International Evaluation 2014-19

NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT (NFA)

Denmark

January 2021

Contents

1 Background for the evaluation

1.1 Terms of reference of March 19 2020 for the international evaluation 2020 of the scientific impact of the National Research Centre for the Working Environment (NFA)

1. Background and purpose

This evaluation will be carried out in accordance with the executive order on evaluation of government research institutes.

NFA's core tasks are research and the affiliated tasks dissemination of research results, education of researchers and counselling of and service to the authorities. The evaluation covers the scientific impact of research, academic dissemination of research results and education of researchers. A separate evaluation will be carried out of the societal impact of NFA's research, dissemination of research results as well as counselling of and service to authorities. The chairmen of the two evaluation panels will ensure the coordination between the two evaluations.

The purpose of the evaluation is

- *to evaluate the scientific quality and relevance of NFA's research, dissemination of research results[1] and contribution to education of researchers*
- *to give specific recommendations with respect to how NFA may strengthen its research quality, relevance and scientific impact on research, dissemination of research results and contribution to education of researchers.*

Scientific quality, relevance and impact are pivotal in ensuring that authorities, working environment professionals and workplaces can make as much use as possible of NFA's research and dissemination of research results – and thereby ensuring societal impact.

The evaluation and recommendations are requested in relation to each research areas and to NFA as a whole.

The evaluation covers the period 2014-2019.

2.Form and participants

Research and education of researchers are evaluated by an international panel of highly acknowledged international researchers who cover NFA's core research areas 'psychosocial working environment', 'musculoskeletal disorders and physical working environment', 'occupational accidents and safety culture', 'chemical working environment', and the cross-sectional research area 'seniors'.

[1] Dissemination of research results means academic dissemination to peers, other researchers and experts, e.g. in networks, expert groups and at conferences.

Moreover, the evaluators must be experienced in research management as well as in user-oriented research for users at societal and enterprise level.

The panel must be independent of the Ministry of Employment and NFA.

The panel is appointed by the Board of Governors of NFA after nomination by the Innovation Fund Denmark.

3. Scope and main tasks

The evaluation must address the following questions:

Research

- *Is the research quality of a high standard and scope when compared to similar national and international research groups?*
- *To what extent is the research focused on solving scientifically relevant and prioritized working environment issues?*
- *To what extent is the research relevant for the specific needs of authorities and workplaces?*
- *Do researchers have sufficient knowledge, systematics and methods on how to involve stakeholders and target groups in research?*
- *To what extent are NFA's research topics and project portfolios – fund applications as well as grants - in line with and prioritized according to overall formal requirements, such as national strategies and NFA's own strategies and research programs?*
- *To what extent has the NFA succeeded in finding new financing opportunities?*
- *To what extent have scientific networks with important research groups at universities and other research institutions in Denmark and abroad been relevantly and sufficiently developed?*

Dissemination of research results

- *Do the researchers participate to a sufficient extent and in the most relevant conferences and other forums of international knowledge sharing and scientific debates?*
- *Do the researchers participate to a sufficient extent in international research collaboration during work on specific projects?*

Education

- *Does NFA to a sufficient extent contribute to the education of undergraduates/-postgraduates and PhDs within the working environment field, and thereby also to future working environment researchers?*
- *Does NFA to a sufficient extent contribute to lectures and seminars at Danish universities, at NIVA-courses (Nordic Institute for Advanced Training in Occupational Health), at other seminars etc.?*

4. Background material

The NFA will provide the necessary background material such as:

- *The NFA's by-laws*
- *The international evaluation from 2014 and the follow-up statement from the Board of Governors of NFA*
- *The national working environment strategies for the evaluation period*
- *NFA's strategies, research programs and performance management contracts for the evaluation period*
- *Data on NFA's portfolio of fund applications and grants during the evaluation period*
- *NFA's annual reports and accounts for the evaluation period*

5. Procedure

An independent academic consultant will assist the evaluation panel during the visit to the NFA and in the preparation of the evaluation report. The secretarial assistance to the evaluators will be independent of the NFA and the Ministry of Employment.

