

Estimating the Costs of Job Related Arthritis

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ABSTRACT. Objective. To present the first estimate of the costs of job related osteoarthritis (OA) in the USA.

Methods. Data were drawn from national data sets collected by the US Bureau of Labor Statistics, the US National Center for Health Statistics, and existing cost estimates for arthritis in the literature. We used proportional attributable risk (PAR) models to estimate the percentage of acute and repetitive injuries resulting in OA. These PAR vary between men and women. We used the human capital method that decomposes costs into direct categories such as medical expense and indirect categories such as lost earnings.

Results. We estimate job related OA costs US\$3.41 to 13.23 billion per year (1994 dollars). Our point estimate is that job related OA contributes about 9% (\$8.3 billion) to the total costs for all OA. About 51% of job related costs result from medical costs and 49% from lost productivity at work and at home. These costs are likely to underestimate the true burden since costs of pain and suffering as well as costs to family members and others who provide home care are ignored.

Conclusion. The cost of job related arthritis is significant and has implications for both clinical and public policy. Depending on the PAR selected, job related arthritis is at least as costly as job related renal and neurological disease combined, and is on a par with the costs of job related chronic obstructive pulmonary disease and all asthma, whether job related or not. (J Rheumatol 2001; 28:1647–54)

Key Indexing Terms:

ECONOMICS

OCCUPATIONAL SAFETY AND HEALTH

OSTEOARTHRITIS

Recent studies indicate that the costs of job related illnesses are significant. Fahs, *et al*¹ and Leigh, *et al*^{2,3} put the figure at between US\$19 to 30 billion in 1992 dollars for 5 deadly diseases and many nonfatal conditions combined in the United States. These studies estimate job related costs for cancer, circulatory disease, chronic obstructive pulmonary disease, renal disease, and neurological disease. Job related arthritis is not mentioned in these studies. This is unfortunate as costs have become a critical statistic in the ongoing debate about health care. For example, the costs of job related arthritis are unlikely to be covered by Workers' Compensation insurance but instead are paid by injured workers and their families, private insurance companies, health maintenance organizations (HMO), and taxpayers. Other examples of the importance of this subject are the implications for benefit-cost studies of occupational safety and health (OSH) ergonomic policies⁴. Ergonomics standards would presumably reduce injuries among current

workers and thereby reduce the job related osteoarthritis (OA) these workers might experience later in life. Yet no benefit-cost studies of ergonomic standards with which we are familiar account for job related arthritis.

Job related arthritis is a relatively new concept and therefore we reviewed the literature indicating a relationship between injuries and the subsequent development of OA. In addition, because there is no mention of it in the literature, we estimated the costs of job related arthritis and show why these costs are unlikely to be covered by Workers' Compensation.

MATERIALS AND METHODS

Definition of terms. Injury related OA is either an acute or repetitive trauma to a joint that ultimately results in OA in that joint. Job related injuries are all acute and repetitive injuries that result from job exposures, and job related OA is a subset of both injury related arthritis and job related injuries (Figure 1).

Job related arthritis is OA caused by an on-the-job injury. A typical case might involve an individual who experiences a knee injury resulting from trauma while working and later in life develops OA of that knee. The typical injury would occur at work and the OA would not manifest itself until some time later, perhaps not until retirement.

Felson's^{5,6} reviews of the epidemiology of OA discuss several specific jobs and tasks. He lists several definite risk factors for knee and hip OA, a number of which cannot be altered (age, sex, and hereditary factors). Among the factors that can be altered are obesity, major knee injury, and farming as an occupation. Felson lists only one probable risk factor for knee OA: occupational knee bending/lifting. Several probable factors are listed for hip OA including occupations with physical labor. Presumably, bending, lifting, and physical labor can produce acute or repetitive trauma. Indeed, more attention is paid to job related injuries than any other type of injury in the discussion of joint injuries. Felson⁵ describes 2 types of joint

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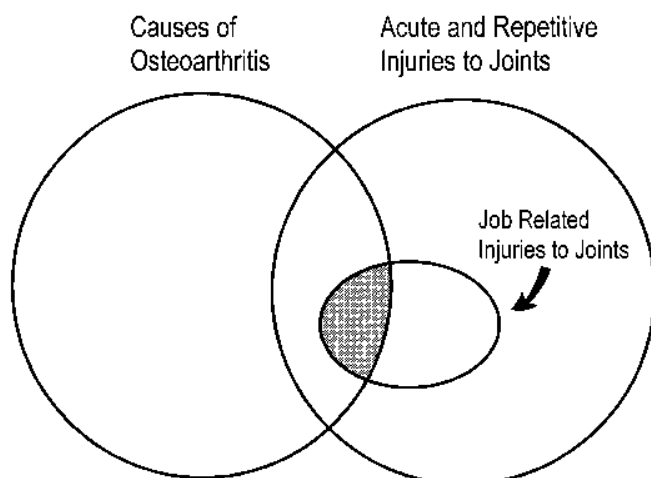


Figure 1. Job related arthritis. Causes of OA and repetitive injuries to joints. Shaded area represents the amount of job related arthritis.

injuries: acute and repeated impact loading. In the acute category, he provides examples of fractures or ligamentous tears. In the repeated impact category, he suggests a job that requires repetitive use of a joint.

