REVIEW

How is sex considered in recent epidemiological publications on occupational risks?

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Abstract

***Objectives*—Although women account for almost half the working population in industrialised countries, a sex bias persists in publications on medical research in general and occupational health in particular. The objective was to review recent publications on how sex is considered in epidemiological studies of occupational health, and to answer the following questions: are men and women studied equally, what are the respective characteristics of the studies which comprise only men, only women, and both, and what strategy of data analysis is chosen by the authors to take account of the sex factor in mixed studies.**

***Materials*—This review was based on publications in six journals during the year 1997, and included all the original articles reporting an epidemiological study of occupational health.**

***Results*—In all, 348 articles were reviewed. In 40 articles (11%), the sex of the study population was not specified. In 177 articles (51%), the study population was mixed. In 108 (31%), the population consisted exclusively of men, and in only 23 (7%), exclusively of women. Even when study populations were mixed, they included fewer women than men. The sex composition of the population was related to the occupational risk factor considered, and also to health outcome. Industrial sector workers, and exposure to chemicals were more likely to be studied in samples of men. Mortality and health outcomes such as neoplasms and cardiovascular diseases were also more often studied among men. Surprisingly, study design differed significantly according to the sex of the population, and prospective studies, cohort studies, and exposed versus non-exposed studies were more often carried out in samples of men. Among the 177 mixed studies, sex was not investigated in over a quarter (27%). In 26 articles (15%), sex was not taken into account, but the authors attempted to justify this decision. In 46 mixed studies (26%), the results were adjusted for sex, and in 46 (26%), the authors gave separate results for men and women. In 11 studies (6%), more complete strategies of data analysis were chosen, including research for interactions or adjustment, followed by stratification.**

***Conclusion*—This review of recent publications in occupational health epidemiology showed that women are still less often studied than men, and that the sex factor is not investigated in many mixed studies. The results therefore underline the need for further research on occupational hazards among women, and on sex differences.**

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In the countries of the European Union, as in the United States and Canada, women account for more than 40% of the working population[1–3]; this proportion has steadily increased since the mid-1960s. In France, the proportion of men at work is decreasing, but that of women is rising.[4]

Several years ago, women researchers stressed the sex bias characterising medical knowledge in general, and the field of occupational health in particular. They argued that the subjects, hypotheses, and designs of the surveys were more likely to involve men than women. For instance, a synthesis of all the studies of occupational cancer published between 1971 and 1990 showed that only 437 (35%) out of 1233 studies included white women.[5] In 1990, steps were taken by the National Institutes of Health in the United States to remedy the failure to include women as subjects of research.[6] Guidelines were adopted and a committee was set up to advise on research on women's health and to monitor compliance with the guidelines on the inclusion of women as subjects in surveys. In Sweden, there is a formal requirement for sex based analysis in all government activities, including those in occupational health. Consequently, a search program on sex and occupational health has been set up at the National Institute for Working Life (see Web site: www.niwl.se). To the best of our knowledge, there is no recommendation for research

projects on sex approved by the European Union.

In the field of occupational health, the results of research may vary substantially according to the sex of the subjects, for several reasons: firstly, there is a clear division of work according to sex, both in the labour market and in unpaid work. As women are engaged in work activities different from those of men, they are subject to different occupational exposures.[7 8] This division is so general that men and women in the same factories, and even in the same occupational titles, do not have the same working conditions.[9] Secondly, the prevalence of diseases and symptoms, health perception, and reporting are not the same for men and women.[10–15] Thirdly, health responses to exposure may be different for men and women due to biological differences—such as the effects of body fat or endocrinological factors.[16] On that point, workplaces are usually sized to male measurements, and women are more likely to report that their worksite is not well adapted to their size.[17] In the special case of pregnant women, the worksite is not adaptable to the body changes due to pregnancy.[18] Lastly, external factors—such as activities and work outside the job, and types of behaviour or living conditions—are different, leading to distinct patterns of confounders among men and women.[19]

For these reasons, epidemiologists in occupational health must, to draw reliable conclusions, be especially aware of the differences between sexes, and must pay special attention to sex when formulating hypotheses, designing surveys, and analysing data.

