Int Arch Occup Environ Health (2011) 84:911–925
DOI 10.1007/s00420-011-0633-8

ORIGINAL ARTICLE

Fractions of cardiovascular diseases, mental disorders, and musculoskeletal disorders attributable to job strain

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Received: 8 September 2010 / Accepted: 17 March 2011 / Published online: 2 April 2011

Abstract
Objectives The aim of this study was to evaluate fractions of diseases attributable to job strain defined using Karasek's model among the French working population for cardiovascular diseases (CVD), mental disorders, and musculoskeletal disorders (MSD).
Methods Job strain was defined as the combination of high psychological demands and low decision latitude. The prevalence of exposure (P_e) was estimated using the representative national sample of 24,486 employees of the French SUMER survey. Relative risks (RR) were estimated from a literature review (1990–2008) using the same inclusion criteria for the three health outcomes. P_e and RR estimates were used to calculate attributable fractions (AF).
Results P_e estimates were 19.6% for men, 28.2% for women, and 23.2% for men and women combined. The literature review led to a selection of 13 studies for CVD, 7 studies for mental disorders, and 11 studies for MSD. RR estimates were 0.63–2.45 for CVD (morbidity and mortality), 1.2–3.3 for mental disorders, and 0.94–2.3 for MSD. AF estimates for CVD morbidity were 4.9–21.5% for men, 0–15.9% for women, and 6.5–25.2% for men and women combined, for CVD mortality 7.9–21.5% for men, 2.5% for women, and 6.5–25.2% for men and women combined, for mental disorders 10.2–31.1% for men, 5.3–33.6% for women, and 6.5% for men and women combined, and for MSD 0–19.6% for men, 0–26.8% for women, and 3.4–19.9% for men and women combined.
Conclusion This study is the first one to provide fractions of diseases attributable to job strain for three health outcomes in France on the basis of a systematic review of the literature. These results could contribute to the estimation of the economic cost of diseases attributable to job strain.

Keywords Attributable fractions · Work stress · Cardiovascular diseases · Mental disorders · Musculoskeletal disorders

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Introduction

Work stress has become a major occupational health and safety issue as one of the leading occupational risks in all industrialized countries (Karjalainen et al. 2004; World Health Organization 2008). Furthermore, many epidemiologic surveys have shown that work stress is a risk factor for various health outcomes, especially cardiovascular diseases and mental disorders (Belkic et al. 2004; Van der Doef and Maes 1999) as well as musculoskeletal disorders

(MSD), although less conclusive results have been found for these last disorders (Bongers et al. 2006). These facts highlight the need to reinforce research prevention activities in this area.

Much is at stake since diseases attributable to work stress are usually not recognized as occupational diseases by occupational health insurance systems in European and Northern American countries (EUROGIP 2004). These health outcomes have many implications in terms of number of years of healthy life lost, medical costs, and lost productivity for companies due to sickness absence. Generally, very few studies have evaluated the magnitude of morbidity or mortality induced by occupational exposures. Some studies have investigated the fractions of health consequences attributable to occupational exposures and examined specific health outcomes and exposures, for example, hearing loss resulting from noise exposure or occupationally induced asthma (Driscoll et al. 2005; Nelson et al. 2005; Fingerhut et al. 2005). However, almost no literature has been devoted to global levels of morbidity or mortality due to psychosocial exposures at work. One major exception is the study by Nurminen and Karjalainen (2001), which provides estimates of fractions of annual deaths attributable to occupational factors in Finland, including the proportion of cardiovascular and mental diseases related to psychosocial work factors. LaMontagne et al. (2008) produced estimates of fractions of depression attributable to job strain for the Australian population. Although attributable fractions produce only approximate estimates, they are a very useful method for estimating the global burden of diseases attributable to a risk factor since the fraction can be applied to the total number of cases or deaths, as well as to the total cost of a disease (Levi and Lunde Jensen 1996; Bejean and Sultan-Taïeb 2005).

The aim of this article was to estimate the fractions of three health outcomes—cardiovascular diseases, mental disorders (depression and anxiety syndrome), and musculoskeletal disorders—attributable to job strain, as defined by Karasek's model of work stress (Karasek 1979; Karasek and Theorell 1990).

This model is based on two main dimensions: psychological demands (i.e. job demands, time pressure, and conflicting demands) and decision latitude (i.e. control over work, decision authority and possibility of learning new skills, and skill discretion). According to this model, the most detrimental situation corresponds to a combination of high levels of psychological demands and low levels of decision latitude and is termed job strain. Our study adopts this work stress model since the Job Content Questionnaire (JCQ) is considered to be the leading instrument measuring work stress exposure. Its validity has been studied in various languages including French (Karasek et al. 1998; Niedhammer 2002; Niedhammer et al. 2006), and data obtained in a French national survey were made available recently.

In this article, we produced two sets of original data. First, we performed a systematic review of the epidemiologic literature, before producing estimates of relative risks of cardiovascular diseases, mental disorders, and musculoskeletal disorders associated with job strain exposure. Second, we calculated the fractions of the three health outcomes attributable to job strain exposure. This is the first time that such attributable fractions have been estimated for the three health outcomes in France, and such an attempt has never been performed elsewhere to date.

Methods

Attributable fractions (AF) produce an estimate of the fraction of cases that is "attributable to an exposure in a population and that would not have been observed if the exposure had been non-existent" (Nurminen and Karjalainen 2001). AFs are calculated from the estimate of the proportion of the population exposed to this risk factor, combined with estimated relative risks of disease or death due to exposure to this risk factor (Levin 1953):

$$\mathrm{AF} = P_{\mathrm{e}}(\mathrm{RR}-1)/(1+P_{\mathrm{e}}(\mathrm{RR}-1)) \quad (1)$$

where RR is the relative risk and P_{e} is the prevalence of exposure of the total population (the proportion of the population exposed to the risk factor). The formula (1) was used for adjusted RRs. We did not use the recommended formula (2) as unadjusted RRs were not always available in the studies:

$$\mathrm{AF} = (P_{\mathrm{e}} \times \mathrm{RR}/(P_{\mathrm{e}}(\mathrm{RR}-1)+1)) \times (\mathrm{RR}_{\mathrm{a}}-1)/\mathrm{RR}_{\mathrm{a}} \quad (2)$$

where RR is the unadjusted relative risk and RR_{a} the adjusted relative risk.

