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Modeling the economic burden of diseases imputable to stress at work

Work-related stress is generally considered as being detrimental to workers' health and costly to society. Physicians and social workers agree that work-related stress is the source of several illnesses, including musculoskeletal disease (MSD), back pain, cardiovascular disease (CVD), depression, and burnout. Apart from being the direct cause of several medical conditions, stress also induces harmful behavioral practices such as excessive drinking, smoking, and drug abuse. The problem is that work-related stress is on the increase, partly because of the emergence of new technologies and the spread of new ways of organizing work [9]. The phenomenon seems to affect all categories of workers, including executives.

Acknowledging the occupational origin of this risk factor may have significant institutional and financial implications. In France work injuries and occupational illnesses are covered by a specific branch of public health insurance system which is funded solely by employers' contributions, whereas insurance for nonprofessional illnesses is funded jointly by employers' and employees' contributions. The topic is thus highly sensitive since the attribution of some diseases and deaths to a cause related to working conditions would imply transferring the financial burden from one category to another. This would have a direct impact on firms' involvement in health insurance financing.

The purpose of this study was to carry out the first available measure of the costs of work-related stress for France along with a pioneering analysis of different methodological hypotheses. Three illnesses that may result from exposure to work-related stress are included in our survey: cardiovascular diseases, depression, MSD and back pain. To evaluate the costs of work-related stress as a risk factor for the three illnesses we used the attributable fractions method. The proportions of cases attributable to the risk factor are calculated for each disease, and the results are then imputed either to the total cost of the illnesses or to the number of cases recorded.

We adopt the perspective of cost of illness (COI) studies to assess the cost of occupational stress for society. Although the interest of COI studies is sometimes questioned [1, 34], they may provide very useful information [6, 11] especially in the case of diseases attributable to occupational stress. COI studies provide (a) a standard of measurement for the year 2000 so as to make projections of occupational stress prevalence and economic burden for the future, (b) a measure of the cost of occupational stress for society allowing international comparisons, and (c) more specifically in the case of France a measure of the costs that may be borne by the occupational illnesses and work injuries branch of the health insurance system if the diseases originating in work-related stress were recognized as occupational illnesses.

Our study includes both direct medical costs and indirect costs of diseases originating in occupational stress. For indirect cost evaluation, we have used two different methodological hypotheses: (a) Our first hypothesis is based on the human capital theory in order to allow international comparisons with other surveys that have used the same method, especially that of Levi and Lunde-Jensen [25] for Sweden and Denmark. Here indirect costs are defined as the loss of production due to sick leaves and premature deaths attributable to occupational stress. However, this option raises methodological [34] as well as ethical problems, as discussed below. (b) According to our second hypothesis, indirect costs are restricted to pensions and compensation that would be paid to patients or to their family by the occupational illnesses and work injuries branch of the public health insurance system if the occupational origin of diseases were to be acknowledged. This perspective raises the issue of the monetary value of human life for society.

These two hypotheses allow us to provide complementary evaluations of the social cost of occupational stress for France. (Note that the present study does not allow direct assessment of the costs and benefits associated with the prevention of occupational stress. Therefore we do not discuss the question of the nature of the "future costs" that could be included in the evaluation of the costs induced by the increase in life expectancy [27]). The full results are presented and discussed in the light of a sensitivity analysis of the evaluations that were worked out.

Methodology

Stress definition

In our model we adopt as our definition of work-related stress the definition of job strain elaborated by Karasek [15] and Kara-

Table 1

Relative risk of illness related to occupational stress (our own calculations)