Felson cites Croft, *et al*⁷ to demonstrate the link between farming and OA of the hip. Felson⁵ notes that jackhammer operators are especially prone to develop OA in upper extremity joints. Miners, shipyard workers, and cotton mill workers are all found to have higher than expected rates of OA^{8,9}. Hadler, *et al*¹⁰ found that women whose jobs require a fine pincer grip are at increased risk for OA of the fingers. Occupational knee-bending, lifting, and carrying heavy loads have been shown to be especially strong risk factors¹¹⁻¹³. Vingard, *et al*¹⁴ found farmers, firefighters, millworkers, butchers, dockers, fishers, miners, construction workers, unskilled manual workers, and crane operators to be at increased risk for either hip or knee OA. Among older workers, a larger percentage of OA is attributed to occupational knee bending than to obesity¹¹. Repetitive injuries in leisure sports activity appear less significant than job related activities in their association with OA⁵.

At least 3 important studies have been published since Felson's review. O'Reilly, *et al*¹⁵ obtained data on 3327 individuals aged 40–80 in Nottingham, UK. Information was available on jobs and knee pain. After controlling for age, sex, body mass index, social class, smoking history, and psychological distress, O'Reilly found carpenters, miners, and construction workers had odds ratios from 1.9 to 4.6 for knee pain. They attributed these high odds ratios to be the knee bending and heavy lifting associated with these jobs. Holte, *et al*¹⁶ analyzed government data in Norway on all employed people 50–56 years of age at baseline who ultimately received disability pensions beginning from age 51 to age 66 at the end of the study. They looked specifically at OA as the primary cause of receiving the disability pension and found that manual workers had nearly twice the odds of becoming a disability pensioner with OA compared to professionals after adjusting for part-time work, income, education, marital status, and sex. Yoshimura, *et al*¹⁷ in a case controlled study compared 114 individuals with hip arthroplasty due to OA to similar people with no arthroplasty. They concluded that lifting very heavy loads in the workplace at regular intervals predisposed to hip OA¹⁷.

There are also studies pertaining to all injuries, whether job related or not. A review of these studies convincingly demonstrates that loss of cruciate ligament integrity or damage to the meniscus can lead to OA of the knee¹⁸.

Evaluation of OA. OA has multiple causes and determining a cause of OA in a particular person is difficult. We used the proportionate attributable risk (PAR) method to evaluate costs for job related OA. This PAR method is widely applied to chronic diseases and conditions for which there are

multiple causes^{19,20}. Some potential causes of OA are environmental, occupational, genetic, or behavioral. The idea behind the PAR is to suggest that if a particular risk were eliminated, then a given percentage (the PAR) of the disease would be eliminated. For example, suppose the PAR for occupational asthma is 10%. The interpretation is that if we could eliminate relevant job exposure to sulfur dioxide, chlorine gas, and other aeroallergens, not just for one year but for entire lifetimes, adult asthma would be expected to drop by 10%²⁰.

Because some risks act synergistically and because in these synergistic relations both risks are necessary to produce the disease, the sum of all PAR for individual risks for a given disease might be more than 100%. For example, it could be that for some people, both a genetic predisposition as well as an occupational exposure are required to produce OA. Researchers who use PAR generally provide a range of possible PAR so that readers can determine which number they think is most reliable.

Two points should be made about our PAR. First, our PAR apply to costs that are not the same as cases. On-the-job injuries tend to be more costly than off-the-job injuries³. Second, because we use the PAR cost method, we need not estimate the number of all acute injuries or repetitive strain injuries. We simply assigned a given percentage reduction in OA costs (the PAR) that would result from the hypothetical elimination of all injuries or jobs involving bending and carrying.

Several variables affect our calculations and PAR. These include Yelin's most recent estimate for arthritis costs for persons over age 18²¹; Felson and Zhang's estimates of percentage of OA that could be attributed to acute injuries and percentage of knee OA that could be eliminated if all jobs involving excessive knee bending and carrying heavy loads could be eliminated²²; a National Health Interview estimate³ of percentage of acute injuries among persons of working age (22 to 64); and Yelin and Callahan's direct and indirect estimates of costs for persons of all ages²³.

