

and products (20%), prevention (20%), and scientific knowledge (14%).

The final survey questions looked into the researchers' views on future research and knowledge needs. As indicated by table 4, traditional work environment issues appeared to dominate. Consequences from societal changes in recent years also seem to have

had an effect on priorities, as well as the relationship between work and leisure time. Contributions to improved work conditions and individual differences in sensitivity and vulnerability were also frequently mentioned. The researchers had a tendency to mention ideas for future research close to their on-going research.

Table 4. Prioritized research areas by work environment research groups (number of responses by priority area).

Priority area	Number of responses
Analysis of new risks or deeper knowledge of old risks	35
Consequences of combined exposures	7
Studies of differences in individual sensitivity (primarily of physical exposures)	4
Attitudes towards work and its consequences, along with the relation between work and leisure time and the significance of recovery, rest, and sleep	22
Limitations to work ability and possibilities to work, as well as rehabilitation and issues concerning return to work	8
Questions around the organization and design of occupational health activities	7
Consequences of national or international rules in the area of the work environment	3

International evaluation of Swedish work environment research

by David H Wegman, MD,¹ Alex Burdorf, PhD,² Paul Oldershaw, PhD,³ Brigitte Schulte-Fortkamp, PhD⁴ & Eira Viikari-Juntura, MD⁵

The evaluation of research on the work environment focused on evaluating whether Swedish contributions to work environment research met international standards in quality, quantity, and relevance. The approach to this evaluation was organized into seeking a response to the following questions:

- Does work environment research address gaps in international research and significantly enhance the knowledge base or mainly repeat research that has been carried out elsewhere?
- Does work environment research pay adequate attention to engaging with the international research community?

- Do efforts in work environment research include knowledge distribution and knowledge implementation in addition to knowledge development?
- Does the research and its transfer provide a good basis for policy decisions, strategies, and activities to promote a good work environment?
- Does the structure in the support of work environment research appear appropriate and optimal?

The original international evaluation report has been somewhat edited for this supplement to make it more accessible to an international readership. Most of the relevant background information has been provided

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earlier in this supplement. The entire report is available from the Swedish Council for Working Life and Social Research (FAS). Brief comment is offered here on the system for registering worklife risks and their consequences, as well as on the funding of work environment research in Sweden.

Sweden has a well-developed national system for registering and surveying worklife, the work environment, health, and safety. The information system is constant, well standardized, well organized, and available for research. In spite of the high quality and reasonable coverage of the data systems, the picture still remains somewhat fragmentary. A well-structured Swedish worklife profile presented in a user-friendly format is suggested.

The total amount of funding for work environment research is substantial and was 275 million Swedish crowns in 2005. However, the structure for funding work environment research has become decentralized. Previously, most of the investigator-initiated funding available for application in work environment research had been organized within the Worklife Research Council (RALF). The funding available for open competition through the Council (100 million Swedish crowns in 1996 and 68 million Swedish crowns in 2000) was reallocated to the Swedish Council for Working Life and Social Research and the Swedish Government Agency for Innovation Systems (VINNOVA) in 2001.

Moreover, there has been a substantial reduction in funding from the two latter-mentioned organizations in comparison with the funding available from the Worklife Research Council before the split. Currently only 32 million Swedish crowns is available for open competition. In the case of the Swedish Government Agency for Innovation Systems, it seems to be a conscious decision not to make this kind of research a priority and, for the Swedish Council for Working Life and Social Research, the number of applications has decreased proportionally to the awarded funding. The "success rate" for applications seems to be around 15% of all applications, and several of the interviewed researchers indicated that they found it easier to get funding from other sources (eg, insurance companies).

Work environment research is conducted in a variety of large and small units. Some of these units are integrated parts of normal university structures, while some are private organizations, and some are part of the regional structure of the National Institute for Working Life, and the remainder are outsourced from this institute with uncertainty about long-term circumstances. This structure is not optimal and could probably be better coordinated to identify areas in work environment research of the highest concern and emerging issues. The absence of a coordinated structure may reflect the lack of transparent priorities of stakeholder needs for work environment research.

The funding support for these units is also complex. A mix of support from core university funds, earmarked university funds, the National Institute for Working Life, competitive research funding, and, increasingly, contracts with the labor market insurance company (Afa) and private industry make for a diffuse and unclear system. There is little evidence of priority-driven research funding, some of which would be desirable.

The following provides the body of the evaluation report by the International Evaluation Group organized into three major sections—evaluation of scientific production, quality, and relevance. At the end of the evaluation is the Group's response to the five posed questions and, finally, a list of recommendations.

Scientific production in work environment research

A bibliometric analysis was undertaken to evaluate two core aspects of the scientific production in Swedish work environment research, the quantitative contribution of Swedish research to the international literature, and the relative impact of Swedish articles in the international literature.

This analysis was carried out using two databases, an inventory of publications as reported to the National Institute for Working Life in Stockholm by research groups and the Web of Science database on publications in selected journals included in the Science Citation Index. The first database was used to describe the overall productivity of Swedish research in different fields, as well as the contribution to top journals in medical research. The second database was used to evaluate the quantity and quality of Swedish research relative to those of other countries.

Publications from Swedish research groups

The database from the National Institute for Working Life contains 1166 publications by Swedish groups in work environment research during the period 2001–2005. It should be noted that this database relies on self-reports by the research groups and thus may not represent the complete scientific production. However, a cross-evaluation with the database PubMed showed a strong correlation for scientific articles published in the international literature.

In the 5-year period 2001–2005, primarily journal articles (71%) and reports (16%) were reported, but also 39 doctoral dissertations and 12 licentiate theses. About 78% (N=647) of all of the articles were published in English language scientific journals. The analysis of the most frequently used key words and major fields shows that, with respect to the total scientific output,

the areas of “chemical and biological health risks” and “ergonomics” were far more productive than the area of “physical health risks”. Important subfields in the area of “chemical and biological health risks” were cancer, exposure assessment (including biological monitoring), respiratory disorders, and toxicologic studies. Important fields in the area of “ergonomics” were musculoskeletal disorders, psychosocial risk factors, physical load, and occupational physiology.