Illness	Sources	Sample country	Stress factors	Our hypotheses	Relative risk	
					Men	Women
CVD • Morbidity • Mortality	Schnall et al. [33]	10 cohort studies in Europe	Job strain Low control	RR identical for men and women	1.45 1.60–1.83	1.14 1.60–1.83
Depression • Mortality, morbidity	Niedhammer et al. [29]	France	High demand	RR identical in terms of morbidity and mortality	1.77	1.37
MSD, back pain • Morbidity	Hoogendoorn et al. [12]	11 cohorts and case-controlled studies in Europe	Low job satisfaction	RR identical for back pain and musculoskeletal disorders	1.7–3	1.7–3

sek and Theorell [16], according to which not all stressful situations at work lead to negative psychological strain. The type of occupational stress having a negative impact on workers' health is defined as *job strain*. This derives from situations which combine two different variables. First, *job demands* is an independent variable that measures stress sources present in the work environment. High job demands can be associated with intense pressure of work provoked by the performing tasks at high speed and by being subjected to tight deadlines. Second, *job control* measures decision latitude at work on the individual level. Job control is low when workers do not have autonomy in organizing work, in choosing working methods, and the order in which to carry out tasks. Job strain occurs when job demands are high and job decision latitude is low. A third moderating variable is introduced in the model by Karasek and Theorell [16]. Low social support at work (technical and emotional support from colleagues) is considered to strengthen the relationship between job strain and diseases imputable to occupational stress.

This definition of stress is a widespread reference in surveys on occupational stress and working conditions [5, 25]. This definition can be used in data analysis since it corresponds to a number of items in the questionnaire of the Third European Survey on Working Conditions [30]. Moreover, Karasek and Theorell's model is a common reference used by epidemiological surveys when measuring the impact of occupational stress on workers' health. For all these reasons we adopt job strain as our definition of occupational stress. (Other definitions include Cooper's [3] model of stress that is based on a much broader definition, including other types of stressors (sociological, biological, mechanical stressors) and leads to estimates of the cost of stress that are not comparable to ours. Siegrist's [35] effort-reward imbalance model of stress focuses on a negative trade off between experienced "costs," or efforts, and "gains," or rewards, such as esteem, money and occupational status, at work rather than on specific job task characteristics, as in the job strain model.)

The attributable fractions method

Defining the parameters

The proportion of cases attributable to a risk factor (PCA), or attributable fraction, is defined as:

$$PCA = \frac{Pe(RR-1)}{[Pe(RR-1)+1]}$$

where *Pe* is prevalence of exposure to a factor of illness (here, occupational stress), that is, the proportion of workers exposed to the factor; and *RR* is relative risk which measures the strength of the relationship of cause and effect between the risk factor and the frequency of an illness for an individual. The PCA measures excess morbidity, and where applicable the excess mortality that can be attributed to the factor of illness. In the absence of this factor of illness the number of persons suffering from the illness would be reduced in this same proportion.

Valuation of the parameters

Valuation of prevalence of exposure. The Third Survey on Working Conditions in Europe held in 2000 [30] provides the data required for valuation of prevalence of exposure in France. The survey distinguishes between the proportion of workers subjected to job strain for more than 75% and those subjected to it for more than 50% of their working hours. We use only the lower evaluation of prevalence of exposure (75% level), reserving the higher evaluation (50% level) for a subsequent sensitivity analysis. The probability of exposure to stress varies between men and women. We assume that it applies to the whole of France's working population for 2000, including the unemployed who may have been exposed to stressful working conditions with delayed consequences. The findings of the survey for the French population in 2000 were: job strain more than 75% of working hours, 20.8% of men and 13.6% of women; job strain more than 50% of working hours, 27.3% of men and 17.0% of women [30].

Items from the Third European Survey on Working Conditions used for the calculation of exposure to occupational stress were the following. The survey sample included 1,500 French workers (drawn from

Abstract

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Abstract
This study evaluated the costs of work-related stress in France. Three illnesses – cardiovascular diseases, depression, musculoskeletal diseases and back pain – that may result from exposure to stress are identified and the proportions of cases attributable to the risk factor are calculated from epidemiological studies. Two methodological hypotheses allow us to provide complementary evaluations of the social cost of occupational stress and raise the ethical questions inherent in the choice of methodology. For the year 2000 our model shows that of a working population of 23.53 million in France some 310,000–393,400 persons (1.3–1.7%) were affected by illnesses attributable to work-related stress, and that 2,300–3,600 persons died as a result of their illness. Work-related stress costs society between €1,167 million and €1,975 million in France, or 14.4–24.2% of the total spending of social security occupational illnesses and work injuries branch.