Table 1 shows how we estimated total costs. We assumed that no job related OA would occur prior to age 18. Although we reviewed several sources for our estimates^{21,23-25}, we primarily relied on Yelin²¹ because his study is the most recent and focuses on OA, whereas the others consider either all musculoskeletal conditions^{23,24} or both OA and RA²⁵.

The 1998 Yelin²¹ study relies on the National Health Interview Survey, which adds OA together with RA, as well as all other forms of arthritis. The survey information was self-reported by subject. To estimate OA only, we subtracted the cost of RA and all other forms of arthritis. One method would simply split the total arthritis cost on the basis of prevalence in the US population. Lawrence, *et al*²⁶ estimated those prevalence figures to be 12.1% for OA, 1.0% for RA, and 1.9% for all other forms of arthritis (spondyloarthropathies, gout, and fibromyalgia making up the bulk of the other arthritides). We could have used the ratio 12.1/15 to estimate that 80.1% of total arthritis costs would be due to OA. But this calculation ignores the relatively higher cost for RA compared to OA on a per-case basis. Yelin surveyed clinical studies indicating that the cost of RA exceeds OA by roughly 70% per case²¹. We assumed that the cost per case for all other arthritides is the same as the cost per case for OA. We combined this figure with the 12.1, 1.0, and 1.9 prevalence percentages from Lawrence, *et al*²⁶ to generate the following equations:

$$\text{Equation 1: } \$OA \times 12.1 + \$RA \times 1.0 + \$OTHER \times 1.9 = 100\% \text{ of total costs;}$$

$$\text{Equation 2: } \$OA \times 1.7 = \$RA;$$

$$\text{Equation 3: } \$OA = \$OTHER,$$

where \$OA equals the cost per case for OA; \$RA equals the cost per case for RA; \$OTHER equals the cost per case for all other forms of arthritis including gout and fibromyalgia, spondyloarthropathies, and other less common forms of arthritis; 12.1, 1.0, and 1.9 in Equation 1 indicate that for each RA case there will be 12.1 OA cases and 1.9 cases of all other forms of arthritis; 1.7 is the amount by which each \$RA case exceeds the \$OA. Last, we assumed the cost per case for OA and all other arthritis is identical. If we substituted Equations 2 and 3 into 1 we would find

$$\begin{aligned} \$OA \times 12.1 + \$OA \times 1.7 + \$OA \times 1.9 &= 100\% \\ \text{or } \$OA \times 15.7 &= 100\% \end{aligned}$$

and solving for \$OA yields 6.3694%. If each OA contributes 6.3694% and there are 12.1 of them, then the total OA contribution would be $12.1 \times 6.3694\% = 77.07\%$. This 77.07% is the percentage of total costs of arthritis we assumed is attributable to OA only. Note 77.07% is less than our initial estimate of 80.1%, which did not account for the relatively higher per-case cost of RA compared to OA.

We assumed that women and men generate 58.97% and 41.03% (100 – 58.97) of OA costs. This 58.97% is the percentage of women in the age adjusted number of persons with self-reported arthritis in Table 1 from Lawrence, *et al*²⁶. Specifically, it is the age adjusted number of females and males reporting arthritis minus the ratio of age adjusted to crude prevalence percentages multiplied by the unadjusted number of females. We used the age adjusted rather than the crude percentages to account for the fact that a higher percentage of indirect costs will arise from men than women in preretirement years. This indirect cost difference is the result of a higher percentage of men than women below age 50 having OA³; a higher percentage of men than women with jobs; and a greater percentage of men with high-paying jobs.

OA is rare among minors and children. Our downward age adjustment would therefore give little, if any, weight to minors and children where indirect costs would be minimal.

There is no consensus on the precise numerical association between cases of acute and repetitive joint injuries (whether job related or not) and cases of OA. Moreover, we are unaware of any study attributing a given percentage of costs of OA to acute and repetitive joint injuries. Nevertheless, some related data are available. By relying on statistics in the literature, we first estimated OA caused by acute injury for men and women separately. We then estimated OA produced by repetitive injury, again for men and women separately.

Acute injury. Felsen and Zhang²² estimated that 25.3% of knee OA among men and 13.8% among women could be prevented if major knee injury were prevented. We interpreted major knee injury to mean serious, disabling, acute injury. In our attempt to derive reasonable estimates, we assumed that 25.3% and 13.8% applied to all forms of OA, not just knee OA. In defense of these assumptions, the prevalence of knee OA is about 6.1% among persons age 30 and over²², and therefore knee OA makes up roughly half of all OA prevalence (12.1%). We assumed that a serious, disabling, acute injury to the hip, cervical spine, lumbosacral spine, first metatarsophalangeal (MTP) joint, or the hand would be just as likely to produce OA at that joint as a serious, disabling, acute injury to the knee is to produce OA at the knee. We also assumed that these injuries are more frequent in men than in women in part because of the disparity in acute injury-producing jobs traditionally held by men. As increasing numbers of women enter these jobs, new assumptions will be required.