The NFA will organize site visits to the NFA and will provide practical assistance to the evaluators.

6. Time schedule

The evaluation report must be submitted to NFA in English no later than 1st February 2021 and include a Danish version of summary and recommendations.

The details of the time schedule will be discussed with the evaluators when the panel has been appointed.

7. Financing

The evaluation will be financed by the Ministry of Employment.

1.2 Evaluators

The Board of Governors of the NFA appointed the following members of the evaluation panel, and the secretary was recruited by the chairman:

Signild Vallgårda (chairman, independent of the research areas). Professor in health policy analysis at Department of Public Health, University of Copenhagen. MA in history and literature from the University of Copenhagen, doctor of medicine from the University of Copenhagen for her research in the history of hospitals in 20th century.

Tommi Alanko (specialist in research in occupational accidents and safety culture). Director for Occupational Health at the Finnish Institute of Occupational Health since 2016. MSc and PhD in physics from University of Jyväskylä. Adjunct professor and researcher at University of Jyväskylä, Tampere University, Tampere University of Technology, and the Finnish Institute of Occupational Health. Focus on occupational safety, risk management, health, electromagnetic radiation, and risk communication.

Karin Broberg (specialist in research in the chemical working environment). Professor at the Institute for Environmental Medicine, Karolinska Institutet, since 2015 and Professor in Occupational and Environmental Medicine, Lund University since 2018. MSc in biology and PhD in Experimental Clinical Genetics, Lund University 2001. Combines field studies with genetics and biomarkers measurements to address health effects of the chemical environment. Scientific Advisor for the Spanish mother-child cohort INMA 2010-2012, for the National Institute of Nutrition and Seafood Research 2012-13, Norway, director of Metalund, a centre for work environment research, 2020-.

Ingrid Sivesind Mehlum (specialist in research in musculoskeletal disorders and the physical working environment). Senior physician and researcher at the National Institute of Occupational Health, Oslo, since 2013 (researcher at the institute since 2000). MD 1989 specializing in occupational medicine. PhD in occupational epidemiology, University of Oslo, 2010. Combines clinical work and research with emphasis on studies of occupational problems in the population at large including musculoskeletal disorders and physical exposures (noise etc.), especially by way of register studies.

Jussi Vahtera (specialist in research in the psychosocial working environment). Professor at the Department of Public Health, University of Turku since 2009. MD specializing in occupational health, and PhD. Employed at the Finnish Institute of Occupational Health 1997-2016, PI of the Finnish Public Sector Study, which is currently part of the IPD-WORK Consortium. Focus on psychosocial stress, psychosocial work environment, social determinants of health, and neighbourhood influences on health, especially by way of major cohort studies combining register and survey data across the life-course.

Hans Okkels Birk (secretary). Part time lecturer at the University of Copenhagen, Department of Public Health since 2006. MSc in economics, PhD in health services research from University of Copenhagen 2015. Secretary to political and administrative committees and working groups, including a research ethics committee and a committee allocating funding to clinical research.

1.3 Evaluation procedures

The evaluation panel was formally appointed by the NFA on April 1st 2020.

See section 1.4 for a detailed list of the data provided by the NFA on its own initiative or by request by the evaluation panel.

The evaluation panel held eight web-meetings from May 2020 to January 2021[2]. Due to the COVID-19-pandemic interviews with junior and senior researchers and the general director were performed as web-meetings as well.

Responsibility for preparation of questions for each interview was allocated to a single member of the evaluation panel, but all members of the panel had the opportunity to ask questions, and the whole group participated in each interview and discussed it afterwards.

The members of the evaluation panel and the secretary prepared drafts for the chapters/sections which were commented on and revised by the whole evaluation panel.

The NFA reviewed the report for factual errors prior to its completion.