These 647 English publications were published in 215 different scientific journals, of which 10 journals in occupational health and ergonomics captured 36% of all the publications (table 6). These 10 journals were the ones thought best able to capture the most representative reports related to work environment research. It is worth noting that the researchers included in this evaluation also published in other well-known journals such as *The Lancet*, the *BMJ*, *Epidemiology*, *Spine*, the *American Journal of Epidemiology*, *Environmental Health Perspectives*, the

International Journal of Cancer, *Allergy*, *Pain*, and the *Journal of the National Cancer Institute*.

International comparison of the quantity of Swedish research

The Web of Science database on publications in the Science Citation Index was used to evaluate the relative contribution of Swedish authors to scientific articles published in peer-reviewed journals. According to the database from the National Institute for Working Life, 36% of all publications appear in seven occupational health journals with the highest impact factor in the subject category “public, environmental and occupational health” and three ergonomics journals with the highest impact factor in the subject category “industrial engineering” from the *Journal of Citation Reports*. It has to be kept in mind that these 10 journals do not reflect the position of Swedish research in some specialized fields, such as noise, indoor climate, cold environments, ionizing radiation, cancer, and respiratory disorders, since key publications in these fields often appear in specialist journals, where work-related issues compromise a small minority of the total publications.

This bibliometric analysis does not permit a structured evaluation according to the three areas distinguished in this evaluation (chemical and biological risks, ergonomics and musculoskeletal disorders, and physical factors). Physical factors will certainly be underrepresented in the selected 10 journals.

The impact factor and associated rank in the subject category illustrates that occupational health journals have a rather modest position relative to journals on epidemiology, environmental health, or public health (table 6). Within the subject category “industrial engineering”, ergonomics journals have a much better rank although a lower impact factor. The impact factor is a strongly criticized measure of the overall quality of a journal, but it is used by many researchers to select journals for the submission of their scientific work. Hence the bibliometric analysis in the 10 journals does not capture any shift among research groups to publish in high-quality journals outside the domain of occupational health or ergonomics.

Articles with at least one Swedish author contributed about 8% to the world production in occupational health and in ergonomics. Figures 6 (occupational health) and 7 (ergonomics) show the relative contribution of articles with a Swedish author, expressed by the average number of articles per year per 1 million inhabitants) in the period 2002–2005. In occupational health, Sweden ranks number 2 in the world, and in ergonomics Sweden ranks number 1 in the world.

A trend analysis was performed on publications of Swedish research in occupational health and ergonomics.

Table 6. Journals selected for the bibliometric analysis (2005).

Journal	Impact factor	Rank
Subject category “public, environmental and occupational health”		
<i>Occupational and Environmental Medicine</i>	1.93	34 ^a
<i>Journal of Occupational and Environmental Medicine</i>	1.89	38 ^a
<i>Scandinavian Journal of Work, Environment & Health</i>	1.82	40 ^a
<i>International Archives of Occupational and Environmental Health</i>	1.48	52 ^a
<i>American Journal of Industrial Medicine</i>	1.31	57 ^a
<i>Annals of Occupational Hygiene</i>	1.14	61 ^a
<i>American Industrial Hygiene Association Journal</i>	0.83	79 ^a
Subject category “industrial engineering”		
<i>Ergonomics</i>	0.93	5 ^b
<i>Applied Ergonomics</i>	0.73	12 ^b
<i>International Journal of Industrial Ergonomics</i>	0.53	16 ^b

^a Of 99.

^b Of 33

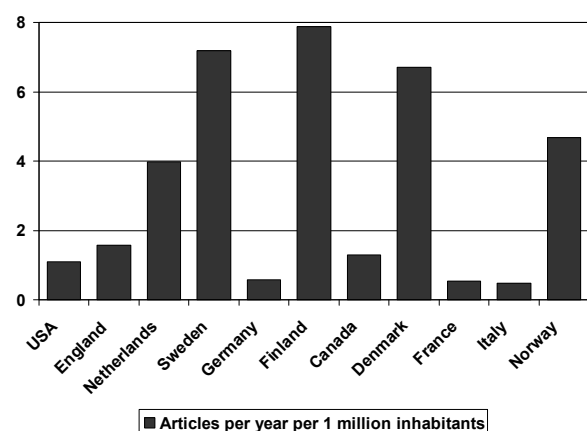


Figure 6. Productivity in occupational health journals by country in 2002–2005.

Table 7 shows that, in the past 20 years, the market share of Sweden in the total scientific output has remained remarkably stable.

One metric for measuring the overall quality of scientific publications is their citation rate (the number of citations per article per year). Although this metric has attracted severe criticism, it is one of the few available metrics that allows a cross-country comparison. The comparison in this evaluation report is again based on the articles published in the selected journals as described earlier, but citations may be from other journals as well.

In the past 5 years, Swedish articles were cited an average of 3.5 times, which ranks Sweden among the top five countries (table 8). Thus Swedish articles attract an above-average number of citations, suggesting that the quality of Swedish research is above the world average.

The collaboration index shows that, on the average, 28% of the authors of Swedish articles are from another country. An additional analysis showed that 38% of all publications with at least one Swedish author have at least one author from another country, most often the United States (24%), Denmark (21%), Finland (21%), Germany (18%), France (16%), Norway (14%), or the Netherlands (13%). This is a clear illustration of the international collaboration of research in Sweden.

Conclusions

Swedish researchers contribute about 8% to the world production of scientific articles in occupational health and ergonomics. Adjusted for country population, Sweden ranks number 1 in the world in this area. In the past 20 years, the market share of Sweden in the total scientific output has remained stable, around 8%. As measured by citations, the quality of Swedish research is above the world average. There is considerable international collaboration in research, mostly focused on the Nordic countries.

Quality of Swedish work environment research

The International Evaluation Group (comprised of the authors of this section) was asked to review research contributions in a select subset of the work environment (chemical or biological factors, ergonomics and musculoskeletal disorders, and physical factors). These areas are, of course, not uniquely distinct from other workplace risks, but they are reasonably coherent and have a long history of attention in Sweden. The assessment was focused on a relatively limited time period (5 years), which, by necessity, was constrained by the fact

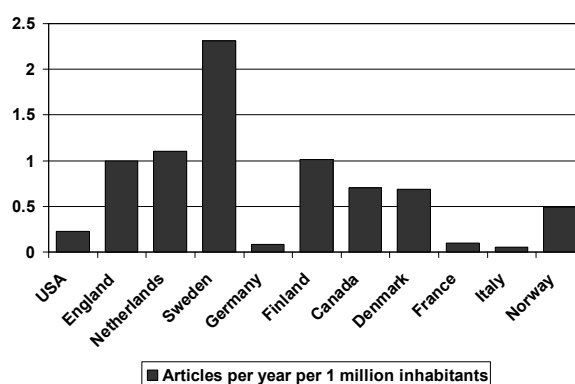


Figure 7. Productivity in ergonomics journals by country in 2002–2005.