The next pair of assumptions apply to the percentage of acute injuries that occur at different ages. Roughly 53.3% of all injury episodes for men and 52.8% for women occur during working ages 22 through 64 in the National Health Interview Survey²⁷. Finally, for acute injuries, percentages apply to work related versus non-work related injuries. Among people of working age, not all injuries are work related. Hensler, *et al*²⁸ estimated 51.7% of acute disabling injuries among working age men were work related. No estimate was provided for women. However, Leigh, *et al*³ drew on data from the Bureau of Labor Statistics Annual Survey to estimate a ratio of 507 to 1000 for female to male disabling job related injuries. We therefore assumed that among working age women 51.7×0.507 or 26.2% of acute injuries are job related.

Repetitive injury. Again, few empirical PAR estimates are available for repetitive injury. We relied on data from Felson and Zhang²² (Table 2). One US²⁹ and one Scandinavian³⁰ review of the literature estimated the percentage of knee OA (for men only) that could be prevented if all jobs requiring knee bending and carrying heavy loads were eliminated. We interpreted those bending and carrying tasks as occurring over time, generating repetitive injuries. This is the same interpretation offered by Felson and Zhang²². We preferred the US study, which provided a conservative

15% estimate (that applied only to jobs requiring knee bending and carrying heavy loads) in comparison to the Scandinavian review, which gave estimates as high as 30%. It is unlikely that the 15% applied to all jobs that generate the many different kinds of repetitive injuries. Also, it is not likely that even within these jobs, 15% of hand OA, 15% of spine OA, and so on, could be eliminated with the elimination of these jobs. Therefore, for this calculation, we assumed only knee OA (which makes up 6.1% of 12.1% of all OA cases) applied. Felson and Zhang²² suggested that all knee OA for men could be reduced by 15% if these jobs were eliminated. In our calculations, then, we did not account for the percentage of working age men compared to all men, or the percentage of all injuries among working age men only due to jobs.

For women, this 15% would likely be too high given the historical overrepresentation of men in knee-bending and carrying jobs. We therefore used the same adjustment for women as for men. We assumed 50.7% as many repetitive injuries occur among women as among men.

In defense of this figure of 15%, it could be argued that repetitive injuries are obviously more prevalent at work than anywhere else: fastening rivets in the same spot on the car assembly line, repeated kneeling or bending, holding wrists in the same rigid position to type for several hours at a time. Table 1 shows the formulas for the PAR and the dollar values from Yelin²¹ used to estimate costs of job related OA.

The formulas and assumed ratios for direct and indirect costs are shown in Table 2. Again, we relied on estimates and ratios from Yelin²¹ and Yelin and Callahan²³. There is some dispute about the contributions of direct and indirect costs. Yelin's²¹ best estimate attributes more dollars to direct than indirect categories. But the clinical studies discussed by Yelin and in the earlier Yelin and Callahan study (based upon Rice²⁴) attributed far more dollars to indirect than direct costs. As a result, we calculated 3 estimates for the split between direct and indirect costs. In the first, we used Yelin's²¹ preferred direct/indirect ratio. In the second, we used Yelin's clinical studies ratio. In the third, we used Yelin and Callahan's direct/indirect ratio.

RESULTS

The total cost of OA (whether job related or not) was estimated to be 77.07% of Yelin's²¹ estimate of \$115.64 billion ($0.7707 \times \115.64) or \$89.1237 billion (Table 3). Our estimate of \$8.316 billion, therefore, represents 9.3% of the total. Table 3 also gives the estimates for acute injuries for women (\$1.01 billion); acute injuries for men (\$2.55 billion); repetitive injuries for women (\$1.99 billion); and repetitive injuries for men (\$2.76 billion). The total for women is \$3.0 billion (36.1%) and for men \$5.3 billion (69.9%).

In the sensitivity analysis that develops lower and upper bounds, we focused on assumed percentages that appear to be more fragile than others. The first fragile number is 25.3% of total OA costs for men, which is assumed to capture the contribution of all acute joint injuries, on and off the job²⁵. However, that study only provided a range for knee OA prevented by eliminating jobs requiring knee bending and carrying heavy loads for men: 15–30%, which is considerable. The midpoint in this range, 22.5%, would be 7.5% above the lower bound and 7.5% above the upper bound. We assumed the same 7.5% range applied to our 25.3%. But the 25.3, 15, 22.5, and 7.5% applied to knees, not other joints, and to prevalence, not costs. To allow for these additional factors, we assumed an additional 5% in the range, or 2.5% on either side of the midpoint. Our lower and