To calculate AF estimates using formula (1), P_{e} and adjusted RR had to be estimated first.

Prevalence of exposure (P_{e})

The data we used for the estimate of prevalence of exposure to job strain came from the results of the national SUMER survey that was conducted in France in 2003. This survey is a periodical cross-sectional survey conducted by the French Ministry of Labour (DARES). Its purpose is to evaluate all types of occupational exposures in the French working population in order to define preventive strategies and research priorities in France (Arnaudo et al. 2004). The SUMER survey used a questionnaire completed by occupational physicians in charge of medical examination of employees (occupational medicine is mandatory for all

employees in France) as well as a self-administered questionnaire, including Karasek's JCQ. In total, 24,486 employees, 12,241 men and 10,245 women, selected on a random basis responded to the self-administered questionnaire (response rate: 96.5%). The data of the SUMER survey were weighted to provide estimates that were representative of the French working population. As a result, the 2003 SUMER survey provides high-quality data for exposure to job strain among the French national working population according to gender and occupational category (Niedhammer et al. 2006, 2007, 2008a, b, c).

The estimates for the prevalence of job strain exposure obtained from the SUMER survey were 19.6% for men, 28.2% for women, and 23.2% for the total population. These estimates were consistent with previous results on the differences in the prevalence of job strain between genders, women being more likely to be exposed (Steenland et al. 2000). The demands and latitude scores were dichotomized at the median of the total sample of the SUMER survey, following the recommendations for JCQ use and making the comparison between genders possible. Furthermore, this definition of job strain is commonly used, making our results consistent with the literature.

Relative risk estimates

The selection process was performed as follows. Since very few high-quality epidemiologic studies have been conducted on psychosocial work factors in France, we included studies from other industrialized countries in our literature review. As recent and updated literature reviews were available for the three health outcomes, we selected papers on the basis of literature reviews on CVD (Belkic et al. 2004; De Lange et al. 2003; Hemingway and Marmot 1999; Kasl 1996; Kivimäki et al. 2006b; Kristensen 1995, 1996; Kuper et al. 2002; Schnall et al. 1994; Tennant 2000; Theorell and Karasek 1996; Van der Doef and Maes 1998), mental disorders (Bonde 2008; De Lange et al. 2003; Michie and Williams 2003; Netterstrom et al. 2008; Sanderson and Andrews 2006; Siegrist 2008; Stansfeld and Candy 2006; Tennant 2001; Van der Doef and Maes 1999; Wilhelm et al. 2004) and MSD (Van der Doef and Maes 1998; De Lange et al. 2003; Ariens et al. 2001; Bongers et al. 1993, 2002, 2006; Burdorf and Sorock 1997; Davis and Heaney 2000; Ferguson and Marras 1997; Hales and Bernard 1996; Hartvigsen et al. 2004; Hoogendoorn et al. 2000; Linton 2000, 2001; Malchaire et al. 2001; Riihimaki 1991; Van der Windt et al. 2000; Walker-Bone et al. 2003; Weiser and Cedraschi 1992; Winkel and Westgaard 1992; Macfarlane et al. 2009). Secondly, we checked the completeness and exhaustiveness of the references provided by these reviews using our own literature bases and Medline interrogations. We then adopted two steps for the selection process using two sets of inclusion criteria to select the studies that were ultimately used to provide data for RR estimates.

The following is the first set of inclusion criteria used for all studies

- Year of publication: between 1990 and 2008 (inclusive).
- Articles published in peer-reviewed journals.
- Sample size of more than 100 individuals.
- Exposure assessment with an explicit reference to Karasek's model. Studies referring to other work stress models were excluded.
- Health outcomes related to cardiovascular diseases, mental disorders, or musculoskeletal disorders.
- Design: prospective studies. Incidence of the three health outcomes was considered, but recurrence was excluded.

This first set of inclusion criteria was designed to identify a first corpus of studies in line with standards of scientific quality: peer-reviewed journals, sample size above 100 individuals, and prospective design to study the predictive effects of psychosocial work factors as defined by Karasek's model on the health outcomes considered. The second set of eligibility criteria aimed at restricting this corpus of studies to those that actually provided useful information on RR estimates: type of statistical analysis, exposure and health outcome assessment. This procedure enabled us to calculate a selection rate with the first corpus of studies used as the denominator. The numerator for this calculation consisted of the number of studies actually retained.

The second set of inclusion criteria used for all studies retained in the first step was as follows:

1. Statistical analysis: The data analysis had to include an adjustment for covariables or potential confounding variables, and the results had to be clearly presented with sufficient statistical analysis to permit estimation of RRs.
2. Exposure assessment: Given the available studies in the literature, it would have been too restrictive to refer only to those based on the recommended version of the JCQ (including 9 items for psychological demands and 9 for decision latitude). Consequently, we selected studies based on questionnaires using Karasek's two dimensions (demands and latitude) and including more than one item for each dimension. We excluded studies that used isolated items derived from JCQ as well as studies that used the two dimensions of demands and latitude separately (and not as a job strain measure). Selected studies had to provide information on the instrument's psychometric properties (at least internal

consistency or reference to other published works). We also excluded studies based on a job exposure matrix, which corresponds to an exposure assessment method different from questionnaires and known to underestimate RRs (Niedhammer et al. 2008c).