The aim of the present study was to describe how sex has been taken into account in the international contributions to epidemiological studies recently published in scientific journals on occupational health. More specifically, three questions were considered: (*a*) are men and women studied equally; (*b*) what are the respective characteristics of the studies which include only men, only women, or both; and (*c*) in mixed studies, what strategy of data analysis do the authors use to take account of sex?

Materials and methods

The regular 1997 issues of six epidemiology journals dealing with occupational health were reviewed (54 issues in all). This year was the most recent complete year when we began the review. Five journals were English language journals and one was a French journal. They comprised the following: the *American Journal of Industrial Medicine* (12 issues), *Archives des Maladies Professionnelles* (8 issues), *International Journal of Occupational and Environmental Health* (4 issues), *Journal of Occupational and Environmental Medicine* (12 issues), *Occupational and Environmental Medicine* (12 issues), and the *Scandinavian Journal of Work Environment and Health* (6 issues). According to our knowledge of journal contents, these journals were the most likely to include epidemiological studies in occupational health at the international level. The review included all the original articles that reported an epidemiological study of occupational health. Epidemiological studies of environmental health or approaches through other disciplines (ergonomy, toxicology, etc) were excluded. Literature reviews, meta-analyses, letters, and editorials were also not considered. Consequently, the selected articles were those based on quantitative and observational data aiming to improve knowledge on relations between occupational factors and health.

For each article reviewed, the following items of information were collected: name of the journal, country where the data were collected, sample size, the specification or not of the sex of the study population or absence of such specification, the numbers of men and women included, the occupation and economic sector of the study population, the occupational exposure and health outcomes considered, the scientific aim and design of the study, and the strategy of data analysis.

Three classifications were used to code occupations, economic sectors, and health outcomes, the French classification of occupations by the National Institute for Statistics and Economic Studies,[20] the French classification of activity sectors,[21] and the 10th version of the international classification of diseases (ICD-10).[22] Information on occupational groups and economic sectors was reduced to three categories: the agricultural, industrial, and service sectors. Five categories of occupational exposure were studied: chemical factors, ergonomic factors, psychosocial factors (job stress, shift work, etc), physical factors (noise, electromagnetic fields, etc), and biological factors (exposure to blood, animals, etc). Health outcome was classified into 21 categories, and for further analysis, into five main groups: diseases of the respiratory system, neoplasms, injuries, musculoskeletal disorders, and other. Surveys were classified according to their scientific aim, as descriptive studies, aetiology, evaluation of intervention, and methodological studies of evaluations of exposure or health outcome. The design of the surveys was defined as follows: cross sectional, cohort, exposed versus non-exposed, case-referent, and systematic registers. We therefore distinguished between prospective design, defined as evaluation of exposure before measurement of health outcome, and retrospective design. When population samples included both men and women, five strategies for data analysis were distinguished: no consideration of the sex factor, sex not taken into account but justification attempted, statistical adjustment for sex, stratification by sex, and more complete strategies such as a search for interactions or adjustment followed by stratification.

Statistical analysis was performed with SAS software[23]; data were analysed with Pearson's χ^2 test or Fisher's exact test and Mantel-Haenszel adjustment test.

Results

The review included 348 original articles published during 1997 in the six journals selected (table 1). Of these, 162 (46%) came from North America, mainly the United States, and

Table 1 Articles (n (%)) included in the present review, by journal and sex distribution (row %) of samples according to journal

			Study population (row %)			
	n	%	Sex unknown	Both sexes	Men only	Women only
Am J Ind Med	127	36.5	15.8	47.2	31.5	5.5
Arch Mal Prof	14	4.0	7.1	28.6	50.0	14.3
Int J Occup Environ Health	24	6.9	16.7	41.6	29.2	12.5
J Occup Environ Med	63	18.1	12.7	66.7	14.3	6.3
Occup Environ Med	85	24.4	7.1	47.0	38.8	7.1
Scand J Occup Environ Health	35	10.1	2.9	60.0	34.3	2.8
Total	348	100	11.5	50.9	31.0	6.6

