately by gender or SES. ''Lifestyle'' factors, or non-occupational correlates of SES, appear to explain only a small amount of variation in back pain [e.g., Smedley et al., 1995; Leino-Arjas, 1998; Morken et al., 2000]. Although the causal pathway(s) remains uncertain, adjusting for SES in the estimation of LBP relationships with ergonomic exposures would certainly be conservative because SES would capture at least some of the explanatory power of occupational factors. The most influential study for this analysis [Leigh

TABLE VI. Comparison of Ranges of Effect Estimates for Selected Risk Factors for Low Back Pain in Working Populations of China, India, and Russia

	China, India, Russia		Developed countries[a]	
Risk factor	**Studies (n)**	**POR[b] range**	**Studies (n)**	**POR range**
Bending and twisting	4[c]	3.1–16.5	9	1.3–8.1
Static posture	5[c]	2.0–19.9	3	1.3–3.3
Whole-body vibration	4[c]	2.5–14.2	14	1.5–9.0
Heavy manual lifting	2[d]	1.4–3.5	9	1.5–3.1

[a]Data from Tables 4.2 and 4.3 of National Research Council, the Institute of Medicine [2001].
[b]POR, prevalence odds ratio.
[c]Data taken from Jin et al. [2000] for China.
[d]Data taken from Ory et al. [1997] for India and Toroptsova et al. [1995] for Russia.

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and Sheetz, 1989] included SES in the multivariate analysis, so the estimated RRs for occupation, and thus for this analysis, were likely to be underestimates of the work-related proportion.

The attributable fractions were here estimated within strata of age and gender, but this approach assumed uniform distribution of potential confounding variables by occupational group across the population and no effect modification. However, if there is effect modification by age, gender, or other covariates, error would have been introduced by this assumption. The direction of any such error is unknown.

Additional potential sources of error include the ''healthy worker effect;'' unknown effects on LBP of work in the household or the informal sector or child labor; possible evolution of disease after retirement; possibly differential under-reporting of LBP among occupations or sectors; and possible variability in exposure intensity, timing, co-variation, and other characteristics within occupation (see more detailed discussion in [Concha-Barrientos et al., 2004]. None of these could be taken into account due to scarce data. Given the inevitable uncertainties accompanying such analyses, we have sought wherever possible to ensure that any resulting bias was more likely to be in the direction of the null value rather than overestimating the disease burden.

Ergonomic exposures have been demonstrated to be modifiable by application of ergonomic job design principles. Minimum risk was thus defined here as the risk that would occur if all excessive physical and psychosocial stressors were abated, by effective implementation of ergonomic controls, to the levels experienced by managers and professionals.

The public health importance of these findings is striking. While interventions to reduce ergonomic stressors have not yet been widely implemented, studies from specific settings demonstrate the great potential for exposure (and disease) reduction. Removal of ergonomic stressors can lead to the removal of back pain or its reduction to negligible levels [Frank et al., 1996; Westgaard and Winkel, 1997; Marras et al., 2000; National Research Council, the Institute of Medicine, 2001]. The available literature includes evidence of the feasibility and benefits of workplace ergonomics interventions (training and engineering controls) that have been implemented by employers in numerous economic sectors. Effective abatement measures include redesign of workstations to eliminate need for bending and twisting; installation of material or patient hoists and other lifting devices; greater variety of work tasks, to avoid repetitively loading the same body tissues; and improved mechanical isolation to reduce whole-body vibration transmission. Training programs are most effective when they address job design, target supervisory, and management personnel along with the hourly labor force, and empower workers to utilize the knowledge imparted. The coordination of multiple interventions, workstation improvements, training, enhanced medical surveillance, and management, appears to be the most effective [Hagberg et al., 1995]. Similar conclusions were reached in the analyses of cost-effectiveness of ergonomic interventions [Lahiri et al., 2005a].

In summary, this highly preventable risk is very common in working populations with high physical loading on the back and possibly also high psychosocial strain. Outcomes such as days of restricted activity, long-term disability, health care utilization, and use of medication are very common among people with back pain, indicating the public health importance and cost of these disorders even when self-reported pain is not confirmed objectively [Badley et al., 1994, 1995; Guo et al., 1999; Miedema et al., 1998; Punnett, 1999]. Prevention of the relevant exposures should be given due priority.

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