1.4 Data

The evaluation was performed based on:

1.4.1 The formal framework for the NFA's work and the evaluation

In Danish only unless otherwise stated:

- Bekendtgørelse nr. 1072 af 7. september af lov om arbejdsmiljø
- Bekendtgørelse nr. 581 af 1. juni 2014 af lov om sektorforskningsinstitutioner
- By-Laws of January 1 2007 for The National Research Centre for the Working Environment (in English)
- Organizational diagram of 2020 for the NFA
- Bekendtgørelse nr. 281 af 22. marts 2006 om evaluering af sektorforskningsinstitutioner

1.4.2 Strategies and research programs

In Danish only:

- The NFA's strategy, 2014-18
- The NFA's strategy, 2015-19
- The NFA's strategy, 2016-19
- The NFA's strategy, 2017-20
- The NFA's strategy, 2018-21

[2] May 8th, June 25th, August 8th, September 23th, October 8th, October 29th and December 11th 2020; and January 7th 2021.

- The NFA's strategy, 2019-22
- The NFA's targets and measures, 2020
- The NFA's targets and measures, 2019
- Research program of April 11 2018 for accidents and safety culture, 2018-21
- Research program of October 2015 for microbiology, 2015-19
- Research program (undated) for nano-safety
- Research program (undated) for the psychosocial working environment, 2018-21
- Research program (undated) for the physical working environment, 2018-21

1.4.3 Register data

For each of the four research areas, chemical working environment, musculoskeletal disorders, occupational accidents and safety culture, and psychosocial working environment, the NFA provided the following data:

- Verbal presentation of the research area
- Employees by December 31 2019 including data on name, degree, position, employment from/to, share of time allocated to the research field, affiliation to the NFA, age and gender
- Employees at the NFA in the evaluation period whose employment was terminated before December 31 2019
- Research projects in the evaluation period including data on title, researcher, funding, funding period and funding source
- PhD, master, and bachelor projects including data on subject, faculty, university, supervisor initials and duration from/to
- Teaching: list of courses taught including data on course name, university, faculty, number of lessons/sessions, year, and teacher initials
- Lists of publications
  a) Articles with original data in international peer-reviewed journals
  b) Review articles separately (also included editorials and invited commentaries)
  c) Scientific articles in national (Danish) journals
  d) Scientific articles in very-high-impact journals: impact factor > 10
  e) Conference abstracts (for studies not yet published in journals)
  f) Books and book chapters
  g) Popular-science publications
  h) Communications to the public
- The ten publications from the evaluation period from the research area, which the NFA considers to be its most important contributions to the research area
- Collaborations and networks in the evaluation period
- Participation in scientific conferences including data on title of conference, participating researchers, posters, and oral presentations from NFA (if the data is available)
- Applications for external funding and received grants

For the cross-disciplinary area working environment epidemiology the NFA provided the following data:

- Employees by December 31 2019 including data on name, degree, position, employment from/to, share of time allocated to the research field, affiliation to the NFA, age and gender

- Employees at the NFA in the evaluation period whose employment was terminated before December 31 2019
- List of PhD, master and bachelor projects including data on subject, faculty, university, supervisor initials and duration from/to

1.4.4 Interviews

On September 29 and September 30 2020, all members of the evaluation panel performed interviews (web-meeting) with representatives of:

The four research areas:

- Chemical working environment: four senior researchers and the research director
- Musculoskeletal disorders: two senior researchers and the research director
- Occupational accidents and safety culture: three senior researchers and the research director
- Psychosocial working environment: two senior researchers and the research director

PhD-students:

- Five PhD-students

The management:

- The general director of the NFA

1.4.5 Memos and reports

In Danish only unless otherwise stated:

- Memo in Danish of April 27 2000 from the Ministry of Employment: 'Introduktion til særlig relevante bilag fra ekspertudvalget om udregning af arbejdsmiljøindsatsen.'
- Report of September 2018 from the Ministry of Employment: Et nyt og forbedret arbejdsmiljø. Bilag (two appendices).
- International Evaluation of November 2014 of the National Research Centre for the Working Environment (in English).
- Follow-up statement of December 10 2014 from the NFA's board of governors on the International Evaluation of November 2014 of the National Research Centre for the Working Environment
- Annual reports from the NFA, 2014-19 (in English)
- Annual financial reports from the NFA, 2014-18 (in English)
- Overview of applications for funding and grants, 2014-19