3. Health outcome assessment: The selected studies had to use precise definitions/measurements for health outcomes.

   CVD had to be clinically diagnosed or measured using validated instruments, such as the Rose questionnaire. We retained all ischemic diseases including coronary heart diseases (CHD) such as myocardial infarction (MI) and angina.
   Mental disorders including depression and anxiety were evaluated using either validated self-administered questionnaires, such as the Beck Depression Inventory (BDI), Center for Epidemiologic Studies Depression Scale (CES-D), General Health Questionnaire (GHQ), and Psychiatric Symptom Index (PSI), or standardized diagnostic interviews such as CIDI (Composite International Diagnostic Interview).
   MSD had to be measured using standardized instruments such as the Nordic questionnaire or clinical diagnosis. We included all locations related to back, neck, shoulder, and upper extremity.
   Criteria #1 and #2 applied to all studies and all health outcomes, and criterion #3 applied differently according to each health outcome.

This second set of criteria enabled us to select the papers finally used to provide RR estimates. As far as possible, we attempted to provide results for men and women separately.

Attributable fractions

As our literature provided ranges of RRs, we were able to provide ranges of AF estimates. For each health outcome, the low-range value for AF estimate resulted from the calculation using formula (1) with the lowest RR estimate obtained from our literature review. The upper-range value for AF estimate resulted from the same calculation with the highest RR estimate.

Results

Results of the selection process from the literature

The studies finally included in our review indicate that the level of knowledge of the association between job strain and health varies according to the health outcome considered. Moreover, the impact of each criterion on the selection rate differed according to health outcome. It should be noted that a study could be excluded because of more than one criterion (therefore exclusion rates sum could total above 100%).

CVD The first set of inclusion criteria led us to select 20 studies. After the second set of inclusion criteria, 13 studies were retained: 3 for morbidity (Bosma et al. 1998; De Bacquer et al. 2005; Orth-Gomer et al. 2000), 2 for mortality (Brunner et al. 2004; Kivimäki et al. 2002), 7 for morbidity and mortality (Kivimäki et al. 2005, 2006a, 2008; Uchiyama et al. 2005; Kuper and Marmot 2003; Netterstrom et al. 2006; Kornitzer et al. 2006), and 1 produced RR estimates for mortality and morbidity separately (Lee et al. 2002). All the 7 studies (35%) were excluded because of shortcomings in exposure assessment. The selection rate (65%) for CVD was the highest among the three health outcomes studied.

Mental disorders The first set of inclusion criteria led us to select 36 studies. However, the selection rate after the second set of inclusion criteria was low (19%) with only 7 studies selected (Bildt and Michelsen 2002; Ahola and Hakanen 2007; Bourbonnais et al. 1999; Niedhammer et al. 1998; Shields 1999, 2006; Clays et al. 2007b). Of the initial 36 studies,

- 25 (69%) had exposure assessment shortcomings,
- 13 (36%) used statistical methods, which did not allow calculations of RR estimates,
- and 2 (6%) had outcome assessment shortcomings.

Ten (28%) studies were excluded because of 2 criteria or more, and among these 10 studies, one was excluded because of 3 criteria.

MSD The first set of inclusion criteria led us to select 50 studies, out of which 11 studies were finally retained (Bildt et al. 2000; Elders and Burdorf 2004; Josephson et al. 1997; Krause et al. 1998; Rugulies and Krause 2005; Canivet et al. 2008; Ijzelenberg and Burdorf 2005; Ostergren et al. 2005; Clays et al. 2007a; van den Heuvel et al. 2005; Hannan et al. 2005), thus representing a selection rate slightly higher than that for mental disorders (22%). Of the initial 50 studies,

- 36 (72%) had exposure assessment shortcomings,
- 6 (12%) did not produce RR estimates,
- and 4 (8%) had outcome assessment shortcomings.

Only seven studies (14%) were excluded because of 2 criteria. The studies retained covered all locations of back, low back, neck, shoulder, upper extremity, elbow, hand, and wrist, which were not always studied separately, thus impairing the comparison of results.

Table 1 provides a description of the main characteristics of the 31 included studies.

RR estimates associated with job strain exposure

RR estimates for CVD morbidity and mortality were between 0.63 and 2.45 for men and women (Fig. 1). Among the 13 selected studies, 10 produced RR estimates for coronary heart diseases (CHD) and 3 studies yielded RR estimates for CVD (Brunner et al. 2004; Kivimäki et al. 2002, 2008), i.e., for a broader range of cardiovascular outcomes. Among the selected studies, one study (Lee et al. 2002) produced a non-significant RR estimate below unity for women's morbidity (0.63). This RR estimate was non-significantly different from 1 and was consequently considered to equal 1 in the subsequent analyses to make possible the calculation of attributable fractions for CVD.

RR estimates for mental disorders were 1.58–3.3 for men and 1.2–2.8 for women (Fig. 2).

RR estimates for MSD were 0.94–2.3 (Fig. 3), each corresponding to a location or a series of locations. Among the selected studies, 2 produced non-significant RR estimates below unity, one for neck and shoulder pain (0.94) for men (Ostergren et al. 2005), and the other one for low back pain (0.99) for women (Clays et al. 2007a). They were consequently considered to equal 1 in the subsequent AF estimations.

Estimates of attributable fractions

For men, 4.9–21.5% of CVD morbidity was attributable to job strain, 0–15.9% for women, and 6.5–25.2% for men and women combined. Attributable fractions for CVD mortality were 7.9–21.5% for men, 2.5% for women, and 6.5–25.2% for men and women combined. For men, 10.2–31.1% of mental disorders were attributable to job strain, 5.3–33.6% for women, and 6.5% for men and women combined. Fractions of MSD attributable to job strain were 0–19.6% for men, 0–26.8% for women, and 3.4–19.9% for men and women combined. Attributable fraction estimates are shown in Fig. 4.