Keywords
Occupational stress · Attributable fractions method · Cost of illness analysis

a population of 21,703 workers from 15 European countries) in different sectors [30]. We based our calculations on this population of 1,500 French workers. High job demands can be measured by question Q21b1: "Does your job involve working at a very high speed?" and question Q21b2: "Does your job involve working to tight deadlines?" In our calculations workers subjected to high job demands for more than 75% of their working hours answered "about three-fourths of the time" or "almost all of the time" or "all the time" to question Q21b1 *or* they answered "about three-fourths of the time" or "almost all of the time" or "all the time" to question Q21b2. Low job control can be measured by questions dealing with autonomy in the questionnaire. Question Q25.1 asked workers: "Are you able, or not, to choose or change your order of tasks?" Question Q25.2 asked: "Are you able, or not, to choose or change your methods of work?" Question Q25.3 asked "Are you able, or not, to choose or change your speed or rate of work?" In our calculations workers subjected to low job control (or low autonomy) answered: "No" to at least one of these three questions (Q25.1, Q25.2, or Q25.3). As a result we considered workers subjected to *job strain* for more than 75% of their working hours to be workers subjected to high job demands *and* low job control simultaneously, according to Karasek and Theorell's [16] model. For calculations of job strain for more than 50% of working hours we added workers who answered "about one-half of the time" to question Q21b1 or question Q21b2.

Valuation of relative risk. In their study Levi and Lunde-Jensen [25] take damage to the worker's health, mostly through CVD, as the only consequence of occupational stress. However, stress has also been shown to have an effect in other illnesses such as mental health problems, MSD, and back pain. For this reason we added in our model depression, MSD, and back pain to CVD. The strength of the connection between the factor of illness and ill-health is evaluated by RR. **Table 1** summarizes sources and data used for RR.

Identification and selection of the literature for RR data were as follows. The inclusion criteria for all epidemiological surveys were based on criteria applied in the clinical literature. We included only historical cohort studies or case-control studies with sufficient number of cases compared to the number of independent variables, published between 1990 and 1999. Analysis and data presentation include multivariable model and adequate adjustment factors. Two systematic reviews of epidemiological literature based on Karasek and Theorell's [16] stress definition helped us to select high-quality epidemiological surveys in line with the above inclusion criteria. One of those deals with CVD [33] and the other one with MSD and back pain [12]. For these two illnesses, we assumed that RR data obtained in European countries could be used for the French population. For example, the literature review by Schnall et al. [33] revealed strong evidence for an effect of job strain on CVD morbidity and for an effect of low control on CVD mortality (**Table 1**). The review by Hoogendoorn et al. [12] found strong evidence for low social support in the workplace and job dissatisfaction as risk factors for back pain. Insufficient evidence was found for an effect of a high work pace and low job controls because the available information was too limited. Since social support at work is considered by Karasek and Theorell as a moderating variable only, we used RR for job dissatisfaction as an approximation of RR for job strain (**Table 1**). We adopted a different method to select studies concerning the risk of depression because of the difficulty in transposing results from other countries to the French population. Indeed, a number of authors insist on the strong link between sociocultural factors and the pathological prevalence of depression [8]. Moreover, transpositions are not to be encouraged because of the language and cultural problems in measuring depression [31]. We confined our survey of this literature to studies carried out in France. The only French academic work that satisfies the scientific criteria presented earlier is that of Niedhammer et al. [29]. This survey shows that three psychosocial factors at work (high demands, low decision latitude, and low social support) are significant predictors of subsequent depressive symptoms of men and women (**Table 1**). However, no significant interaction was found between the three psychosocial factors in relation to depressive symptoms.

This is also the case for any combination between two of the three factors.