2 The NFA: organization, stakeholders, and strategy

The NFA is a government research institute under the Danish Ministry of Employment which aims at conducting research at the highest international level to:

- Provide consultancy services within the institute's core areas
- Perform development work with clear social objectives
- Disseminate research-based knowledge to workplaces, authorities, social partners, and safety consultants
- Participate in the training of researchers and educational activities at the universities in its core areas

2.1 Organization: The Ministry of Employment

The Ministry of Employment is responsible for the framework and rules for employment and working conditions, safety, and health at work and industrial injuries, financial support, and allowances to all persons with full or partial working capacity as well as placement activities, services in relation to enterprises and active employment measures.

The Ministry of Employment is responsible for legislation and programs for labour law, safety and health at work, and compensation in connection with industrial injuries. In addition, the Ministry is responsible for several work-related allowances such as unemployment and sickness benefits, and social activation measures.

The Ministry of Employment consists of a department and the following three government agencies:

- The National Research Centre for the Working Environment
- The Danish Working Environment Authority
- The Danish Agency for Labour Market and Recruitment

2.2 Stakeholders

Authorized by the Law of Government Research Institutes (in Danish: Lov om sektorforskningsinstitutioner) and the Danish Working Environment act (in Danish: Lov om arbejdsmiljø), the Ministry of Employment by a statutory rule (in Danish: Vedtægt for det Nationale Forskningscenter for Arbejdsmiljø) defined the role of the NFA as to provide the Ministry of Employment and its agencies with national and international work-environmental research-based knowledge.

In addition, the NFA shall operate as a national coordination centre of work-environmental research knowledge, and disseminate such knowledge to various authorities, labour organizations, enterprises, and work environmental advisors.

In practice the NFA, as established through its by-laws, transfers knowledge to society in three ways, by:

- Counselling the Ministry of Employment

- Dissemination of research knowledge to OSH actors (i.e., the social partners, OSH consultants/practitioners and enterprises) and society at large (OSH: Occupational Safety and Health)
- Contributing to undergraduate and postgraduate education

2.3 Strategies

The NFA's strategy 2018-21 includes the following subjects and objectives:

The strategy defines three long-term impact goals for the NFA:

1) The NFA's monitoring of the working environment and its research-based knowledge contribute to achieving the goals set in the Danish national working environment strategies
2) The NFA's research, knowledge retrieval and monitoring of the working environment constitute an important platform for the working environment effort and for the working environment regulation in Denmark
3) The NFA contributes to identifying, exploring, preventing, and addressing the working environment challenges of tomorrow as well as new, potential risks at Danish workplaces and in cooperating countries

According to the strategy

- The NFA aims at delivering research of a quality which is similar, to or exceeds research conducted at Danish universities. The centre's research findings are subject to quality assurance in the form of publication in peer-reviewed scientific journals, and it strives to publish in journals with a high impact factor within relevant research areas. Moreover, approximately every five years, the quality of the centre's research activities is assessed through an independent evaluation by an international evaluation panel, the most recent evaluation being performed in 2014
- The NFA research aims at creating knowledge that contributes to developing healthy and safe workplaces where employees remain free of psychosocial and psychophysiological-related conditions throughout their entire working life and retain a high ability to work
- The NFA states that more research is needed on causation with regard to current known OSH challenges, as is more research on how the ever-changing conditions in the labour market affect the working environment. Moreover, it is stated that more research on prevention is needed, including research into how research-based knowledge can be implemented in working environment efforts at enterprises. In addition to generating knowledge, the NFA will examine which factors inhibit and promote the use of this knowledge in practice
- In collaboration with other research institutes, priority will be given to include new research disciplines to expand the scope of the NFA's research. This includes new researcher profiles within the fields of working environment economics as well as management and organization
- The NFA aims to adhere to high research ethics standards and has adopted the Code of Conduct for Research Integrity
- The NFA's research aims at being characterized by relevance and practical applicability. One of the fundamental objectives of the NFA is, that a significant share of all knowledge produced and research results will be applied in practice. Thus, close cooperation with authorities, social partners, OSH professionals, workplaces, the European Union (EU), and other stakeholders is of key importance to ensure, that the NFA's research is relevant and can be