Table 7. Proportion of Swedish and other countries represented in research published in the 10 selected occupational health and ergonomics journals over time (percentage of all papers in which a given country occurs).

Country	1986–1990 (%)	1991–1995 (%)	1996–2000 (%)	2001–2005 (%)
United States	38.5	38.4	37.8	35.7
England	10.8	9.7	10.7	12.3
Sweden	8.5	8.0	8.2	8.3
Canada	6.4	6.4	6.3	6.1
Netherlands	3.3	3.9	4.7	7.6
Finland	3.7	4.3	4.4	4.3
Japan	2.8	4.1	3.5	2.8
Germany	0.5	2.5	4.8	5.1
France	1.9	2.9	3.6	3.8
Italy	2.6	2.9	3.7	2.9
Denmark	2.2	2.2	2.8	3.6
Australia	1.5	2.0	2.2	3.3
Norway	1.1	1.8	2.1	2.3

Table 8. International collaboration and citation rate (impact) of publications in occupational health and ergonomics journals by country (2001–2005). (Note: citations to internationally co-authored papers have been fractionalized)

Country or territory	Collaboration index	Mean number of citations per article
United States	1.13	3.6
England	1.14	2.9
Sweden	1.28	3.5
Canada	1.24	2.8
Netherlands	1.27	3.8
Finland	1.30	3.1
Japan	1.19	3.3
Germany	1.34	3.1
France	1.29	2.4
Italy	1.24	2.5
Denmark	1.33	3.7
Australia	1.23	2.1
Norway	1.30	3.1

that many studies in process had not yet been published and that the published literature represents work undertaken over a rather broad time interval.

Most of the groups active in work environment research were asked to submit examples of their best research publications for direct inspection by the Evaluation Group. In response, the researchers submitted 2–10 research publications. The total number of submissions was 244, 103 of which addressed chemical or biological subjects, 91 concerned ergonomics and musculoskeletal disorders, and 50 dealt with physical factors. The evaluation was organized so that each paper was read by two members of the review team and assessed with respect to (i) the overall contribution and the degree to which the work filled critical gaps or were pioneering efforts, (ii) the contribution to methodology or the use of existing data or unique Swedish population resources, and (iii) attention to exposure assessment and applications (or potential) for intervention. Consideration was given to the standing of journals in which the research was published, as well as to publications that contributed through organized review or assessments of the published literature for an expanded understanding of the selected focus areas.

Chemical and biological risks

Description of the research area. Swedish work environment scientists continue to pay substantial attention to the study of chemical and biological risks. Advances in exposure assessment are considered important, and recent publications report on new metrics and approaches to exposure assessment for application in epidemiologic studies. In addition, notable are studies directed towards developing biomonitoring methods relevant to the guidance and evaluation of control efforts with special attention given to exposures related to dermatitis and dermal uptake. Attention is also focused on developing biomarkers for the noninvasive detection of outcomes, some of which could be useful in population studies. Population studies remain a strength, with studies presented that examine important work risks, particularly work-related respiratory conditions, cancer, and dermatitis. These efforts are enhanced by efforts to better characterize the background population incidence and prevalence of respiratory and skin conditions. Finally, there is evidence of attention to the study of the effectiveness of efforts to control work risks. These efforts have primarily been observation studies designed to assess the impacts of changes in work exposures systematically in a given industry, commonly examining change in exposure to carcinogens.

Members of the research community who responded to the survey of the National Institute for Working Life on Swedish worklife research (2005–2006) provided

their vision of important future research areas. Highlighted were research on skin exposure (methods and knowledge), user-friendly methods for exposure control and assessment, biomarkers, nanotechnology, and cross-scientific research, particularly the combination of epidemiology with molecular biology and occupational hygiene.

Evaluation of the contributions. Among the scientific publications reviewed, the International Evaluation Group found particular importance in the developments concerning biomonitoring, dermal exposure to specific chemical substances, and attention to improvements in retrospective exposure assessment in epidemiologic studies. Important advances have been made in the understanding of exposures related to conditions important to the Swedish workforce, including attention to agricultural workers and those in the service industries. These efforts include investigations to identify biological risk factor(s) that cause farmer's lung, as well as to determine the agents that are most worrisome regarding dermatitis among hairdressers and dental technicians. The application of retrospective exposure assessment methodologies is state-of-the-art in studies of cancer and respiratory disease. Biomarker exploration was appreciated in several studies, and attention to the understanding of the mechanisms of airway disease in association with exposure to organic acid anhydrides is promising.

An epidemiologic examination of large Swedish cohorts was included in several submissions demonstrating high-quality work in general. These efforts ranged from primarily descriptive cross-sectional assessments to an extended follow-up of a unique Swedish cohort. A descriptive study of the relationship between type of disability and type of occupation contributes to a better understanding of disability and potentially of disability trends. The follow-up of the important cohort of persons exposed to organic solvents provides greater appreciation of the long-term neurocognitive effects of these historical exposures. In addition, the application of biomarkers in population studies begins to reveal a deeper understanding of risks for cancer and asthma.

Although no formal experimental studies of intervention were presented, there were valuable systematic examinations of settings in which exposure has been reduced, for example, asbestos and organic solvents. Technology has also been designed for innovative application in promoting intervention on a task-specific basis by using video exposure monitoring to reveal exposure sources and the impact of improved controls.

In addition to formal scientific investigations, there were valuable contributions of a different sort. For example, Swedish researchers have played an important role in developing an internationally relevant statement on the occupational burden of respiratory disease

(statement of the American Thoracic Society). On a different scale, Swedish investigators have shown innovation in working with investigators in developing countries to adapt advanced exposure assessment technology for use in local circumstances. Examples include the application of video exposure monitoring and an assessment of dermal exposure to pesticides.