Table 1. Formulas for total costs,

- 1) $AcEstWomen\$ = Yelin\$ \times 0.7707 \times WomTot\% \times AcInjWom\% \times WomWrkAgeInj\% \times (MenAtWrkAcInj\% \times WomMenRatio)$
- 2) $AcEstMen\$ = Yelin\$ \times 0.7707 \times MenTot\% \times AcInjMen\% \times MenWrkAgeInj\% \times MenAtWrkInj\%$
- 3) $RepEstWomen\$ = Yelin\$ \times 0.7707 \times WomTot\% \times (MenBendJob\%) \times WomMenRatio \times RatioKneeAll$
- 4) $RepEstMen\$ = Yelin\$ \times 0.7707 \times MenTot\% \times MenBendJob\% \times RatioKneeAll$
- 5) Our Estimate for Total Costs = $AcEstWomen\$ + AcEstMen\$ + RepEstWom\$ + RepEstMen\$$

Definitions:

AcEstWomen\$: estimate of total costs of job related OA for women caused by acute injuries.

AcEstMen\$: estimate of the total costs of job related OA for men caused by acute injuries.

RepEstWomen\$: estimate of the total costs of job related OA for women due to repetitive injuries.

RepEstMen\$: estimate of the total costs of job related OA for men due to repetitive injuries.

Yelin\$: Yelin (1998) estimate for all arthritis costs in 1994 (\$115.64 billion).

0.7707: derived from Equations 1–3. It assumes a 12.1% prevalence for OA, 1% for RA, 1.9% for all other arthritis, and that each RA is roughly 1.7 times as costly as each OA case and each OA case costs the same as each “all other” arthritis case. Source: Felson⁵, Lawrence, *et al*²⁶, Yelin²¹.

WomTot%: % of total cost attributed to women (58.97%, derived in text and from Lawrence, *et al*²⁶)

MenTot%: % of total cost attributed to men (41.03%, derived in text and from Lawrence, *et al*²⁶)

AcInjWomen%: contribution of all acute joint injuries for women (on and off the job) to total OA costs (13.8%, Felson and Zhang²²)

AcInjMen%: contribution of all acute joint injuries for men (on and off the job) to total OA costs (25.3%, Felson and Zhang²²)

WomWrkAgeInj%: % of acute injury costs of all injuries among women of working age (22–64) (53.8%, Warner, *et al*²⁷)

MenWrkAgeInj%: % of all injuries among men of working age (22–64) (53.3%, Warner, *et al*²⁷)

MenAtWrkAcInj%: % of acute injury costs of all acute injury costs to men of working age (22–64) (51.7%, Hensler, *et al*²⁸)

WomMenRatio: ratio of number of female to male disabling, acute job related injuries (50.7%, Leigh, *et al*³)

MenBendJob%: % reduction in knee OA for men if all bending and heavy carrying jobs were eliminated (15%, Felson and Zhang²²)

RatioKneeAll: ratio of knee OA prevalence to all OA prevalence (6.1 to 12.1) (Felson and Zhang²² for 6.1; 12.1 is our calculation)

Table 2. Calculations for direct and indirect costs.

Formulas

1. $EstDirect\$ = (YDirect\$/YTotal\$) \times OurTotal\$$; $(59.3/115.64) \times \$8.3164 = \4.2646
2. $EstIndirect\$ = (YIndirect\$/YTotal\$) \times OurTotal\$$; \$4.0518
3. A second set of estimates were derived using “clinical studies” cost estimates in Yelin (1998)²¹. (Direct = \$11.3972; indirect = \$6.9192)
4. A third set of estimates were derived using Yelin and Callahan’s²³ update of Rice’s²⁴ estimates. (Direct = \$1.9544; indirect = \$6.3620)

EstDirect\$: estimate for direct costs; EstIndirect\$: estimate for indirect costs; YDirect\$: Yelin’s²¹ estimate for direct costs for all arthritis in 1994 (\$59.3 billion, or 51.28% of the total); YIndirect\$: Yelin’s²¹ estimate for indirect costs for all arthritis in 1994 (\$56.34, or 48.77% of the total); YTotal\$: Yelin’s²¹ estimate for total costs for all arthritis in 1994 (\$115.64 billion); OurTotal\$: our estimate for total costs of job related arthritis only, from Table 1.

Table 2A. Assumptions for the direct/indirect percentages.

Formulas	Direct (%)	Indirect (%)
1, 2	51.3	48.7
3	16.8	83.2
4	23.5	76.5

upper bounds are then separated by 20 percentage points: 15.3 to 35.3%. We assumed the same range applied to women. Our point estimate for women is 13.8%. The range, therefore, would be 3.8 to 23.8%.

Another fragile number for a lower bound is the 15% assumed for the reduction of all OA prevalence for men if all jobs involving bending and carrying heavy loads were eliminated. Following the analysis above, we assumed 10%

below as the lower bound and 10% above as the upper bound. Thus our upper bound for men is 25% and for women is (25/15) larger than the point estimate.