Discussion

RR selection process

Some limitations concerning the RR estimate selection process must be pointed out. The studies retained in our selection used Karasek's concept of job strain. However, there were differences in the instruments used to measure it (i.e. different item contents and a wide range of numbers of items for latitude/demands) as well as in the methods adopted to define exposure (medians or quartiles for demands/latitude, ratio or difference between these two dimensions, etc.). However, the use of more restrictive exposure assessment criteria would have reduced the number of studies selected even further, especially in the case of mental disorders and MSD. These differences may be a source of heterogeneity between studies, as well as the differences in population studied, outcome measurement, adjustment variables, or follow-up period between studies.

The adopted selection process also had several strengths. Although some differences in exposure assessment were observed, exposure in our study referred to a well-known and commonly used work stress model. Furthermore, the prevalence of exposure to job strain was estimated using representative French national data and Karasek's JCQ. Moreover, wherever possible, we produced data for each gender separately.

RR estimates

Our results for CVD are consistent with those from the meta-analysis by Kivimäki et al. (2006b), providing a summary age- and gender-adjusted RR of 1.45 (95% CI: 1.15–1.84) using 11 prospective studies and a multiple-adjusted RR of 1.16 (95% CI: 0.94–1.43) using 10 prospective studies. The CVD studies selected in our review were not all based on independent samples; 4 came from the Whitehall study (Bosma et al. 1998; Kivimäki et al. 2005, 2006a; Kuper and Marmot 2003) and 2 came from a study in a metal working company (Brunner et al. 2004; Kivimäki et al. 2002). Only three studies produced RR estimates for women (Bosma et al. 1998; Lee et al. 2002; Orth-Gomer et al. 2000). Moreover, among the 10 selected studies for CVD mortality, 2 produced RR estimates for mortality only (and not a mixed measure of morbidity and mortality) for men and women together (Brunner et al. 2004; Kivimäki et al. 2002) and 1 produced RR estimates for mortality and morbidity separately for women (Lee et al. 2002). Additional epidemiologic studies would be required in order to obtain more robust RR estimates for CVD for women and for mortality alone.

Our results for mental disorders are consistent with those summarized in the meta-analysis by Stansfeld and Candy (2006) (summary OR: 1.82, 95% CI: 1.06–3.10 using 2 prospective studies). Differences between studies may be due to differences in measurement of the outcome (self-administered questionnaire or diagnosis interview) or in the questionnaire used. The severity of health outcomes may vary across studies (for example, Shields (2006) included major depressive episodes). We reanalyzed the data from the GAZEL cohort to provide RR estimates of depressive symptoms for individuals exposed to job strain; the initial article considered the effects of demands and

Table 1 Included studies

First author Publication year Country	Study design and population	Exposure assessment	Outcome assessment	Adjustment variables
Association between job strain exposure and cardiovascular diseases				
Bosma 1998 UK	Prospective 10,308 men and women Civil servants (Whitehall)	Job strain	Coronary heart disease (diagnosis + Rose questionnaire)	Age and length of period
Brunner 2004 Finland	Prospective 812 men and women Employees of a metal working company	Job strain	Cardiovascular mortality (national death register)	Sex, age, height, father's occupational group, education, occupational group, and income
De Bacquer 2005 Belgium	Prospective 14,337 men 25 companies	Job strain (JCQ)	Coronary heart disease (clinical diagnosis)	Age, education, body mass index, smoking, diabetes, systolic blood pressure, serum total cholesterol, ISCO code, and company
Kivimäki 2006a UK	Prospective 7,253 men and women Civil servants (Whitehall)	Job strain	CHD death, a first non-fatal myocardial infarction, or definite angina (clinical records)	Sex, age, and grade
Kivimäki 2008 Sweden	Prospective 3,160 men 40 companies	Job strain	Ischemic diseases (hospital admissions + death records)	Age
Kivimäki 2002 Finland	Prospective 812 men and women Employees of a metal working company	Job strain	Cardiovascular mortality (national death register)	Sex, age, occupational group, smoking, physical activity, systolic blood pressure, cholesterol concentration, and body mass index
Kivimäki 2005 UK	Prospective 6,442 men Civil servants (Whitehall)	Job strain	Coronary heart disease morbidity and mortality (medical records)	Age, employment grade, effort–reward imbalance, and injustice at work
Kornitzer 2006 Europe	Prospective 21,111 men Various companies	Job strain (JCQ)	Acute coronary events or coronary deaths (clinical and hospital records)	Age, smoking, and systolic blood pressure
Kuper 2003 UK	Prospective 10,308 men and women Civil servants (Whitehall)	Job strain	Coronary heart disease morbidity and mortality (clinical records)	Age, sex, grade, cigarette smoking, serum cholesterol, hypertension, exercise, alcohol consumption, and body mass index