used in practice. However, research that does not lead to applicable solutions in the short run is also important in order to develop knowledge, methods and theories which may be relevant in order to be prepared to answer future challenges

- As a national research centre, the NFA aims at serving as a focal point for working environment research in Denmark. The centre's primary collaboration partners include universities; occupational health clinics; government research institutes; authorities; the social partners, including Sector Councils on OSH (in Danish: Branchefællesskaberne for Arbejdsmiljø, BFA); and OSH professionals. By way of collaboration with national and international research groups, the NFA research holds a strong position nationally and internationally

The NFA's strategy goes into more detail about its role and priorities in the four research areas and on training:

Psychosocial working environment: The psychosocial working environment constitutes one of the prioritized areas in the national OSH strategy. With its research program on the psychosocial working environment, the NFA intends to create knowledge that contributes to healthy and safe workplaces where employees remain free of psychosocial and psycho-physiological-related conditions and retain a high ability to work. Research will be carried out on risk factors and their consequences for health and well-being and on positive factors that can promote a good psychosocial working environment. With regard to research in this area, the NFA focuses its efforts on the following three key topics:

1. The psychosocial working environment
2. Organization and social relations
3. Labour retention

Musculoskeletal disorders and physical workload: Musculoskeletal disorders constitute another of the prioritized areas in the national OSH strategy, and with its research program on musculoskeletal disorders and physical workload, the NFA wants to create knowledge that contributes to healthy and safe workplaces where employees avoid musculoskeletal disorders and retain a high ability to work. Research in the area of physical workload includes factors that may contribute to developing or escalating musculoskeletal disorders and factors that may prevent and reduce strain. With regard to research in this area, the NFA's efforts focus on the following key topics:

1. Physical workload that contributes to developing or escalating musculoskeletal disorders and factors that can prevent, reduce, and address strain
2. Labour retention, including returning to work after a long period of absence due to sickness

Accidents at work and safety culture: Preventing accidents at work is the third prioritized area in the national OSH strategy, and the aim of the research program on accidents at work and safety culture is to create knowledge that contributes to healthy and safe workplaces with a high level of safety and a proactive safety culture. The NFA's efforts focus on the following three key topics:

1. Background and causes of accidents at work

2. Concrete actions and interventions
3. Continued accident prevention

Chemical hazards and the working environment, toxicology, nanosafety and microbiology: The fourth prioritized area is chemical hazards. As a consequence of the introduction of new technologies, new materials and new ways of using materials already available, the centre aims at developing new methods for measurement and characterization as well as hazard assessments that can be used to advise authorities and the political system. The aim of this research area is to explore and analyse the primary sources of chemical and biological exposure at Danish workplaces; to examine how these sources affect workers' health; and to determine how exposure can be prevented. The centre will develop risk assessment tools and prevention measures which may be adapted to individual workplaces. Moreover, the NFA will also develop documentation, on which the authorities can base their regulation of chemical substances.

Training/education: As a government research institute, it is mandatory for the NFA to offer training programs to students and researchers on the centre's core research areas. To ensure that the OSH system can obtain the necessary knowledge today and, in the future, research into matters related to workplace health and safety depends on the continuous influx of new talented researchers.