International impact and collaboration. Swedish research on cancer risks has a high standing internationally, especially through the approach to exposure assessment in risk studies. In addition, the investigations on dermal exposure assessment methods and the study of the relationship of exposures to dermatitis are notable. The long-standing work on occupational asthma has been important, and the international collaboration in this area is well recognized. Continued attention to the impact of organic solvent exposure on neurological function not only demonstrates the specific value of this research beyond Sweden's borders, but also provides a model for the type of longitudinal cohort investigations for which Sweden is appropriately recognized as an international leader.

Summary assessment. The epidemiologic studies in this area have utilized exposure assessment effectively in a range of studies on chemical and biological exposures. Studies of cancer and asthma risks remain a successful area of attention and positive contribution. Experience in these epidemiologic investigations and related exposure assessment expertise has been less focused on the development of exposure modeling than on the application of existing models to epidemiologic research.

Ergonomics and musculoskeletal disorders

Description of the research area. The approaches to exposure characterization include the development of strategy and measurement techniques for the assessment of physical exposures, using instruments ranging from questionnaires to video recordings, specific posture measurement devices, and electromyography. Analyses have been carried out to describe the physical and psychosocial factors in traditional and modern occupations and by gender. Lately, a system approach has been applied to assess the exposure determinants to model the exposure. Traditional and new production systems have been evaluated with this approach.

The prevalence and incidence of local musculoskeletal pain were the most commonly used outcomes in epidemiologic studies in this area. A community-based sample was used to assess physical and psychosocial risk factors for neck and shoulder disorders. Other studies assessed individual and work-related factors associated with seeking medical advice due to low-back

and neck disorders and factors affecting the course of symptoms and disability after a pain episode. A prospective study looked at risk factors for musculoskeletal pain among computer users.

Some groups explored the mechanisms of muscle pain by looking at inflammatory factors in work-related myalgia or the increase in such factors after various types of physical exercise in people with diagnosed work-related myalgia. Several research groups used electromyography to look at patterns of the recruitment of muscle fibers.

Rather few studies addressed sick leave and disability due to musculoskeletal disorders. They included a qualitative approach to factors that induce people to go on sick leave and, in turn, aid them to return to work. Other studies looked at the effects of musculoskeletal disorders on productivity and direct costs related to musculoskeletal disorders.

Among the few workplace intervention studies, a randomized study looked at the effects of giving feedback on workplace ergonomics and psychosocial data to workers and supervisors. Other trials assessed the effects of different types of exercises combined with cognitive approaches to neck and back disorders. Some studies compared worktasks and workload factors as a consequence of technical development and could be considered a description of the effects of a natural intervention.

In the survey conducted by the National Institute for Working Life, new areas that were emphasized included methods to be used in the assessment of the outcome of interventions, the development of tools to design better production systems, and the need for randomized controlled trials in workplace settings. A better understanding of pathophysiology in the development of disorders and better diagnostic tools were called for. A stronger connection between research in ergonomics and industry was considered beneficial.

Evaluation of the contributions. The measurement techniques developed for exposure are, in general, of high international quality. Research into the design of measurement strategies for postural load is of high international quality, and it utilizes a large international network. A promising area is production ergonomics, in which a production system is linked to the physical exposures of individual workers.

Although most cross-sectional studies on the determinants of musculoskeletal disorders among working populations had good quality, only a few prospective studies have been conducted that give new insight into the effects of physical and psychosocial risk factors and their combinations.

In research into the pathomechanisms of musculoskeletal disorders, research areas of high relevance for

occupational health included the effect of physical and psychosocial exposures and work patterns on motor recruitment. Methods for analyzing electromyographic signals have been developed to a high level. The role of inflammatory factors in muscle myalgia is a new area of research that has the potential to increase our understanding of the development of the disorders and provide insight for prevention. It also has the potential of providing methods for the early identification of musculoskeletal disorders. It is recognized that Sweden is one of the few countries in the world conducting research in this area.

The qualitative approach using the illness flexibility model to look at factors driving those with spinal pain to sick leave and back to work was assessed as highly innovative and methodologically qualified. An emerging research area was identified, namely, assessing direct and indirect costs of musculoskeletal disorders; this work is important with respect to evaluating the cost-effectiveness of interventions.

The few intervention studies that used a randomized design were, in general, of high quality. Most of them looked at the effects of various types of physical exercise and cognitive techniques on neck and low-back disorders. Among the few studies in workplace settings was a cluster-randomized trial that addressed the effects of a short feedback discussion of ergonomics and psychosocial work environment data to individual workers, supervisors, or the work group as a whole.

Interviews among the researchers in this area provided evidence of a lively debate concerning differing concepts of the proper design and nature of intervention studies. They ranged from the view that such studies should only be accepted if they were randomized controlled trials applying interventions decided in advance at one extreme to following and documenting a naturally occurring development in industry at the other extreme. The broad spectrum of methodologies appropriate to the range of study types seems to be well represented in the Swedish research community in this area.

International impact and collaboration. Research in the measurement and evaluation of physical loads is of high international quality, and an extensive international collaborating network has been established. Sweden has a strong tradition in research into the pathophysiology of musculoskeletal disorders and continues to produce research of internationally high quality.

Summary assessment. Strong areas of research include the measurement and evaluation of physical loads at the workplace and the application of this knowledge in the design of new workplaces. This research area is of great international importance and contributes to filling a gap in knowledge. The use of this knowledge has,

however, been limited in observational epidemiologic and intervention studies. Sweden is internationally one of the few actors in research into the pathophysiology of musculoskeletal disorders. This area was assessed to have continuing high productivity and is extending to new approaches. The application of this knowledge into the prevention of work-related musculoskeletal disorders was, however, limited to relatively few areas.

Physical factors

Description of the research areas. In the area of physical risks, the papers broadly covered the key areas of temperature extremes, fatigue, sleeplessness and temperature, electromagnetic radiation (including potential health risks of mobile telephones as a major issue and of public concern), noise effects (ranging from physical health risk to annoyance, speech and noise), noise and performance, classroom acoustics, and low-frequency noise. Several papers addressed the health risks of vibration. There were also examples of scientific work being converted into guidance and other interventions, particularly in the area of electromagnetic radiation as a matter of public briefing.