Table 1 continued

First author Publication year Country	Study design and population	Exposure assessment	Outcome assessment	Adjustment variables
Lee 2002 USA	Prospective 35,038 women Nurses	Job strain	Myocardial infarction + fatal coronary heart disease (medical records)	Age, follow-up period, smoking, alcohol intake, body mass index, history of hypertension, diabetes mellitus, and hypercholesterolemia, menopausal status, current use of postmenopausal hormones, aspirin use, past use of oral contraceptives, saturated fat intake, vitamin E intake, physical activity, parental history of myocardial infarction, education, marital status, and husband's education. Age only for the analysis of fatal CHD.
Netterstrom 2006 Denmark	Prospective 659 men Population-based study	Job strain	Ischemic heart disease (hospitalizations/deaths)	Age, social status, leisure time activity, alcohol, and serum lipids
Orth-Gomer 2000 Sweden	Prospective 292 women Population-based study	Job strain	Coronary heart disease (hospitalizations)	Age, estrogen status, educational level, diagnosis at index event, symptoms of heart failure, systolic blood pressure, diabetes mellitus, smoking, triglyceride level, and high-density lipoprotein cholesterol level
Uchiyama 2005 Japan	Prospective 1,615 men and women Population-based study	Job strain	Cardiovascular events (clinical examination and death)–9 cases only among women (not considered for women alone)	Age, (sex), mean SBP, BMI, total cholesterol, HDL-cholesterol, proteinuria, family history of stroke, left ventricular hypertrophy, ischemic ST-T change, atrial fibrillation, and current smoking
Association between job strain exposure and mental disorders				
Ahola 2007 Finland	Prospective 2,555 men and women Dentists	Job strain	BDI	Sex, age, marital status, and burnout at baseline
Bildt 2002 Sweden	Prospective 420 men and women Population-based study	Job strain	GHQ-12	None (men), and age, shift work, and poor quality of social contacts (women)
Bourbonnais 1999 Canada	Prospective 1,741 women Nurses	Job strain (JCQ)	PSI	Social support at work, hours worked/week, age, type A behavior, stressful life events, and non-work social support
Clays 2007b Belgium	Prospective 2,821 men and women 9 administrations/ companies	Job strain	CES-D	Age, educational level, social network, satisfaction with private life, locus of control, and baseline score for depression symptoms
Niedhammer 1998 France	Prospective 20,624 men and women Gas/electricity company	Job strain	CES-D	Age, marital status, educational level, previous absenteeism for mental disorders, stressful personal events, occupation, stressful occupational events, and social support

Table 1 continued

First author Publication year Country	Study design and population	Exposure assessment	Outcome assessment	Adjustment variables
Shields	Prospective	Job strain	CIDI	Age, married, child(ren) under 12, education, household income, white-collar, self-employed, multiple job holder, shiftworker, long working hours, job insecurity, and supervisor support
1999	3,830 men and women			
Canada	Household and institutional residents			
Shields	Prospective	Job strain	WMH-CIDI	Employment, occupation, working hours, shift work, self-employment, age, marital status, presence of children, household income, education, monthly drinking, emotional support, smoking status, personal stress, and co-worker and supervisor support
2006	20,095 men and women			
Canada	Population-based study			
Association between job strain exposure and musculoskeletal disorders				
Bildt	Prospective	Job strain	Low back pain (clinical diagnosis)	Age (men)
2000	420 men and women			Age and temporary employment (women)
Sweden	General population			
Canivet	Prospective	Job strain	Neck, shoulder, lumbar pain (Standardized Nordic Questionnaire)	Sleeping problems, mechanical exposure, country of birth, socioeconomic status, daily smoking, and alcohol consumption
2008	4,140 men and women			
Sweden	Population-based study			
Clays	Prospective	Job strain (JCQ)	Low back pain (Standardized Nordic Questionnaire)	Age, BMI, educational level, sector of employment, occasional back pain, smoking status, living situation, physical activity, physical effort, lifting heavy loads, rapid physical activity, awkward body positions, and awkward arm positions at work
2007a	2,556 men and women			
Belgium	9 companies and public administration			
Elders	Prospective	Job strain	Low back pain (Von Korff scale and scheme)	Age
2004	288 men			
Netherlands	Scaffolders			
Hannan	Prospective	Job strain (JCQ)	Neck-shoulder, arm-hand (exposure and symptom diary)	Gender, age, experimental group, history of neck-shoulder, or arm-hand symptoms, hours keying per week, and supervisory support
2005	337 men and women			
USA	Computer users			
Ijzelenberg	Prospective	Job strain	Low back pain, neck/upper extremity symptoms (Nordic questionnaire)	Gender, age, BMI, living alone, educational level, sports, manual materials handling, awkward back postures, strenuous arm movements, physical load, coworker and supervisor support
2005	407 men and women			
Netherlands	Industrial workers from 9 companies			
Josephson	Prospective	Job strain	Neck, shoulder, back pain (Nordic questionnaire)	Age, occupation
1997	565 women			
Sweden	Nurses			

Table 1 continued

First author Publication year Country	Study design and population	Exposure assessment	Outcome assessment	Adjustment variables
Krause 1998 USA	Prospective 1,449 men and women Transit vehicle operators employed by the San Francisco Municipal Railway	Job strain (JCQ)	Spinal injury (compensation claim)	Age, sex, height, weight, vehicle type, and physical workload (assessed by driving years, regular weekly driving hours, and hours of overtime driving)
Ostergren 2005 Sweden	Prospective 4,919 men and women Population-based study	Job strain	Shoulder/neck pain (modified Nordic questionnaire)	Age, mechanical exposure, marital status, country of origin, educational level, and pain from other regions
Rugulies 2005 USA	Prospective 1,221 men and women Public transit operators	Job strain (JCQ)	Low back or neck injury (compensation data)	Age, sex, race/ethnicity, height, weight, years of professional driving, driving hours per week, vehicle type, self-reported physical demands, low back/neck back pain at baseline
van den Heuvel 2005 Netherlands	Prospective 787 men and women 34 companies	Job strain (JCQ)	Neck/shoulder, elbow/wrist/hand symptoms (Nordic questionnaire)	Gender, age, flexion or rotation of the wrists, lifting, neck rotation, prolonged sitting, prolonged computer work, long working days, negative affectivity, and avoidance coping

latitude separately (Niedhammer et al. 1998). In contrast to CVD and MSD outcomes, a high proportion of studies on mental disorders (36%) had to be rejected because the statistical methods did not provide RRs.