Researchers from the NFA wish to achieve this by:

- Supervising students at bachelor, master, and PhD level
- Teaching courses at Danish universities
- Qualifying to become affiliated to a university

Furthermore, the NFA wishes to:

- Ensure that researcher programs at the centre are successful and result in positive senior researcher assessment
- Ensure continued competence development and recruitment of international guest researchers to the NFA through an international exchange program for researchers
- Contribute to continuing training of advisors and other OSH professionals

3 The NFA: overview

3.1 Description of the NFA

The NFA is an independent national research centre organized under the Ministry of Employment at the same level as two sister agencies, the Working Environment Authority (abb.: WEA; in Danish: 'Arbejdstilsynet'), and the Danish Agency for Labour Market and Recruitment (in Danish: 'Styrelsen for Arbejdsmarked og Rekruttering').

As part of the national efforts to achieve a healthy and empowering working environment, "the goal of the NFA is to provide a research-based knowledge base to ensure safe and developing working conditions in accordance with developments of the society and the needs of businesses and the work environment system" (Danish: "NFA har til formål at tilvejebringe et forskningsbaseret videngrundlag for at sikre sunde og udviklende arbejdsforhold i overenstemmelse med samfunnsudviklingen og behovet hos virksomhederne og arbejdsmiljøsystemet"). This is provided by interdisciplinary surveillance, examination, and research on the effects of work-related factors, and work environmental interventions on health, well-being, and productivity.

However, as a research centre the NFA has a special status, and unlike the ministry's other agencies, it is regulated by the Act on Government Research Institutes (in Danish: Lov om sektorforskningsinstitutioner) as well as the Working Environment Act (in Danish: Lov om arbejdsmiljø). The Act on Government Research Institutes stipulates, that research (choice of methods and publication) is independent of the Ministry of Employment.

3.2 Organization of the NFA

In accordance with the Act on Government Research a board of governors is appointed to ensure and maintain the NFA's independence. The board is appointed by the Minister of Employment and is responsible for the overall management of the NFA, including defining the NFA's strategy, the general guidelines for the centre's organization, long-term activities, and development; whereas day-to-day management, including personnel management, is the responsibility of a director general appointed by the Minister of Employment upon recommendation by the board.

The board consists of 13 members including the chairman, all of which are appointed by the minister of employment:

- The chairman
- Six members with work environmental expertise nominated by the Working Environment Council (in Danish: Arbejdsmiljørådet)
- Four members with relevant research experience nominated by the Danish Council for Strategic Research. One from each of the three universities of Copenhagen and Aarhus, and Denmark's Technical University; and one from a research institution in another country

- Two NFA employees elected by and among the staff

Each member is appointed for a period of four years and may be reappointed.

The Ministry of Employment and the Working Environment Authority appoint observers, who participate in the board's meetings without voting rights.

The board appoints a deputy chairman among its members for a period of two years – alternately a member nominated by the Working Environment Council and a member nominated by the Danish Council for Strategic Research.

The director general reports to the Permanent Secretary of the Ministry of Employment and the chairman of the board. The director general is a member of the corporate management of the Ministry of Employment (in Danish: Koncernledelsen; KCL). The director general also participates as an observer in the meetings of the Working Environment Council, which is a forum of social partner representatives counselling the Minister of Employment on matters relating to occupational safety and health.

The executive officers of the NFA meet quarterly and bilaterally with the directors of the Working Environment Authority for coordination and to share knowledge.

The top management of the NFA consists of two executives: the director general, Steffen Bohni, and the deputy director general Ulla W. Skjøth. The middle management consists of four heads of research (in Danish: forskningschefer), the head of the secretariat, and the head of the management secretariat.

3.3 Objectives

The NFA's strategies for 2014-18 and 2015-19 spelled out the following mission, vision and long-range objectives in the evaluation period:

Mission and vision: the NFA's *mission* is to perform research, to disseminate and to teach, to contribute to developing a safe and healthy working environment in Denmark.

The NFA's *vision* is to produce and disseminate high-quality research which is highly relevant to interested partners and collaborators and contributes to developing the Danish society.

The NFA's *long-range objectives* were to:
1: Identify, do research on and handle future working environment challenges and new potential risks at workplaces in Denmark and in countries we collaborate with.