In the survey of Swedish research on worklife conducted by the National Institute for Working Life in 2005–2006, noise was the most frequently mentioned area for future research with respect to physical factors. There was interest expressed in electromagnetic fields and the health effects of new technology. Several groups mentioned the problem of research on combined exposures, which requires cross-discipline cooperation. Among the cited examples were stress and physical exposures, stress injuries and heart disease, noise and vibration, and ultraviolet radiation and chemical exposures. Another area of importance is climate and vision.

Evaluation of the contributions. The overall quality of this work is of good standard, addressing continually important concerns and representing high scientific challenge. The studies use standard methodologies adapted to particular circumstances and related to current problems in modern societies. We did not note any innovative approaches, but established procedures were applied well.

Swedish expertise in the thermal environment has been developed over several years and was represented by several high-quality papers related to standards and worker protection. The assessment of possible cancer risks from the use of mobile telephones, a major health concern, has been a well-researched target in Sweden, as represented in the research reviewed by the International Evaluation Group. Research on the effects of low-frequency noise on the performance of sensitive persons

builds competently upon the strength of this Swedish work over several years.

The research on the health risks of cold environments and on the health risks of mobile telephones are clearly of high importance in Sweden, and the research is also well targeted towards international concerns about both. Many aspects of noise and its effects are being researched in Sweden, and they particularly address health risks and life quality. Classroom acoustics, a major international issue, is being well investigated. Work on understanding the effects of low-frequency noise fills important gaps in national and international knowledge. There was an effort to understand and control the risks in nontraditional workplaces, particularly in teaching and in call centers.

Health effects due to thermal environments, noise and vibration, and low-frequency noise are clearly important and were well investigated. Aspects on measurement strategies, whole-body and hand-arm vibration syndromes, including neurological effects, were well performed.

International impact and collaboration. An excellent example of international collaboration was observed between leading researchers from five countries (Sweden, the United Kingdom, the Netherlands, Belgium, and Finland) in developing temperature limit values for cold touchable surfaces. This contribution to international standard setting has had a high impact. Collaborations were noted between several research groups in exploring the hypothesis that there are patients with perceived electrical hypersensitivity. This joint work permitted the use of a range of investigative techniques.

In the interviews with work environment researchers, the International Evaluation Group was informed that the successful experiences of some researchers in obtaining EU funding was proving to be important with respect to the sustainability of the research. In one instance, this effort had been proceeding well for 10 years.

Summary assessment. There is a diversity of research in the field concerning physical factors, some of which was quite impressive. However, the research reviewed covered a wide range of topics, and it is difficult to determine how well aspects of the most relevant factors are being addressed as a whole. Much of the work had direct practical relevance. There was an appreciation of the need for effective knowledge transfer.

Relevance of the research on the Swedish work environment

Stakeholders

The evaluation of relevance is discussed from the point of view of funding and enforcement, ministries, trade

unions, and employers, and it is based on data from and interviews with the stakeholders.

The Swedish Work Environment Authority (SWEA) continues to benefit from criteria documents that incorporate literature reviews and assessments of exposure-response for guidance in controlling work exposures. The Authority has identified, however, a need for more research in order to become more proactive (eg, epidemiologic studies on the effects of some common chemicals and, especially, mixed exposures). In addition, human factors and work organization were recognized as areas needing more research. The Authority has no official forum for the continued discussion of research priorities.

Both the trade unions' and employers' representatives clearly expressed the message that they are not well informed about on-going research projects. There is information in publications, brochures, and websites, but the social partners have difficulties in finding the essentials and how to use them in practice. They expressed a multitude of research needs, including the functioning of respiratory protective equipment in real work situations, how to deal with electrical sensitivity, how to handle the directive on electromagnetic fields, and the like. Practically oriented interactive workshops between researchers and workers to communicate research results were commended.

The assessment of relevance is affected by the notion that the different stakeholders use partly different sources of data to identify problems and follow trends in the work environment and health. There is no established mechanism through which stakeholders can organize and communicate with research scientists about what the needs for knowledge transfer are.

The unavailability of representatives from the government and the occupational health services prevented the assessment of the roles of these stakeholders in the setting of priorities.

Knowledge transfer

Work environment research addresses existing and potential future risks to the workforce in the rapidly changing world of work. It often provides knowledge that can be effectively extrapolated to be informative about the risks to the general population. It can have great relevance to human health and well-being and also to industrial development and economic growth. The wide "stakeholder" group needs to be considered in the prioritization and definition of research and in attempts to gain the greatest value from the activity. The International Evaluation Group sought examples from the research community on how these issues were being addressed. Effective means of ensuring that research activity led to practical outcomes was especially

searched for. It should be clearly pointed out that the Group could not refer to any evaluation of implementation or any end user's ranking. No such evaluations or rankings were received.

Research groups were asked to submit a maximum of three examples of the application or communication of knowledge. In the areas of ergonomics and musculoskeletal disorders, chemical and biological risks, and physical factors, several contributions were identified, for example, articles in vocational journals, brochures, leaflets, websites, conferences and workshops, education and training, standards, and guidelines.

Several products in the area of chemical and biological risks were brought to the Group's attention. Most of the products were designed for direct users (eg, risk assessment for hairdressers in magazines and as training tools for apprentices). Concerned with exposure assessment, some groups provided information through workshops addressing the indirect user (eg, companies and manufacturers). A statement of the American Thoracic Society on the burden of occupational factors was directed at professionals. A notable example of a high-impact product was the use of visualization techniques, in which measured exposure levels were superimposed on a video of work activity. Application of these techniques in work settings indicated effective communication to managers and workers concerning the source of risks, as well as the impact of controls.

In the area of ergonomics and musculoskeletal disorders, several useful products were submitted to illustrate the transfer of knowledge into practice. Most of the products were aimed at direct users and some at the general public. A website containing information on various areas in agriculture was considered to be well structured and to contain in-depth information on important technical, ergonomic, and environmental protection aspects. In collaboration with two research groups in production ergonomics, a tool was developed for designers that encompassed aspects of production and material flow together with physical risk factors for the worker. The development of a patented welding visor is an example of a product with producer(s) and end-users as target groups.