Differences may be observed in the prevalence of health outcomes between countries, this has been demonstrated for mental disorders for example (Demyttenaere et al. 2004), but our results suggest that differences might not be significant in RRs associated with job strain exposure between countries. Indeed, our literature review on RRs (Figs. 1, 2, 3) showed that there may be a substantial overlap in the confidence intervals of RRs between studies/countries, reinforcing the pertinence of using an international literature review to obtain RRs for the calculation of AF estimates.

The selection rate for MSD studies was slightly higher than that for mental disorder studies (22%) and 11 studies were selected. RR estimates for MSD need to be interpreted with caution since studies retained in our selection focused on different MSD locations (back, low back, neck, shoulder, upper extremity, elbow, hand, and wrist) and used various measurements of outcome. Among the 50 studies, only 14 performed an adequate exposure assessment. This result emphasizes the need for additional epidemiologic studies based on a validated assessment of job strain exposure, and this conclusion may also be relevant for studies on mental disorders. The independent role of psychosocial work factors in the etiology of MSD has been questioned, and in particular the need to take biomechanical factors into account in the study of the association between psychosocial work factors and MSD. Among the 11 studies retained in our review, 3 did not include biomechanical factors as adjustment variables (Bildt et al. 2000; Josephson et al. 1997; Elders and Burdorf 2004). Therefore, 8 studies provided RR estimates, in our review, on the association between job strain and MSD after adjustment for biomechanical factors, such an adjustment being particularly useful. On the basis of these 8 studies, maximum AFs were 2.5% for men and 12.1% for women, supporting still lower fractions of MSD attributable to job strain.

Estimates of attributable fractions

Estimates of fractions attributable to job strain varied between 0 and 33.6% according to gender and health outcome. We considered that AF estimates for MSD may be null, given that two non-significant RRs were below unity. This result is in agreement with the literature showing an uncertainty about the effects of psychosocial work factors on MSD. Nevertheless, the calculation of AF may be justified even if causality has not been demonstrated to a high degree of certainty (Nurminen and Karjalainen 2001; Benichou et al. 1998; Olsen and Kristensen 1991; Walter 1998; Wilson et al. 1998).

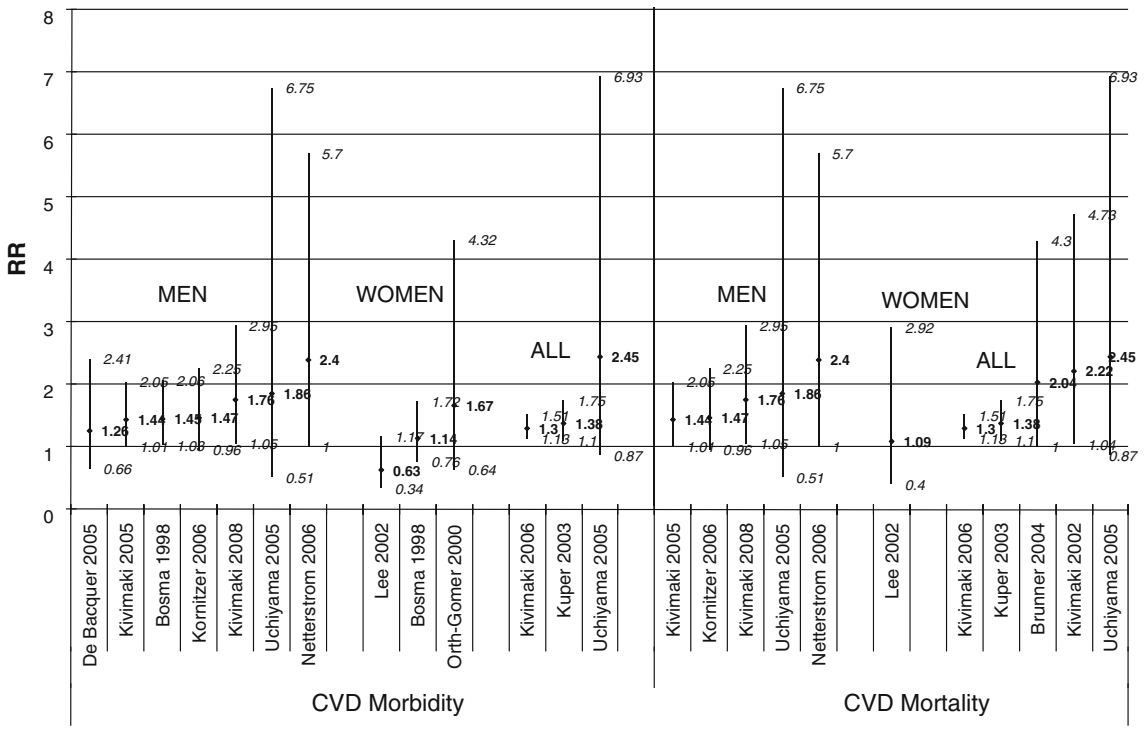

Fig. 1 Relative risk estimates (95% confidence intervals) for cardiovascular morbidity and mortality by gender