Valuation of the proportion of cases attributable. **Table 2** shows the PCA calculated from the parameters for prevalence of exposure to occupational stress and RR.

Method of evaluation and modeling

Exposure to occupational stress has effects that are costly for society. In their calculations for Sweden and Denmark Levi and Lunde-Jensen [25] evaluate spending on health care for occupational stress and lost production as a result of stress. This approach to social costs is commonplace in other areas of health policy such as preventing illness factors [20], public policy pricing such as preventing drinking and smoking, and road safety [19, 26]. However, it calls for a more in-depth discussion of the implied assumptions. The valuation of loss of potential output is based on Becker's theory of human capital which views health as a capital asset from which income can be derived through participation in the system of production. Ill health makes this asset less profitable, that is, it reduces the marginal productivity that can be expected from it. In theory, marginal productivity can be evaluated by the income of the worker by the neoclassical hypothesis of remuneration for the marginal productivity of factors of production. In practice, the marginal productivity lost through time off work or premature death is evaluated by the present value of future income of the person or, where this information is unavailable, by the mean proportion of national wealth per person (per capita GDP). This hypothesis is tenable in principle only in an economy with full employment and no flexibility on the labor market. When there is high unemployment, some of the unemployed can stand in for those off work for long periods. In addition, flexibility within the firm (overtime, distribution of tasks) or outside the firm (temporary workers) may make up for short absences. The conditions for applying this method are therefore very restrictive [6, 34]. However, the human capital method is still relevant if we consider that flexibility within the firm or outside the firm is not costless [11]. (Other ways of estimating production losses have been suggested such as the "friction approach" [18], but applying these instruments is very tricky.)

The method also raises ethical issues because evaluating a death by aggregate discounted income means putting a price on human life by assessing the amount of production lost because of a person's death. The value of human life would therefore vary according to sex, seniority, occupation, etc., and such methods introduce systematic discrimination against the disabled, the nonworking population, women, poorly paid occupations, among others. It will be observed that valuation of lost output in terms of per capita GDP avoids such systematic discriminations. However, in both cases (valuation by the sum of discounted income or by per capita GDP) arises the question of using life expectancy in the calculation. The cost of lost production as a result of early death includes the number of years of life lost through illness, which is greater for the young than for the elderly. Thus the method of valuation of production losses itself introduces systematic discrimination against older persons whose lives appear to be of a lower value. In addition, application of the human capital theory is not consistent with the principles of welfare economics. It offers only a narrow view of the consequences of illnesses for social well-being by limiting itself to the effects on production [7] by omitting the valuation of leisure time and by ignoring any valuation of the lives of the retired and nonworking population.

Confronted with these methodological and ethical difficulties, we chose, in line with the recommendations of health economists, to present the valuation of occupational stress costs in three stages. We begin by presenting losses from the viewpoint of society in physical units (number of deaths, years of life lost, days' work losses). This intermediate information in physical units may also be used in the perspective of evaluating benefits to be expected from a policy for preventing occupational stress. Next we measure the direct costs of medical care for the illnesses caused by occupational stress. The purpose is to impute the fraction of this spending attributable to stress (PCA) on the basis of the data on the cost of the three illnesses concerned. Finally, we make a valuation of indirect costs that can be attributed to job strain in money terms according to two complementary hypotheses:

Hypothesis 1 measures production losses according to the human capital theory to allow international comparisons. It is considered that premature deaths attributable to occupational stress correspond to loss of potential output because of the years of activity lost before retirement age (losses expressed by $P(R)$ in the equation below). Conversely, lack of data means that the number of years of activity lost through early retirement cannot be taken into account. In this view lost production through sickness leave (A in the equation below) must also be evaluated. On top of these costs must be added all spending on health (S). The cost calculation is made in turn for the three illnesses (expressed by subscript i) covered by our model, that is, cardio-vascular diseases (CVD), depression (D), and musculoskeletal disease and back pain (MSD). We must then measure the proportion of these costs attributable to stress at work by ascribing the coefficient of PCA for each illness (PCA_i). This hypothesis provides a model of the cost of stress (CS) as:

$$CS_1 = \sum_{i}^{CVD,D,MSD} [(S_i + A_i + P(R)_i) \times PCA_i]$$

Hypothesis 2 measures human life losses in terms of the amount of money that the occupational illnesses and work injuries insurance would incur if the diseases imputable to work stress were recognized to