Table 2 Sex distribution (row %) of samples according to economic sectors and occupational exposures investigated

	Study population				
	n	Sex unknown	Both sexes	Men only	Women only
Total	348	11.5	50.9	31.0	6.6
Sector:***					
Agriculture	21	14.3	42.9	33.3	9.5
Industry	181	11.0	45.9	41.4	1.7
Service	70	17.1	52.9	15.7	14.3
Other	76	6.6	63.2	19.7	10.5
Exposure factor:					
Chemical*	233	12.0	45.9	36.5	5.6
Ergonomic*	65	6.2	64.6	21.5	7.7
Psychosocial*	59	6.8	59.3	22.0	11.9
Physical	57	14.0	43.9	31.6	10.5
Biological	29	17.2	58.6	20.7	3.5

*p<0.05; ***p<0.001.
Each type of exposure was analysed separately, because several exposures may be studied in the same article. The distribution of sex for each exposure was compared with the distribution of sex for the other studies which did not deal with the exposure considered.

149 (43%) from Europe, mainly Scandinavia, reflecting in part the countries of origin of the journals. Thirty four (10%) articles came from the rest of the world (24 from Asia, five from Africa, and five from Oceania). For the remaining three (1%) articles, the country of origin was unknown.

SEX OF THE STUDY POPULATIONS

Of the 348 articles reviewed, 40 (11%) gave no information on the sex of the study population. This percentage varied from 3% to 17% according to the journal, but these differences were not significant (table 1). Given the occupational groups or economic sectors included in these studies, it may be assumed that in most cases, the population with unknown sex consisted of men. Nevertheless, because this was not explicitly stated, doubts remained about sex. In 177 (51%) of the articles, the study population included both men and women, and these articles were subsequently defined as mixed studies. In 108 (31%) articles, the population consisted exclusively of men, but only 23 (7%) of the studies were exclusively about women. The percentage of study populations composed of women only varied from 3% to 14% according to the journal, but without significant differences (table 1).

The sample was composed of 100 subjects or less in 56 (16%) of the articles, between 100 and 499 subjects in 127 (36%), between 500 and 9999 in 121 (35%), and 10 000 subjects or more in 37 (11%). For the remaining seven (2%) papers, the sample size was unknown. Sample size was not different, whether the sample included only men or only women. However, in 125 (77%) of the 162 mixed studies in which the sample size of each sex was specified, women comprised less than half the total sample. Furthermore, 31 (47%) of the 66 mixed studies which included 500 men or more included fewer than 500 women, compared with three (8%) of the 38 mixed studies based on 500 women or more which included fewer than 500 men.

SEX OF THE POPULATION ACCORDING TO CHARACTERISTICS OF THE STUDIES

A significant difference was found between studies from North America and those from Europe in the sex of the study population ($p<0.001$). Fewer studies from Europe than from North America were based on mixed samples (44% *v* 58%), and the sex composition of the sample was specified in more European studies. Thus, this composition was unknown in 7% of the European studies, compared with 15% of the North American studies.

The economic sector of the study population and occupational exposure differed greatly by sex composition (table 2). As 76 (22%) of the 348 studies were based on a population including several or all sectors of activity, they were coded as other in table 2. Ten (3%) articles did not study any occupational exposure, 260 (75%) studied one category of exposure, 54 (15%) two categories simultaneously, 21 (6%) three categories, and three (1%) four categories. Articles dealing with the service sector and exposure to psychosocial factors at work were more likely to be based on a sample of women only, those dealing with the industrial sector (mainly manufacturing firms and activities) and exposure to chemicals were more often based on men, and those dealing with service activities and exposure to ergonomic or psychosocial factors at work were more often based on mixed populations.