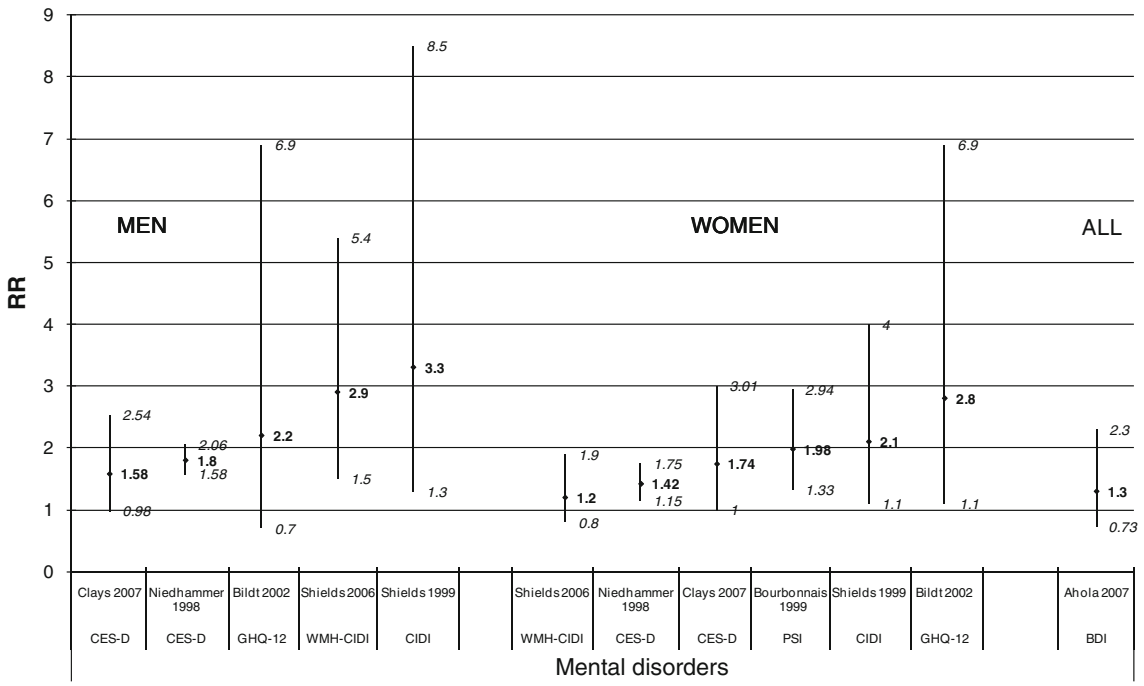

Fig. 2 Relative risk estimates (95% confidence intervals) for mental disorders by gender

Although more conservative, our results for CVD mortality are in line with those reported by Nurminen and Karjalainen (2001), who obtained estimates of 16% for men and 19% for women for the fractions of cardiovascular fatalities attributable to job strain in Finland (with the use of a RR of 2.0). A null AF estimate was found for CVD morbidity among women.

Our results for mental disorders agree with those of LaMontagne et al. (2008) who reported estimates of 13.2% for men and 17.2% for women for the fractions of

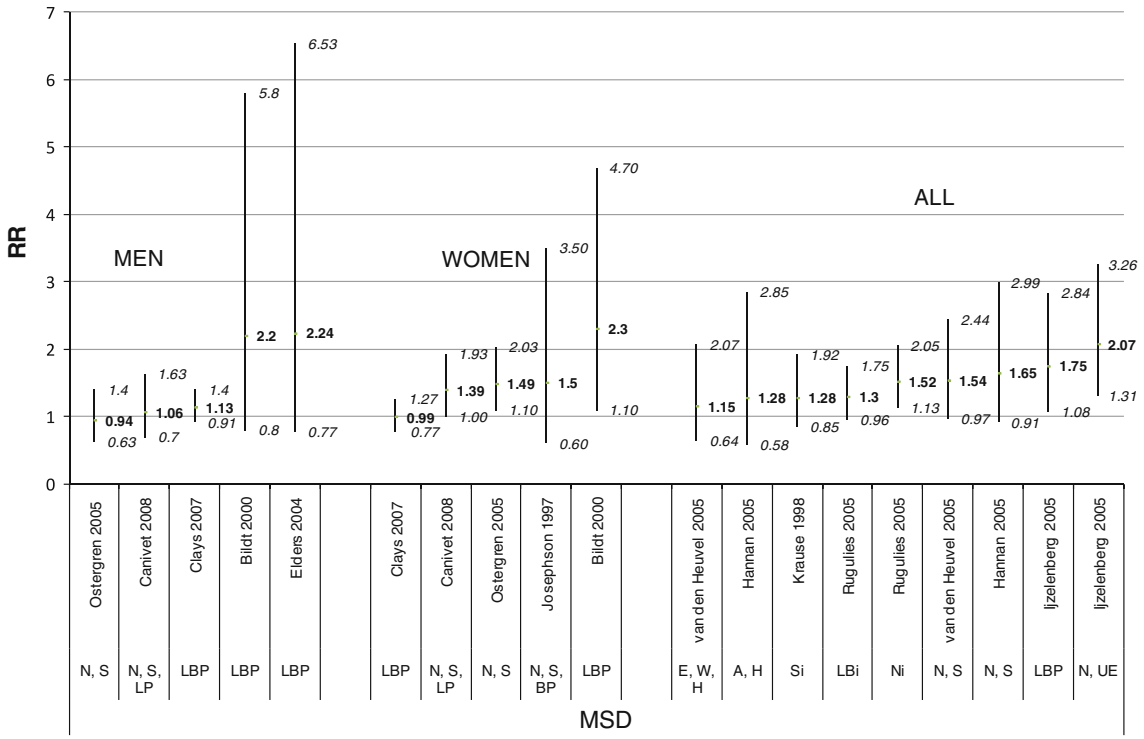

Fig. 3 Relative risk estimates (95% confidence intervals) for MSD by gender (*LBP* low back pain, *BP* back pain, *LP* lumbar pain, *LB* low back, *N* neck, *S* shoulder, *A* arm, *H* hand, *E* elbow, *W* wrist, *UE* upper extremities, *i* injuries)