Table 2

The proportion of cases attributable to occupational stress in France in 2000 (percentages; from Table 1 and our own calculations)

	Men	Women
CVD		
• Morbidity	8.6	1.9
• Mortality	11.1–14.7	7.5–10.1
Depression		
• Morbidity, mortality	13.8	4.8
MSD, back pain		
• Morbidity	12.7–29.4	8.7–21.4

Table 3

Total number of cases of CVD, depression, and MSD, and back pain in the French population of working age in 2000 (from [2, 14, 22, 24] and our own calculations)

	Number of cases		Number of deaths	
	Men	Women	Men	Women
CVD	1,584,000	816,000	12,117	3,865
Depression	628,493	1,474,487	4,416	1,538
MSD, back pain	7,721	7,721	0	0
Total	2,220,214	2,298,208	16,533	5,403

Table 4

Number of cases attributable to occupational stress in France in 2000 (from Table 3, Table 4, and our own calculations)

	Number of cases		Number of deaths	
	Men	Women	Men	Women
CVD	135,573	15,246	1,344	292
Depression	86,763	70,642	610	74
MSD, back pain	981	671	0	0
Total	223,317	86,559	1,954	365

be occupational illnesses. In this view premature deaths may be evaluated in terms of the total number of years of life lost, considering that years spent in retirement are of value to society just as are years in work. This value, in money terms, may be assumed to be equal to the mean wealth created annually per person. In all, such losses for society are equal to the value of years of life lost relative to the mean life expectancy of the population in question (losses expressed by *P(LE)* below). On this assumption, loss of potential output related to sickness leave is irrelevant because we seek only to put a valuation on losses of human life. This second hypothesis can be modeled by:

$$CS_2 = \sum_{i}^{CVD,D,MSD} [(S_i + P(LE)_i) \times PCA_i]$$

This second perspective raises fewer methodological and ethical problems. However, we regard the two perspectives as parallel, particularly in answering the requirement of comparability with other international surveys. In both cases we make a valuation of the years of life lost by per capita GDP to avoid some of the ethical difficulties raised above.

Data collection

Data about the number of cases of CVD, depression, MSD, and back pain in France in 2000

Morbidity. The data are derived from a secondary calculation for each illness. The official report on CVD [24] gives the prevalence of this pathology in the French population. INSERM [14] data report that persons of working age make up 12% of death from CVD. For lack of more precise information we assumed that the distribution of the age group of those affected is identical to that of persons who died of the same illness, which clearly contributes to an underestimation of the cost of CVD. Le Pape and Lecomte [22] provide data on morbidity from depression in 1997. We assumed that the prevalence of depression was stable between 1997 and 2000.

Mortality. The data for the three pathologies studied in our survey are provided by INSERM [14]. To evaluate death attributable to depression we consider that 60% of suicides and of deaths through mental illness are related to depressive illness [10, 17, 36]. No death is recorded for MSD and back pain. **Table 3** summarizes the results of this research.

Data about the medical costs of CVD, depression, MSD, and back pain in France in 2000

A systematic review of the literature and own calculations provide an estimate of the costs of medical cover for 2000 and for each illness.

Cardio-vascular diseases. According to Letouzey et al. [24], expenses of hospital care (medicine, surgery, rehabilitation, emergency services) and ambulatory care (fees, pharmacy, biology, imagery, paramedical transport) in 1993 amounted to more than 57,550 million francs. Spending on CVD for 2000 was simulated on the following assumptions: (a) the change in the price of medical goods and services is assumed equal to the change in consumer goods prices (+11.03% between 1993 and 2000 by INSEE figures); (b) the structure of health spending is assumed to be stable for the cover of CVD; and (c) the increased prevalence of CVD affects changes in spending proportionately (+13.3% between 1993 and 2000). As a result we estimated that the costs of medical cover for CVD for persons of working age came to more than €1,324 million in 2000 in France.