The health outcomes were investigated in 330 articles reviewed and were related to the sex of the study population (table 3). Data on health outcome were not collected from the remaining 18 papers because they were methodological studies focused, for instance, on the evaluation of exposure. Mortality data were included in 70 (21%) of the articles. These data were more often collected in studies of men only than in studies of mixed populations or samples of women only. Of the 330 studies, 30 dealt with all cause morbidity or mortality and were not classified according to health outcomes. Neoplasms were more often studied in articles based on men only, and injuries and poisonings were more often studied in articles based on populations in which the sex was unknown. Musculoskeletal disorders were studied in more mixed or female samples. Diseases of the circulatory system were all studied in samples of men, and diseases of the genitourinary system in samples consisting exclusively of women or men. Pregnancy, childbirth, and the puerperium were of course studied in women; however, one article on men only was

Table 3 Sex distribution (row %) of samples according to health outcomes investigated

	Study population				
	n	*Sex unknown*	*Both sexes*	*Men only*	*Women only*
Total	348	11.5	50.9	31.0	6.6
Mortality outcome**:					
Yes	70	8.6	41.4	48.6	1.4
No	260	12.3	52.3	26.9	8.5
Categories of the ICD-10:					
Diseases of the respiratory system	67	11.9	53.7	29.9	4.5
Neoplasms**	65	7.7	44.6	46.2	1.5
Injury, poisoning, etc***	46	30.4	47.8	19.6	2.2
Diseases of the musculoskeletal system***	40	0.0	75.0	15.0	10.0
Diseases of the nervous system	15	20.0	53.3	26.7	0.0
Mental and behavioural disorders	9	22.2	66.7	0.0	11.1
Pregnancy, childbirth, and puerperium***	9	0.0	11.1	11.1	77.8
Diseases of the circulatory system***	8	0.0	0.0	100.0	0.0
Congenital malformations, etc	7	14.3	57.1	0.0	28.6
Diseases of the genitourinary system**	6	0.0	0.0	66.7	33.3

*p<0.05; **p<0.01; ***p<0.001.
Each category of the ICD-10 was analysed separately because several diseases may be studied in the same article. The distribution of sex for each category was compared with the distribution of sex for the other studies which did not deal with the health outcome considered. The other categories of the ICD-10 had only ⩽5 articles each.

classified in this category because it dealt with sex ratio at birth in relation to fathers' occupations.

Two hundred and forty eight (71%) of the 348 studies were aetiological, 25 (7%) were evaluations of intervention, 33 (10%) were exclusively descriptive, and 42 (12%) were methodological. The scientific aim of these studies did not differ significantly according to sex of the sample.

Study design, however, did differ significantly according to the sex of the population (table 4). Cross sectional studies were more often in mixed samples, cohort studies, and exposed versus non-exposed studies in samples of men, case-referent studies in studies of women, and systematic collection (mainly from registers or national data) in studies without specified sex and mixed studies. Studies with a prospective design were more often in samples of men or in samples without specified sex than in mixed samples or samples of women. This relation between prospective design and the sex of the sample tended to persist after adjustment for health outcome (not shown, p=0.13). For instance, for articles on diseases of the respiratory system (n=67), 25% of the surveys of men had a prospective design, compared with 13% of the surveys of women, mixed sexes, or unspecified sex; for studies of cancer (n=65), these percentages were 33% and 17%, respectively. Furthermore, for each type of occupational exposure considered, men were more likely to be studied with a prospective design, especially when the exposure was a chemical or ergonomic factor (p<0.05).

Table 4 Sex distribution (row %) of samples according to study design

	Study population				
	n	*Sex unknown*	*Both sexes*	*Men only*	*Women only*
Total	348	11.5	50.9	31.0	6.6
Study design:***					
Cross sectional	97	12.4	60.8	19.6	7.2
Cohort	88	11.4	37.5	47.7	3.4
Exposed versus non-exposed	68	11.8	41.2	42.6	4.4
Case or referent	49	4.1	57.1	18.4	20.4
Systematic collection	46	17.4	63.0	19.6	0.0
Design:*					
Prospective	69	17.4	40.6	39.1	2.9
Retrospective	279	10.1	53.4	29.0	7.5

*p<0.05; ***p<0.001.

STRATEGY OF DATA ANALYSIS TO TAKE ACCOUNT OF SEX

In more than a quarter (27%) of the 177 mixed studies, sex was not investigated at all. In 26 (15%) studies, it was not taken into account in the analyses but the authors provided arguments in support of this decision. Another quarter of the studies (26%) gave results adjusted for sex, and a third quarter (26%) stratified results for men and women separately. The remaining studies (6%) adopted more complete strategies, including a research for interactions, or the use of adjustment and then stratification.