Our sensitivity calculations are carried out in Table 3. These new percentages (15.3, 3.8, and 5%) yield a lower bound estimate of \$3.405 billion. The new percentages (35.3, 23.8, and 25%) yield an upper bound of \$13.227 billion.

Table 4 shows estimates for direct and indirect costs. Our preferred point estimates (corresponding to \$8.3164) are \$4.2646 billion for direct and \$4.0517 billion for indirect costs. Had we used the clinical studies assumptions in Yelin²¹, i.e., 16.822% for direct costs, our estimate for direct and indirect costs would be \$1.39896 billion and \$6.9174 billion. Alternatively, using the Yelin/Callahan²³ direct and

Table 3. Estimated total costs, upper and lower bounds.

Preferred Point Estimate		
AcEstWomen\$	$= \$115.64 \times 0.7707 \times 0.5897 \times 0.138 \times 0.538 \times (0.517 \times 0.501) = \1.0107 billion	
AcEstMen\$	$= \$115.64 \times 0.7707 \times 0.4103 \times 0.253 \times 0.533 \times 0.517 = \2.5494 billion	
RepEstWomen\$	$= \$115.64 \times 0.7707 \times 0.5897 \times 0.15 \times 0.501 \times (6.1/12.1) = \1.9911 billion	
RepEstMen\$	$= \$115.64 \times 0.7707 \times 0.4103 \times 0.15 \times (0.61/12.1) = \2.7652 billion	
Estimate of total costs = \$8.3164 billion		
Women = \$3.0018 billion (36.1%); men = \$5.3146 billion (63.9%)		
Lower Bound	Point Estimate \times Factor	
ActEstWomen\$	(3.8/13.8)	= 0.2783
AcEstMen\$	(15.3/25.3)	= 1.5417
RepEstWomen\$	(5/15)	= 0.6637
RepEstMen\$	(5/15)	= <u>0.9216</u>
Total		\$3.4053 billion
Upper Bound		
AcEstWomen\$	(23.8/13.8)	= 1.7431
AcEstMen\$	(35.3/25.3)	= 3.5571
RepEstWomen\$	(25/15)	= 3.3185
RepEstMen\$	(25/15)	= <u>4.6087</u>
Total		\$13.2274 billion

Table 4. Our preferred point estimate and lower and upper bounds for direct and indirect costs using Yelin²¹ estimates of proportion of direct versus indirect costs.

Costs	Point Estimate*	Lower Bound**	Upper Bound***
Direct	\$4.2646	\$1.7462	\$6.7830
Indirect	\$4.0517	\$1.6591	\$6.4444
Total	\$8.3164	\$3.4053	\$13.2274

*Our preferred point estimate assumptions are described in the text; **our lower bound assumes several lower percentages than the preferred point estimate: 3.8% and 15.3% for women's and men's acute injuries; 5.0% for men's reduction in knee OA due to elimination of bending and carrying jobs; ***our upper bound assumes several higher percentages than the preferred estimate: 23.8% and 35.3% for women's and men's acute injuries; 25% for men's reduction in knee OA due to elimination of bending and carrying jobs.

Calculations

Point Estimates Direct $\$8.3164 \times 0.5128 = \4.2646 ; indirect = \$4.0517
Lower Bound Direct $\$3.4053 \times 0.5128 = \1.7462 ; indirect \$1.6591
Upper Bound Direct $\$13.2274 \times 0.5128 = \6.7830 ; indirect = \$6.4444

"Clinical studies" assumptions: $0.16822/0.5128 = 0.32804$; therefore all direct costs for clinical assumptions are 32.804% of these Table 4 direct costs; e.g., direct would be $4.2636 \times 0.32804 = \1.3990 ; indirect = $8.3164 - 1.39896 = \$6.9174$.

Yelin and Callahan Assumptions: $0.23457/0.5128 = 0.457426$, therefore all direct costs for assumptions are 45.7% of these Table 4 direct costs; e.g., direct would be $4.2646 \times 0.457426 = \1.9507 ; indirect = $8.3164 - 1.9507 = \$6.3657$.

indirect cost assumptions (23.457% for direct) our estimates would be \$1.9507 for direct and \$6.3657 billion for indirect costs.

The direct to indirect cost ratios in Yelin's clinical studies are questionable. Yelin cites 3 studies, but only one, Liang, *et al*²⁵, provides an estimate of indirect costs. Their sample, however, was of people who had ever attended a tertiary care facility and Yelin points out that their estimate of direct costs is especially low. The Yelin-Callahan²³ direct to indi-

rect cost ratios are drawn from Rice, *et al*²⁴, who combined RA with OA. RA can have significant indirect cost and can result in premature death and permanent total (in workers' compensation language) disability since it affects so many joints simultaneously. OA, on the other hand, is less likely to result in permanent total disability. Moreover, the Yelin-Callahan²³ ratios include all ages, even those under age 18. We therefore prefer the Yelin²¹ estimate that relied exclusively on OA cases.