Depression. Le Pape and Lecomte [21] evaluate the unit costs of cover for this mental illness in 1991 (15,389 francs for men, 7,555 francs for women). In estimating spending on depression in 2000 we use similar assumptions to those used in evaluating CVD. Spending on health care for depression of persons of working age in 2000 was thus estimated at more than €3,658 million.

MSD and back pain. The medical cost of cover for MSD and back pain is evaluated from statistics from the branch of occupational risk of the National Health Insurance Fund [2]. As a consequence the cases and costs reported relate exclusively to occupational illnesses, which means that we know nothing about morbidity that is not recognized as being work-related. Therefore the impact of MSD and back pain is substantially underestimated in the number of cases, the cost

of medical care, and the lost production for sickness leave. The total of medical costs for MSD and back pain in 2000 is €14.1 million francs for the French working population.

Data about sickness leave in France in 2000

Sickness leave because of CVD in 1993 was estimated by Le Pen and Lévy [23] and was extrapolated for 2000 from the increase in prevalence (+13.3%), which gives a total of 6.1 million days lost for persons of working age. The number of days of work lost for depression is estimated on the assumption of an average of 40 days for 38% of cases [37], which gives a total of 31.9 million days lost in 2000 for the French working population. Days lost because of back pain and MSD are recorded in the CNAMTS/DRP [2] statistical report: 2.6 millions days of work were lost in 2000 as a result of MSD and back pain for the French working population.

Results

Morbidity and mortality attributable to occupational stress, in physical units

By applying the proportion of cases attributable to work-related stress (**Table 2**, PCA) to our estimates (**Table 3**) we find the number of illnesses and deaths attributable to occupational stress (**Table 4**). Where PCAs are given as a range of values, we used the lower value. This choice is generally made by studies based on attributable fractions method [13]. Results of our model with the high range of PCA are presented below. In all nearly 310,000 cases (or about 6.9% of total cases) and more than 2,300 deaths (or 10.6% of total deaths) because of CVD, depression, MSD, and back pain may be attributed to exposure to occupational stress.

Monetary valuation of human losses and loss of potential output attributable to stress at work

Hypothesis 1

The monetary valuation of the lost years of work is made from the mean value of GDP per person (GDP_p in the equation below). The classical rules about discounting monetary values and potential growth of GDP over future years are posited (with a discount rate, DR , of 5% and a rate of growth of GDP, GR, of 2% generally assumed). The data about the number of deaths by age is only available by age groups [14]. For each age group the number of deaths (D_a) is known. In our calculation, a is the middle of each age cohort. On these assumptions the number of years of life lost between the age of death and the mean retirement age (R) is R-a. Production losses related to lost years of work are calculated as:

$$P(R) = \sum_{a=20,30,40,50,60} \left[D_a \times (R-a) \times \sum_{y=1}^{R-a} \frac{GDP_p \times (1+GR)^y}{(1+DR)^y} \right]$$

where y is the number of years of work lost.

Lost output from the number of years of life lost compared with the retirement age is evaluated at €475 million. The monetary valuation of days of work lost measures costs linked to sickness leave for each illness (A_i). This was done by multiplying the number of days off work for each illness (D_i) by GDP per person per day (GDP_{pd}), as shown below, which stood at €91.29 in 2000. Sickness leave linked to work-related stress can be evaluated at a total of €279 million.

$$A_i = D_i \times GDP_{pd}$$

Table 5 summarizes direct medical costs and loss of potential output because of sickness leave and premature death. The total of direct medical costs and indirect costs attributable to occupational stress comes to more than €1167 million.