In the physical factors area, products were submitted with respect to direct and indirect users. The provided examples included international standards addressing the public input to the setting of regulations, electronic information about cold touchable surfaces, direct practical advice for the reduction of risks such as radiofrequency exposure, and brochures in voice training for teachers with respect to gender differences. The complex issue of health risks related to mobile phone use was helpfully described in a leaflet for a wider public audience.

The Evaluation Group recognized the many different approaches by the research community in disseminating

the results of its work, but noted that clear performance indicators for societal impact were generally lacking.

Summary evaluation and recommendations

The evaluation of research on the work environment was focused on determining whether Swedish work environment research is of international standard in quantity and quality and of relevance for society. In undertaking this task the International Evaluation Group formulated several fundamental questions identified at the beginning of this chapter. Here these questions are answered.

Does work environment research address gaps in the international research, significantly enhance the knowledge base, or mainly repeat research carried out elsewhere?

Sweden plays a significant role in enhancing the international knowledge base for work environment research. The bibliometric analysis provided direct evidence of the high standing of research when compared with that of other leading nations in the major work environment journals. In the judgment of the Evaluation Group, Swedish work environment research is located among the top three in the world. In several areas, outstanding contributions were identified. Research in all three of the examined areas of work environment research was found to have good quality, relevance, and a sufficient balance between new areas and developments in existing areas of study.

Changes in the funding of work environment research and the structures of the research organizations may place this standing at some risk. The Evaluation Group has some concern that the current high level in the quantity and quality of work environment research cannot be maintained without recognition of its importance and continuing support. To guarantee the sustainability of the research community, it is of crucial importance to support the recruitment of young researchers and provide opportunities for career development.

Does work environment research pay adequate attention to engagement with the international research community?

The Swedish work environment research community has, for some time, been collaborating with international partners. This engagement is consistent with that of the other major contributors to work environment research in western Europe and North America. More international collaboration in some areas of work environment research would benefit the international community, as well as the Swedish work environment research community.

Do the efforts of work environment research include knowledge distribution and knowledge implementation in addition to knowledge development?

The evidence of knowledge transfer is uneven, both in terms of the translation of scientific research into information widely available to the public and other stakeholders and in terms of transferring the research findings into practice. Some researchers have made great efforts to engage in knowledge transfer, but the social partners expressed a greater need for such a transfer. There appears to be a gap between research and practice that needs further attention in Sweden.

Do work environment research and its transfer provide a good basis for policy decisions, strategies, and activities to promote a good work environment?

Work environment research is largely relevant to policy considerations but could be supplemented by more attention to research related to the surveillance of current work conditions in Sweden and to the identification of emerging risks. The communication of the research findings in a form useful with respect to the needs and actions of work environment policy could be improved.

Does the structure in support of work environment research appear appropriate and optimal?

The structure for work environment research has, in recent years, become decentralized. Now, work environment research is conducted in a variety of large and small units. Some of these units are integrated parts of the normal university structures, some are part of the regional structure of the National Institute for Working Life, and the remainder are outsourced from the National Institute for Working Life with uncertainty about long-term circumstances. This structure is not optimal and needs to be better coordinated. The absence of a coordinated structure suggests inadequate prioritization of research needs.

The funding support for these units is also complex. A mix of support from core university funds, earmarked university funds, the National Institute for Working Life, competitive research funding, and, increasingly, contracts with labor market partners (Afa), and private industry makes for a diffuse and unclear system. There is little evidence of priority-driven research funding, some of which would be desirable.

Summary assessment of strengths and weaknesses

The International Evaluation Group has evaluated the strengths and weaknesses of Swedish work environment

research, and a summary follows, representing key issues identified and discussed during the evaluation.

Strengths

- Extensive well-kept registers and survey systems that provide data on trends in health outcomes for priority setting and a well-organized basis for epidemiologic studies
- Well-functioning networks between researchers, social partners, and authorities providing the opportunity for good access to workplaces and information on current and emerging problems
- Existence of funding organizations that clearly identify work environment research in their objectives
- Research covering a wide range of important work environment issues and providing depth in knowledge that appears relevant to the Swedish work environment
- A large contribution on the part of Sweden to the global knowledge base in work environment research, as demonstrated in the bibliometric analysis
- Excellent expertise with respect to respiratory disorders, cancer epidemiology ergonomics, climate, and electromagnetic field research providing international leadership in these areas
- Close collaboration between university departments and occupational medicine clinics presenting unique opportunities for relevant research
- Good opportunities for doctoral education with a constant high production of doctorates in work environment research
- Good access to an open research structure
- Strong competence in measuring exposures in all of the studied areas of work environment risks.

Weaknesses

- Clear priorities for work environment research not evident and effective priority setting not apparently in place
- Existing survey data on work environment issues not well utilized to drive priorities in funding work environment research
- Inadequately developed hazard surveillance systems and systematic horizon-scanning for emerging work environment risks of concern
- Insufficient multidisciplinary research and the need to better develop networks among and across work environment research disciplines, along with other disciplines of worklife

- Project funding covering 3 years or less limiting effective studies in some highly required areas, such as longitudinal epidemiologic and intervention studies
- Insufficient research funding mechanisms organized specifically to promote the development of the work of young scientists undertaking their own research
- Decreasing funds for open-call researcher-initiated projects that might threaten both innovation and the sustainability of research in this area
- Long evaluation processes of research applications inhibiting rapid response to emerging problems in work environment research
- Age structure of research leadership a threat to the sustainability of work environment research
- Insufficient attention to the study of intervention effectiveness
- Insufficient research directed towards exposure modeling and its role in understanding exposure–risk relationships
- Knowledge interchange between stakeholders and researchers needing strengthening

Recommendations

Funding

1. In order to maintain the current high quantity and quality of work environment research, it is essential to maintain funds specifically dedicated to this research area and open for applications to include both personnel and equipment. The amount of funds available through the Swedish Council for Work Environment Research (RALF), 6 years ago, should at least be re-established

The bibliometric analysis of Swedish work environment research demonstrated a high production of good quality. The evaluation of the quality of submitted research contributions by the International Evaluation Group confirmed the good quality of research in both established and new areas. This high profile of work environment research in Sweden can only be maintained with due recognition and visibility in the allocation of resources within research organizations.