DISCUSSION

Implications. Our range of estimates of \$3.405 to \$13.23 billion (1994 dollars) for job related OA is significant. It corresponds to 3.8% to 14.9% of the total cost of all OA (\$89.12 billion = \$115.64 × 0.7707). The first implication of this significant cost pertains to research. On the basis of our estimates, job related OA can be compared to the costs for job related cancers (\$9.4 billion, 1992 dollars), circulatory diseases (\$5.8 billion, 1992), asthma and chronic obstructive pulmonary disease (\$3.9 billion, 1992), renal disease (\$118 million), and neurological disease (\$290 million)². Considerable research has been directed at job related cancers^{31,32}, circulatory disease^{33,34}, asthma and chronic obstructive pulmonary disease³⁵⁻³⁷, and at renal and neurological diseases³. Little, by comparison, has been directed at job related arthritis. In fact, we were not able to find any cost estimates in the literature.

Our \$8.3 billion (1994 dollars) preferred point estimate is larger than the costs of all asthma (whether job related or not) for 1994: \$5.8 billion³⁸.

The second implication pertains to back pain and injury. OA does not include back pain. But back pain and injury significantly contribute to disability among both people of working age and the elderly²⁴. The cost of back pain and injury may be as much as 50% of the cost of OA²⁴. Moreover, back pain and injury are the greatest sources for all Workers' Compensation claims³⁹. Labor productivity losses due to back pain (whether job related or not) are estimated to cost \$28 billion⁴⁰. Frank, *et al*⁴¹ reviewed causes of back injuries at work and indicated that the best predictor of a current back injury at work is a prior back injury. This phenomenon is so prevalent that entire studies have analyzed recurrent low back pain at work⁴². It is likely that work injuries to the back early in life result in back pain during retirement. If so, our analysis could be extended to include back pain and injury. The resulting cost might be half again as large as the job related OA costs estimated here.

Another implication pertains to benefit-cost studies of ergonomic standards⁴. If injuries at work are reduced through ergonomic standards, then the associated OA costs would also be reduced, yet we are unaware of any benefit-cost study that captures the costs of job related OA.

A final implication pertains to policy. Taxpayers, patients with arthritis, and their families should not have to pay these costs. Workers' Compensation insurance should pay them. In the current environment, most of the costs will likely be borne by Medicare (taxpayers), health insurers (other than Workers' Compensation insurers), and patients and their families. These costs are not likely to be borne by the business firms at which the injuries occurred. In the language of economics, a "negative externality" exists. Businesses do not pay the full costs of production of their product since they do not pay for the costs of job related arthritis. Ideally, these costs should be reflected in Workers' Compensation

premiums, but they are not. Businesses therefore shift the cost to others, in this case, workers, families, taxpayers, and other health insurers. Simple economic analysis shows that under these conditions an inefficient amount (too much) of the "negative externality" (job related arthritis) will be generated by businesses.

Limitations. Several studies have found evidence for a link between job injuries and exposures on the one hand and OA on the other^{7,10-15}. Nevertheless, job related arthritis needs research attention to determine the biological mechanisms whereby joint injuries result in OA. We also need to know which injuries, sprains, and fractures to which joints are more prone to produce it. Ideally, a longitudinal data set could be established to identify persons who sustained, for example, a serious knee injury in one year and ultimately developed OA in that knee (and not in the other). But given the time span required to establish this link might be 30 years — such a longitudinal design might be too costly. Current studies could continue, nevertheless, to exploit existing data by asking about prior job exposures.

None of the PAR rely on more than one study. We applied the most recent PAR from the literature generated by highly regarded researchers. Again, the need for additional research is obvious. The cost estimates in Table 3 display a 4-fold difference in their range. Even with the most conservative assumptions, job related arthritis costs \$3.40 billion each year, considerably more than estimates for either job related neurological diseases or job related renal diseases and more than the costs of job related asthma and chronic obstructive pulmonary disease².