Hypothesis 2

Costs related to premature death are evaluated from monetary valuation of lost years of life [$P(LE)$]. In this hypothesis the total number of years lost is evaluated by the difference between the age at the time of premature death [14] and the mean life expectancy of the population in question (LE). In all, on the assumption that the value of a year of life is equal to the wealth created per person and per year, that is, the mean GDP per person for 2000, it can be considered that premature death costs society €954 million. These estimates are made with the same assumptions about discounting potential growth of GDP above:

$$P(LE) = \sum_{a=20,30,40,50,60} \left[D_a \times (LE-a) \times \sum_{y=1}^{LE-a} \frac{GDP_p \times (1+GR)^y}{(1+DR)^y} \right]$$

where y is the number of years of life lost. **Table 6** shows the direct medical cost for these illnesses and the cost in years of life lost because of premature death attributable to occupational stress. Stressful working conditions cost society a total of €1367 million.

Hypothesis 2 yields a result some €200 million higher than hypothesis 1. Given the orders of magnitude involved, the respective results from the two hypothesis are quite comparable. The difference derives principally from allowance for the number of years of life lost in the calculations. As specified above, this corresponds to the number of years between death brought on by occupational stress and the average retirement age in hypothesis 1 and the number of years between death and average life expectancy in hypothesis 2. It appears that the cost of lost years of life (compared with average life expectancy) is more than twice the cost of lost years of output resulting from death before retirement age. This difference, which increases the cost calculated under hypothesis 2, is partly offset by the inclusion of sickness leave, which accounts for one-fourth of the costs under hypothesis 1. The relative weight of costs calculated under our two hypotheses would probably be brought into question if we had data about the cost of early retirement induced by occupational stress, which should be included in hypothesis 1. Levi and Lunde-Jensen [25] estimate this additional category would represent more than one-third of the total costs of the first hypothesis for Denmark and Sweden.

Sensitivity analysis

In all the above calculations we used the minimum hypotheses, which should in principle lead to underestimate the costs

Table 5

Total costs of work-related stress according to hypothesis 1 in France in 2000 (euros) (from [2, 14, 22, 23, 24, 37] and our own calculations)

	Medical cost	Cost of sickness leave	Cost of premature death (relative to retirement age)	Total for hypothesis 1
CVD	83,227,464	35,098,785	269,599,927	387,926,176
Depression	328,531,763	218,416,225	205,197,580	752,145,568
MSD, back pain	1,512,936	25,638,959	0	27,151,896
Total	413,272,163	279,153,970	474,797,507	1,167,223,640

Table 6

Total cost of work-related stress according to hypothesis 2 in France in 2000 (euros) (from [2, 14, 22, 24] and our own calculations)

	Medical cost	Cost of years of life lost (relative to life expectancy)	Total for hypothesis 2
CVD	83,227,464	632,203,073	715,430,537
Depression	328,531,763	321,804,280	650,336,043
MSD	1,512,936	0	1,512,936
Total	413,272,163	954,007,353	1,367,279,516

Table 7

Sensitivity analysis

	Total number of cases		Total costs (€)	
	Cases	Deaths	Hypothesis 1	Hypothesis 2
PCA with low prevalence				
• Low RR	309,876	2,319	1,167,223,640	1,367,279,516
• High RR	312,143	2,859	1,293,548,267	1,578,338,590
PCA with high prevalence				
• Low RR	390,757	2,921	1,465,900,711	1,719,686,523
• High RR	393,383	3,574	1,616,774,563	1,974,793,027

Low prevalence *exposure more than 75% of working hours,* high prevalence *exposure more than 50% of working hours,* RR *relative risk (from Tables 2, 3, 4, 5, 6, and our own calculations)*

of work-related stress. A sensitivity analysis should be conducted for the prevalence of exposure to stress and for the RR of developing an illness in the event of exposure to stress. First, the data used for prevalence provide a fairly restrictive criterion of exposure (more than 75% of working hours) and tend to underestimate the population exposed. It is therefore worth measuring the effect on the results of lower exposure to job strain, say for 50% of working hours. Second, we must integrate into the reasoning a comparison between the results obtained before from the low end of the range of RR, and thus of PCA (see **Table 1**), and those from inclusion of the high end of the range values. Results are shown in **Table 7**.