There are several uncertainties about the future of funding for work environment research. The most important of these are the reduction in support of the National Institute for Working Life, as well as the stability of research funds that have been reallocated from this institute to the universities. The International Evaluation Group raises concern as to the absorption of support for work environment research into larger research structures [for example, The Swedish Governmental Agency for Innovation Systems (VINNOVA)]

addressing all aspects of worklife or adjacent domains. The International Evaluation Group strongly recommends that the Swedish Council for Working Life and Social Research (FAS) continue and expand its program in work environment research.

The overview of the finances for work environment research shows that public funding through open calls by the Swedish Council for Working Life and Social Research accounts for only approximately 10% of the total budget available for work environment research. The International Evaluation Group is of the opinion that this small proportion of “free money” hampers the development of innovative, new research. Hence the Group strongly recommends a more appropriate level of funding be established through open calls with at least the amount of funds available through the Swedish Council for Work Environment Research, 6 years ago.

2. The duration of projects to be funded in open calls should provide options for funding up to 5 years. This change would greatly enhance the possibility to conduct longitudinal epidemiologic and intervention studies for which there is a high priority.

The current structure of funding has a large impact on the design and content of research projects. In some areas, projects cannot be carried out successfully within a time frame of 3 years. Epidemiologic studies to characterize exposure–response relationships generally require a longitudinal design, and the latency period between first exposure and the incidence of disease may dictate follow-up periods that exceed 3 years. Furthermore, with a 3-year maximum grant duration, intervention studies can only be carried out for risk factors with short-term effects. The International Evaluation Group recommends that the Swedish Council for Working Life and Social Research (FAS) consider more flexibility in the acceptable duration of projects eligible for funding.

3. Rapid assessment processes should be established for smaller project plans to facilitate pilot studies with novel approaches and rapidly emerging issues.

The current structure of funding agencies relies strongly on well-established procedures for the submission and appraisal of applications through extensive peer-review processing and prioritizing. Given the standard time interval between application and the final decision, strong consideration should be given to establishing a fast track procedure for projects of short-term duration. The International Evaluation Group notes that sometimes rapidly emerging issues require a rapid response of researchers that is not possible in the regular funding process. This mechanism could also be considered for seed grants that allow researchers to investigate the potential use of novel approaches in larger,

well-designed studies for a limited period of time or to develop pilot data for the early and conceptual stages of projects that address new hypotheses.

4. *There is a need for a better integration of different domains of knowledge in order to address multifactorial work-related health problems. Interdisciplinary research projects should be encouraged through funding strategies.*

Work-related health problems are often multifactorial in nature and call for input in research projects from different disciplines. The International Evaluation Group has noted that Swedish work environment research has established national and international collaborative networks, but collaboration across different disciplines should be improved. Funding agencies should actively encourage applications on interdisciplinary research and establish mechanisms to fund these collaborative proposals from different programs.

Commission to examine the work environment research structure

The complex state of the research structure and financial support related to and coupled with the apparent lack of a systematic priority setting scheme for identifying the areas of work environment research of highest concern lead to the recommendation to establish a high-level commission. Such a commission should examine the organizational structure in support of work environment research and the setting of priorities and suggest the best funding options to deliver the most appropriate research.

The examination of the extensive materials submitted, accompanied by interviews with both researchers and other interested parties, revealed a very complex state of the research structure and financial support related to work environment research. This fact, coupled with the apparent lack of a systematic priority setting scheme for identifying the work environment research areas of highest concern, make it uncertain how or whether the current structure and funding of work environment research are organized in the best way to serve the needs of Swedish worklife. We suggest that a full understanding of the priorities and the level of resources (both personnel and financing) necessary to address these priorities is essential. To achieve this understanding, the most efficient and effective way would be to establish a high-level commission with representatives from the government, the social partners, funding agencies, and members of the research community.

Sustainable resources

Research institutions should actively pursue the career development of competent work environment researchers

in order to guarantee sustainability. Such activities could include support to attract recent postdoctoral scientists early in their careers and means to stimulate mid-career researchers. Funding mechanisms in support of such activities should be encouraged.

The demographic development in many research groups showed that most research leaders are over 55 years of age and will retire within the next decade.

The lack of possibilities for career development will not only affect research capacity but also discourage excellent students from considering a career in work environment research. This situation raises serious concerns about the sustainability of work environment research. During the interviews with research leaders, this problem was singled out as one of the most urgent to be addressed. An active approach is required to identify and recruit future research leaders and to support and supervise their personal development towards a senior position with full responsibility for the acquisition, research, and management of a research group. Funding agencies should establish appropriate means to support active career development (eg, grants for sabbaticals and study trips).

Important research areas to be developed

1. *Research on exposure assessment modeling and related risk modeling needs to be strengthened. This recommendation includes research on exposure variability, which factors determine exposure patterns, and how this knowledge is applied in the design, conduct, and interpretation of epidemiologic studies and workplace interventions.*

In all three areas of work environment research, the techniques and methods for the measurement and evaluation of exposure are well developed. However, the International Evaluation Group observed that, in epidemiologic and intervention studies, the focus is on the application of existing exposure assessment methods and that there is less attention being paid to methodological development in exposure strategies and exposure modeling. In recent years, statistical techniques have become available that allow a simultaneous evaluation of the magnitude of variance components, as well as determinants of this variability. These techniques are powerful instruments in the design of measurement strategies in epidemiologic studies and in the implementation of control and prevention strategies to reduce hazardous exposure. The incorporation of advances in biomarker research will benefit this work as well. The International Evaluation Group recommends targeted research in this area to improve further the quality of epidemiologic and intervention studies.

2. *More systematic intervention studies are needed. There is a major need for the development of scientific methods for determining the efficacy and effectiveness of interventions. It is also recommended that more attention be paid to the use of appropriate study designs and methods for exposure and outcome assessment in intervention studies, along with economic evaluation techniques. Interdisciplinarity is likely to be important in achieving this objective.*

The International Evaluation Group observed that research is mainly focused on risk identification, the occurrence of health problems in different occupational groups and workplaces, and the characterization of exposure–response associations. Research into the effectiveness of interventions is less well developed. The Evaluation Group acknowledges that intervention studies are difficult to conduct, but, with the growing understanding of exposure–response associations, a shift is needed towards intervention research. Therefore, we recommend a substantial increase in resources being allocated to intervention studies. Insight is needed into the use of appropriate study designs, varying from natural experiments to quasi-experimental designs and randomized controlled trials. Development is required in strategies to better characterize exposure patterns and health outcomes in intervention studies and methods embedded in intervention studies to evaluate whether the underlying etiologic hypotheses of their association can be corroborated. A special area of attention is the economic evaluation of workplace interventions designed to reduce work environment risks. Available economic evaluation techniques and methods should be adapted specifically for use in work settings, and, where necessary, appropriate new methodologies should be developed.