Diseases were counted in 1994. Our time dependent estimate (1994) carries several limitations. First, the true numbers of disease are moving targets. Our estimate applies only to one year and is likely to change in the future. Second, current numbers of disease may not reflect current job conditions, but rather, conditions in the workforce perhaps 20 to 50 years ago. To create an incidence estimate we could simply use a regression time trend to make a forecast. But forecasts of costs 20 to 50 years into the future would strain credibility. Bureau of Labor Statistics (BLS) data indicate that the total number of all job related acute injuries, whether joint injuries or not, have been slowly dropping for at least 20 years^{43,44}. Repetitive injuries, on the other hand, are rising³. Moreover, they are likely to be rising at a rate faster than BLS data suggest since as many as 75% of them are never reported to Workers' Compensation insurers⁴⁵. In addition, the labor force grows every year. Cases of OA, whether job related or not, are forecast to rise⁶ because longevity is increasing, and soon baby-boomers will retire. We generated prevalence numbers for a given year (1994) to provide a general picture of the overall burden of OA. As our ability to generate credible assumptions about the future course of arthritis and treatments improves, a study of current job hazards and exposures will

become more viable. In any event, the methods and estimates we developed here will likely prove useful to future researchers.

We ignored the cost to the individual due to arthritis associated pain, disability, and lost quality of life. This is likely to be considerable, since so much OA takes place during retirement. The usual source of indirect costs (lost wages) would be very low for retirees. It is difficult to estimate indirect costs for activities outside paid employment, however. Lawsuits involving nonfatal injuries almost always involve some payment for pain and suffering. A rule of thumb frequently cited in the courts is that pain and suffering costs 3 times the medical expenses and lost wages⁴⁶. For the preferred point estimate, this would mean adding another roughly \$25 billion to our costs. This limitation suggests we significantly underestimated total costs.

We did not include the costs of family caregiver's time or the costs of health problems that occur among caregivers. The costs for family caregivers has been estimated to be roughly 20% of medical costs for many other medical conditions⁴⁷. We are not aware of any estimate of the health costs to family caregivers. McFloyd and Flanagan⁴⁸ document the deleterious psychological consequences on spouses who care for persons with chronic conditions. These limitations suggest we underestimated costs.

Some expenditures will be made on nonprescription drugs. These were omitted from Yelin's preferred estimate for OA and RA of \$59.2 billion in direct costs.

We did not account for the health benefits of active employment. Many jobs associated with acute injuries also involve considerable activity and perhaps exercise, both of which are associated with good health, i.e., lower rates of circulatory disease and osteoporosis. Whereas this argument may have some merit for jobs with acute injuries, it is less likely to have merit for jobs with repetitive injuries. Fastening rivets would not likely be characterized as healthy exercise. Some knee bending might be healthy, but relentless bending or bending to lift especially heavy objects may not be. Moreover, we would never argue for the outright elimination of these jobs, just for the reduction of the injuries. For example, bending can be greatly reduced if automated leveling tables are used at the worksite⁴⁹.

Another potential limitation involves the calculation of indirect costs. It could be argued that these are not costs at all⁵⁰. Injured workers can simply be replaced by a pool of unemployed workers. This argument requires that the economy be operating at less than full employment, i.e., that a sufficient number of unemployed workers be ready and available for work. If the economy operates at full employment (if a sufficient number are not available), this argument would not apply.

There are a number of responses to this argument. First, we were seeking to measure costs from a societal perspective⁵¹, not the perspective of an individual firm. From the

societal perspective, the economic loss to the victim and his or her family is a cost. Second, this criticism applies to all cost-of-illness studies, and there are many of them. The methodology continues to be the method of choice in medical and legal studies because the concept of lost wages is so easily understood by non-economists. Third, the full employment assumption probably does apply for death and what Workers' Compensation systems refer to as permanent (either total or partial) disability. A death is forever and a permanent disability injury lasts a lifetime. A replacement worker can be found, but to argue that a deceased or permanently disabled worker would not have added any economic productivity over a lifetime is equivalent to arguing that the replacement worker would otherwise have been unemployed over his or her lifetime. This seems untenable. Therefore, a death or permanent disability is likely to result in significant economic costs regardless of whether the economy is currently operating at full employment. Whereas few, if any, deaths result from OA, most OA is permanent. In addition, some indirect costs also include lost home productivity and the business firm's cost associated with locating and training the replacement worker. These costs would accrue regardless of the level of employment. Most OA occurs after retirement, hence a larger percentage of our indirect costs would be due to lost home productivity than for other diseases, such as cancer, for example.

Finally, indirect costs may be viewed as a measure of lost health. It likely is strongly correlated with losses in quality adjusted life-years (QALY)³.

Job related injuries due to acute and repetitive trauma to joints such as the knees, hips, and hands can produce OA in those joints years after the initial injury. We estimated the costs associated with OA that result from these injuries. Since the science involving the injury-OA associations is not well developed, we presented a range of cost estimates from \$3.41 to \$13.23 billion and a point estimate of \$8.32 billion. Estimates within the range are on a par with the costs of job related cancers, circulatory disease, and chronic obstructive pulmonary disease as well as the cost of all asthma, whether job related or not. Currently, Workers' Compensation does not cover these costs. Job related OA merits research and public policy attention.

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