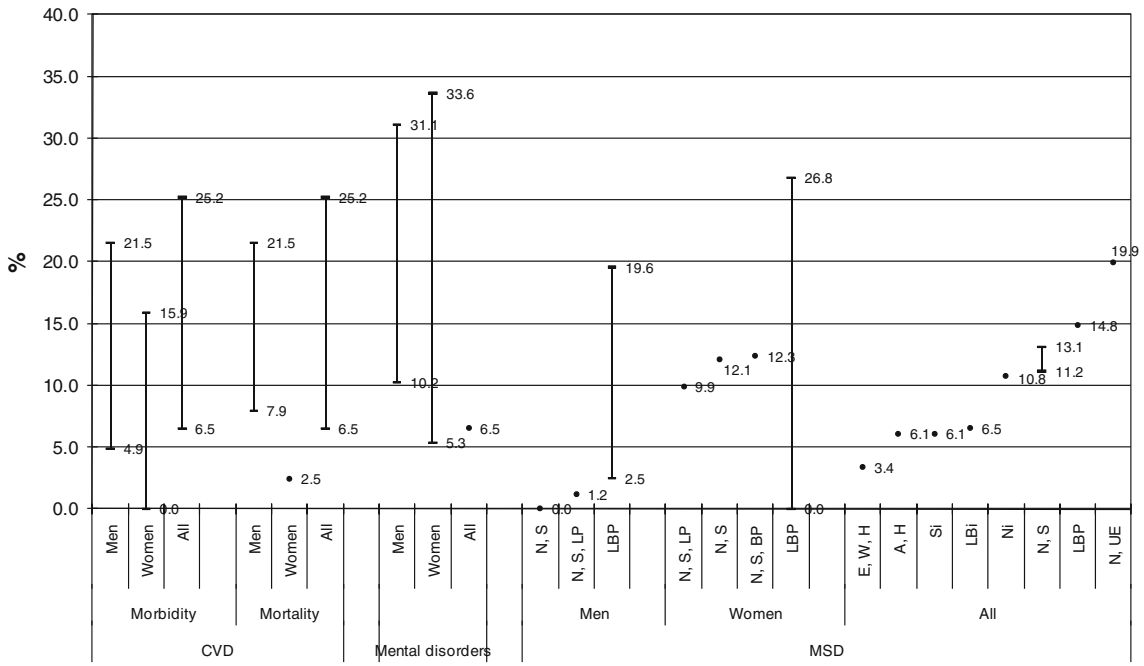

Fig. 4 Fractions of CVD, mental disorders, and MSD attributable to job strain (*LBP* low back pain, *BP* back pain, *LP* lumbar pain, *LB* low back, *N* neck, *S* shoulder, *A* arm, *H* hand, *E* elbow, *W* wrist, *UE* upper extremities, *i* injuries)

depression attributable to job strain in Australia. Their fractions resulted from RR estimates from Stansfeld and Candy's meta-analysis (2006).

As unadjusted RRs were not always available in the studies, we used adjusted RRs and the formula (1) that may produce biased estimates (Nurminen and Karjalainen

2001). However, our AF estimates may be more underestimated than overestimated as adjusted RRs were lower than unadjusted RRs in the studies that provided both. For example, the lowest AF estimate was 5.3% for mental disorders among women. This estimate, derived from Shields et al.'s study (2006), was based on an adjusted RR of 1.2. As this study provided an unadjusted RR of 2.0, we were able to calculate the AF using the formula (2), 7.3%. Consequently, our statistical strategy may be considered as conservative.

It would also be informative to produce AF estimates according to sectors and job titles, and especially for low-skilled occupational categories, such as blue-collar workers, clerks, or service workers, as these groups were found to be highly exposed to job strain in France (Niedhammer et al. 2008c). However, they would require not only data on the prevalence of exposure, but also RR estimates associated with job strain for these groups. Since very few studies produce RR estimates for these occupational groups, it was not possible to calculate AF estimates for high-risk groups. However, we calculated AF estimates for female nurses using the two selected studies in our review of literature, with RR estimates for mental disorders—1.98 (95% CI: 1.33–2.94) (Bourbonnais et al. 1999)—and for MSD (neck, shoulder, and back pain)—1.5 (95% CI: 1.1–2.1) (Josephson et al. 1997). Data from the SUMER survey provided an estimate of the prevalence of exposure to job strain of 26.5% for female nurses. As a result, the fraction of mental disorders attributable to job strain for female nurses was 20.6%, and the fraction of MSD (neck, shoulder, and back pain) was 11.7%. If data were available for high-risk groups, AF calculations would produce very useful information for preventive measures targeting those groups.

The key advantages of our AF estimates should be emphasized. First, studies included in our literature review used a definition of job strain exposure that was very close to the exposure assessment in the SUMER survey. Therefore, our AF estimates were based on a high similarity between relative risk and prevalence of exposure data regarding job strain exposure assessment. Second, we adopted a rigorous estimation procedure that involved a range of RR estimates for each outcome, rather than one single estimate, and were able to provide a range of AF estimates. This study may also permit preliminary AF estimates for other countries where the prevalence of exposure to job strain has already been evaluated at a national level. Such an analysis would produce international comparisons of the burden of diseases attributable to job strain. Moreover, our findings will be easy to revise as new data come to light.

Conclusion

This study emphasizes the importance of evaluating fractions of diseases attributable to job strain for measuring the global burden of diseases attributable to work stress exposure. Within this perspective, it will allow us to estimate the costs that could be avoided by a prevention policy designed to reduce (or eliminate) exposure to a risk factor. However, such an analysis based on a cost–benefit approach will need to consider the extent to which the risk of disease or mortality diminishes when exposure ceases. Unfortunately, little data has been published on this issue (Nelson et al. 2005). Nevertheless, demonstrating the magnitude of the global burden of disease due to a specific risk factor may help policy-makers when defining public health priorities.

Acknowledgments The authors thank Jean-François Chastang for his help with the data analysis of the SUMER survey, Anne-Marie Piketty and Boris Vieillard for their help with the search for bibliographic references, and the two anonymous reviewers for their constructive suggestions. This research was funded by the Agence Nationale de la Recherche (ANR), France (convention no. 05-9-30).

Conflict of interest The authors declare that they have no conflict of interest.

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