Strategy of data analysis did not differ according to the journal. Conversely, this strategy was strongly related to sample size: sex was not investigated at all in 57% of the studies of less than 100 subjects compared with only 14% of the studies of more than 10 000 subjects. Nevertheless, five (14%) of the 35 studies including at least 500 men and 500 women did not provide any analysis of women, even though the female population was sufficiently large. No other characteristic (economic sector, type of exposure, health outcome, or study design) was related to strategy of data analysis.

Discussion

The present systematic review of publications about occupational health epidemiology from six scientific journals during 1997 led to two conclusions: firstly, the occupational risks for working women are still less often investigated than those for working men, and secondly, the differences between the sexes are not given enough consideration in the choice of the strategy of data analysis. Many publications, more than 10%, do not even indicate the sex of the subjects included in the sample. Although it is easy to understand why both the type of occupational exposure and health outcome were related to the sex distribution of the sample, it is less obvious why a prospective design, considered to be the best by epidemiological standards, is more often used in samples of

men than women or mixed samples. Lastly, it was surprising that sex was not considered at all in the data analyses of a quarter of the studies which included both men and women, even when the samples were large enough.

Certain potential limitations of this review deserve to be mentioned. The choice of journals was based on our general knowledge of journal contents, which prompted the selection of those likely to contain many epidemiological studies on occupational health. Although there are other journals in this field besides those reviewed, the six journals chosen give a good picture of the scientific publications on occupational health epidemiology in English and French. When we started this review, we focused on the last complete year of publications, so that those considered would be as recent as possible. Increasing the number of years taken into account would have increased the precision of our descriptive estimations and the power of our statistical comparisons, but there is no reason to think that 1997 was in any way special in the consideration given to sex. In the hope that researchers' awareness of the importance of sex does not decrease with time, we think that a review of additional previous years of publications would either have changed none of our conclusions, or would have reinforced the trend of our results. The findings currently published in the scientific journals are obviously based on past surveys, and in particular, the prospective studies currently published may have been set up during the past 10 years or more, at a time when working women were less numerous and consideration of sex differences might have been less important. It may be assumed that future studies based on current prospective surveys will pay more attention to women's risks and sex differences in occupational health.

To our knowledge, the present study constitutes the first attempt to use a systematic procedure to describe how sex is, or is not, taken into account in the full range of scientific publications on occupational health epidemiology. Only one review has been published of sex in health research, dealing with the papers published in a general medical journal over 10 years[24]; in another, the epidemiological studies in occupational cancer research published in eight journals from 1971 to 1990 were summarised.[5] Here, we found that 11% of the articles reviewed did not mention the sex of the study population, and Hoosain *et al*[24] found that this was the case for 48% of the articles published in the *South African Medical Journal* from 1986 to 1995. The difference between these two percentages may be due to several factors—such as the evolution over the past decade, or differences in the peer review process, in disciplinary approaches or in geographical or cultural differences. In agreement with our results, Hoosain *et al*,[24] and Zahm *et al*,[5] found that significantly fewer articles had only women as subjects than those which only included men. Whatever the indicator selected to measure the extent to which the female population was studied (percentage of women, or number of women in the samples), these authors agreed that women are less often investigated than men.