3. *Research is needed on methods and strategies for the implementation of new scientific knowledge.*

In the evaluation of the relevance of work environment research with respect to Swedish work environment practice, several interesting examples of knowledge transfer were presented. During interviews with researchers and stakeholders, various barriers and problems with the implementation of effective interventions were mentioned that exemplify the gap between research and practice. There is a great need for the communication of research findings and access to these findings. However, even when companies and stakeholders are reasonably well informed of effective interventions, the actual application of scientific knowledge to improve work conditions is strongly influenced by behavioral, organizational, economic, and technical constraints. The International Evaluation Group recommends initiating and funding research projects that develop generalizable

methods and strategies for facilitating the implementation of interventions that have been effective in reducing work-related risks.

Basis for priority setting

1. *Research is needed to develop hazard surveillance systems that identify and monitor exposures at the workplace. They should consider, as well, the use of early indicators of risk, for example, noninvasive biological techniques and self-assessment appropriate to the modern structure of Swedish work.*

Systematic ongoing hazard surveillance has not been present for Swedish work environments for some period. At the same time, there has been dramatic evolution in the worklife of Sweden, many classical industries having been replaced by work environments more oriented towards service functions, many of these reliant on modern information technology and systems. The limited data describing risks from physical, chemical, biological, or ergonomic hazards in the current mix of Swedish work environments makes it difficult to target appropriate research and intervention activity. There is a variety of noninvasive methods, recently developed, that have potential in the application in surveillance systems. Research is needed into the most appropriate and cost-efficient systems that are sufficiently representative to provide necessary guidance for policy makers and practitioners, along with research on the best indicators to be used in these systems.

2. *Using modern sampling methods, government agencies need to take advantage of existing health data and hazard surveillance data and consider the structure of Swedish worklife to prioritize the need for work environment research. Information available internationally should be used to advantage. Research leaders should be engaged in this effort as well.*

There are data available from the Work Environment Survey and from the Swedish Information System for Occupational Accidents and Work-Related Disorders (ISA) that has been insufficiently used and could be further developed for priority setting. There is, however, a lack of regularly collected exposure data to be used for surveillance. Existing data have some limitations, but a better and more-complete analysis of these data has the potential to provide a first-order understanding of the distribution of risk and adverse health outcomes on a regional and national level. In spite of the high quality and reasonable coverage of the data systems, the picture still remains somewhat fragmentary. A well-structured Swedish worklife profile presented in a user-friendly format is suggested. For example, registry data could be complemented and strengthened by the appropriate

use of modern sampling methods. Well-targeted national and other surveys can be utilized to monitor problems and assess gaps in registration systems. This possibility applies particularly to the severe underreporting of accidents and diseases.

These surveys could be used, along with data available from other nations with a similar mix of industry types or relevant exposures, to develop an initial set of priorities for research. Continuous improvement of the systems is encouraged in order that the priorities be evidence-based at the best possible level. Care needs to be taken that the evidence informs the priority-setting process but that sufficient flexibility in funding is maintained to allow for new areas of research in the fast-changing work environment to be addressed.

3. Work environment research groups throughout Sweden should be encouraged to interact to minimize overlap and maximize the use of available national research expertise.

There is a variety of research groups in each of the research areas evaluated. The groups vary in size and are spread rather widely throughout Sweden. This situation brings benefits to the different regions but also presents challenges with respect to efficient and effective cross-group collaboration and the appropriate allocation of resources. Some of these groups have found effective ways to interact to identify priority research needs, to orient the leadership of the identified research targets and to promote effective combinations of specialized expertise. Platforms for interactions and methods to support the development and continuation of research networks should be facilitated, where necessary, by some targeted funds.

Interchange of knowledge

1. The interchange of knowledge from stakeholders to researchers and the reverse should be improved. Means and methods should be developed for collaboration between the social partners, other user groups, and the research community to design effective information transfer. Efforts in knowledge transfer need to be systematically assessed.

Evidence suggests that stakeholders' needs are not effectively communicated to the research community. Knowledge transfer requires specific structures and contents of different forms of communication that should depend, only in part, on the scientist responsible for the research. As a rule, research scientists are highly skilled in developing new knowledge and publishing this knowledge in scientific literature. However, scientists

are not specifically trained in determining stakeholder needs or in translating their knowledge into forms that are the most useful for the social partners or specific user groups. It is essential to develop a structure that enables those who are experts in knowledge management and transfer specific to each of the interested user groups and stakeholders to collaborate with research scientists in order to design effective information transfer.

Social responsibility

1. Continued support for the training and education of professionals in work environment research in developing countries is encouraged.

Sweden has an enviable record of engagement with developing nations in research and research training relevant to the needs of these nations. Representative of this work are the doctoral dissertations presented to Swedish research faculties by students from such nations. Given the leadership of Sweden in work environment research, there is a social responsibility to continue these efforts.

Addendum

During the final preparation of this report, the International Evaluation Group was informed that the national budget proposal from the new government presented on 16 October 2006 suggests complete closure of the National Institute for Working Life on 1 July 2007 and that preparations have already started for dismantling the Institute, without any compensatory mechanisms or transfer of ongoing research projects. Although it was not the task of the Evaluation Group to evaluate separate groups or institutions, the Group has noted that the National Institute for Working Life, with a quarter of the total estimated budget for work environment research, represents the largest of all research centers and that its research is of the same quality and relevance as the rest of the evaluated Swedish work environment research. It has noted that the broad, multidisciplinary composition of researchers within the Institute offers excellent conditions for the type of new research areas suggested.

It is obvious that a decision from Parliament in line with the proposal will drastically diminish the resources for work environment research in Sweden unless earmarked compensation is given to the universities or to funding agencies [eg, the Swedish Council for Working Life and Social Research (FAS)] in time for the Institute's researchers to apply for funding or new university positions.