If we take a high level of prevalence instead of a low level (as in Tables 5 and 6), this sensitivity analysis reveals a total cost of work-related stress of close to €1,466 million for hypothesis 1 (€1,720 million for hypothesis 2) or a 25.6% increase (25.8%, respectively). The results obtained are sensitive to the statistics used in the stages preceding the calculation of PCA. A high level of RR shows a total cost of €1,293.5 million for hypothesis 1 (€1,578 million for hypothesis 2), or an increase of 10.8% (15.4%, respectively) over the results calculated with low end of the range values of RR. Sensitivity of results to this new hypothesis is less than in the previous analysis of prevalence of exposure. Crossing the previous two sensitivity analyses by choosing the extreme values yields the following results: total cost of nearly €1,617 million for hypothesis 1 (€1,975 million for hypothesis 2) or a variation of 38.5% (nearly 44.4% for hypothesis 2) compared with the results for low prevalence and low RR. (Other sensitivity analyses could have been conducted from three other variables. The mean annual rate of GDP growth, for which we used a value of 2% for the next 60 years, could be analyzed in other ways (by a range, say, of 1–5%) the same applies to the discount rate (a range of 2–7%, for example, instead of the 5% that we used). These changes would affect the results for the cost of lost years of life. Likewise, estimates used for the change in prevalence of CVD (13.3% from 1993 to 2000) could be revised, which would affect the medical cost and the number of days off work related to this illness.)

Discussion and conclusion

In summary, our model shows that for the year 2000, between 310,000 and nearly 400,000 persons out of a working population of 23,530,000 (between 1.3% and 1.7%) were affected by illnesses attributable to work-related stress, and that 2,300–3,600 persons died as a result of these illnesses. The cost for society of work-related stress can be estimated at €1,167–€1,975 million in France, which represents between 14.4% and 24.2% of the total spending of occupational illnesses and work injuries branch of the public health insurance system. These results provide an underestimated valuation of the economic burden of occupational stress as some costs, especially intangible costs, are not taken into account. (For example, Ramaciotti and Perriard [32], who assess the cost of occupational stress for Switzerland by taking into account those intangible costs through the willingness to pay method, obtain results of a completely different magnitude.)

Sensitivity analysis shows that the total cost of work-related stress varies widely with the hypotheses used in the calculation of proportions of attributable cases, especially prevalence of exposure to stress and

RR parameters. This raises the question of the relevance of the attributable fractions method in this area, as in others such as alcoholism and risk-seeking behavior. This emphasizes the importance of having several convergent epidemiological studies determining as reliably as possible the value of RR for each illness that may be caused by stressful working conditions.

Our study includes a broader scope of diseases related to occupational stress than do previous studies, especially that of Levi and Lunde-Jensen [25]. In fact a large part of the total cost (between 47.5% and 64.5%) is attributable to depression. This is due to higher PCA values for this pathology and to the fact that depression affects more persons of working age proportionally than does CVD. The shares of back pain and MSD are very low, certainly because of an underrecognition by health insurance institutions of the occupation-related causes of these conditions [4, 28]. Better knowledge of the medical cost of these illnesses is a prior condition to obtaining a more precise estimate of occupational stress.

The present study opens up new directions to complement the first results. In particular it would be worth investigating the effect of occupational stress by sex and occupation to refine the first-hand results already obtained at an aggregate level for France and to identify the activities most at risk. It would also be of great importance to assess the course of exposure to occupational stress in the context of intensifying working rhythms. (The scheme would be to adopt an "incidence approach" which assesses the new cases emerging during a given year instead of the "prevalence approach," used here, which assesses the overall number of cases for any given year [6].) Nonetheless, this pioneering research in addition to providing an evaluation of the social cost of occupational stress for France offers useful data to contribute to the debate on ways of developing and financing the prevention of pathological working conditions.

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