How can this difference be explained in the framework of research on occupational risks? The first reason is that men are more often exposed to occupational exposures involving a risk of death. Men are more likely to be employed in the industrial sector as workers, and women are more likely to work in the service sector as clerks.[7 8] Men are also more often affected by severe diseases like cancer or cardiovascular disease before the ages of 60 or 65.[25] The need to prevent major risks of mortality has led researchers to focus on male populations. Consequently, this first reason for preferentially surveying men is due to public health concerns. A second reason, partly related to the first, is technical: epidemiologists need to survey numbers, and if possible, large numbers. For this purpose, it is easier to gather information about large samples of the population, for whom records going back many years are available, in large metallurgical or chemical factories—for example, which mainly employ men—than in services which mostly employ women spread throughout multiple work places. From this point of view, it is not surprising that nurses, and more generally hospital workers, are probably the working women most often studied. Another reason why women are less often surveyed, a purely cultural reason, is related to the place of men and women in the working population. Investigators implicitly have the feeling that working men adequately represent the entire working population, and that studying cancers as well as musculoskeletal diseases among men provides information that is valid for men and women. Conversely, women are often treated as special workers, and have to be studied when the subject is specific. This is why, in occupational epidemiology, the first field in which women were studied was pregnancy outcome, and the accompanying concern for the baby's health.[26] Women have more often been investigated for reproductive hazards at work than men (see review by Gold *et al*[27]).

When studies included both men and women, the sex factor was often ignored in the analysis: either it was not considered at all as was shown in our review as well as in the previous report,[5] or it was simply considered as a confounding factor like any other. Such procedures may lead to false conclusions. Thus, failure to consider sex may introduce a bias due to confounding if the distribution of health outcomes or occupational exposures were different among women and men. This bias may have two consequences: either it strengthens the association between occupational exposure and health outcome, thus leading to overestimation of an occupational risk, or it masks this association, thus preventing the identification of an occupational risk. However, considering sex only as a confounding factor may also be unreliable, if there is an interaction—that is, if the association between occupational exposure and health outcome is not the same (in direction or degree) among

men and women. Such an effect has been described among food processing industry workers in France in an analysis of the factors related to sickness absence.[17] Thus, when male and female workers were combined in a single analysis adjusted for sex, many of the associations that were found for a single sex were no longer found. In a recent study of musculoskeletal disorders of the upper limbs, Derrienic *et al* reported the same conclusion, drawn from a large sample of male and female workers.[28] This reasoning concerns the conventional epidemiological concepts of confounding and interaction.[29 30] Although they are not specific to either the sex factor or the field of occupational health, we think that researchers in this field must be especially aware of potential sex differences in their data analysis. No systematic rule can be formulated as to what constitutes a complete analysis, because the choice of strategy depends on the sample size and preliminary results. At least the data should be examined, especially the differences between women and men, for occupational factors, health outcomes, main confounding factors, and the associations between occupational factors and health. If the results are similar for men and women, they could be given for men and women combined. Lastly, researchers must explain to their readers how they deal with possible sex differences.

Our present study has focused on methods relevant to epidemiology of occupational risks, which have produced scientific results. These points are a contribution, with original and recent materials, to the investigation of sex and occupational health that have been more fully discussed by Doyal[13] and Messing.[9] Specially the division between paid work and unpaid work, based on social and economic considerations strongly related to sex, and the fact that epidemiology of occupational risks is restricted to paid work suggest that our results are only a small part of the bias under investigation. This leads to the conclusion that current research is not entirely adequate, even if promoted by the academic requirements and within the limits of an epidemiological approach to occupational risks. Our choice to limit the review to these six journals and to their regular issues also underlines this: undoubtedly we could find several special issues of scientific journals or books focused on women's situations but our results show that regular production of knowledge still maintains a bias related to sex.

In a comment on sex bias in health care, Ruiz and Verbrugge[31] explained that there are two approaches to sex bias in medicine: one can assume either absolute equality between men and women, or systematic differences between them. This duality is consistent with two extreme approaches to sex in sociology, radical equality or "differentialism".[32] In studies of occupational hazards, it is necessary to develop research that serves to identify both the similarities and differences between men and women.[16]

All over the world—in Europe, North America, and the developing countries—there is a need to investigate the health risks for women at work, in large samples of women in workplaces dominated by women, and, with mixed data bases, to investigate sex differences in health responses to occupational exposures. Also, it is always necessary to improve knowledge about workers' health, whatever their sex, and appropriate consideration of the sex factor in the strategy of data analysis would be helpful in this respect. To fulfil these objectives, journal editors and reviewers who evaluate papers submitted for publication in scientific journals have a part to play, as they must require authors to state the sex composition of the study population, and ask them to give explanations or detailed results from their analyses of the differences between men and women.

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