2: The NFA's surveillance of the working environment and evidence-based knowledge contributes to achieving the objectives in the Danish strategy for the working environment until 2020, including three targets concerning reducing the number of serious working accidents by 25% (controlling for the number of employees), the share of psychologically overtaxed employees by 20%, and the share of employees with musculoskeletal pain by 20%.

3: The NFA's own research and collection of evidence provides an important contribution to the Danish knowledge about the working environment, and to regulation of the working environment in Denmark and the EU concerning:

- The psychosocial area
- The biological area
- The physical area
- The chemical area
- Accidents
- Nanosafety

In the evaluation period, the NFA's key performance indicators and targets changed yearly. For example, in the evaluation period they included:

- Quality assurance of research by publishing at least 2.0 articles/full-time researcher in internationally recognized peer-reviewed, scientific journals
- New results of the NFA's research and surveillance of the working environment must be disseminated quickly and effectively to users of knowledge about the working environment by way of an electronic newsletter, news reports on the NFA's website, www.arbejdsmiljoforskning.dk, and dissemination meetings
    - At least 20 newsletters
    - At least 60 research news reports
    - Development of a system to evaluate the impact of dissemination of research
- Major traffic at the Knowledge Centre's web-portal, Arbejdsmiljoviden.dk, which must maintain its position as the most used portal concerning knowledge about the working environment (400,000 or 500,000 visits)
- The foundation for future recruitment of researchers must be secured by training at least five PhD students a year (three year moving average)
- Completion of data collection for 'Working environment and Health' (50,000 in employment)
- Dissemination of the results of 'Working environment and Health' to the Working Environment Authority and publishing of the results within a specified time frame

The current (2020 – after the evaluation period) strategy includes the following eight specific objectives defined before the end of the evaluation period and therefore defining the objectives at the end of the evaluation period:

- Quality assurance of research by publishing at least 2.0 articles/full-time researcher in internationally recognized peer-reviewed, scientific journals

- New scientific results from the NFA must be translated into coherent and useful dissemination by way of thematical newsletters aimed at the NFA's target groups. Therefore, the NFA must publish at least ten thematical research newsletters
- Seventy percent of the current users of information from the NFA find the information useful for their work to improve the working environment
- Development of a measurement instrument and a baseline for how key and potential target groups utilize information from the NFA in their work to improve the working environment. In 2020 the emphasis will be on the authorized working environment advisors
- The NFA prepares reports on the impact of two key cases to document the societal impact of the NFA's research and dissemination of research systematically
- The foundation for future recruitment of researchers must be secured by training at least five PhD students a year (three year moving average)
- By way of close dialogue with the Working Environment Authority and the Ministry the NFA prepares five analyses which support the total current work to improve the working environment – including policy development
- In order to strengthen surveillance, documentation, transparency, and stability in case of personnel changes on information safety and data protection, in 2020 the NFA will transfer its ISMS- and GDPR-data to the information safety handling system Risma

3.4 Key data

The NFA's research funding consists of:

- A basic government grant
- Politically prioritized grants
- Research fund grants

The funding in the current and latest evaluation period is presented in table 3.1.

<u>Table 3.1:</u> Income (funding), costs and external funding's share of total funding, NFA, 2010-9 (DKK, million, current prices).

Income	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Basic government grant	79.8	92.3	93.2	82.4	81.7	79.6	68.6	65.4	65.6	70.1
External funding	31.0	34.9	25.7	31.1	32.2	32.4	37.5	45.2	48.1	47.1
Other funding	5.4	1.8	2.3	5.2	5.8	7.7	12.4	11.8	12.4	2.4
Total funding	116.2	129.0	121.2	118.7	119.9	119.7	118.5	122.4	126.1	119.6
External funding's share of total funding (%)	26.7	27.1	21.2	26.2	26,9	27.1	31.6	36.9	38.1	39.4
Costs	115	115.3	121.1	118.7	119.4	119.2	116.6	121.8	125.5	117.7
Surplus	1.2	13.7	0.1	0	0.5	0.7	1.9	0.6	0.6	1.9

Sources: NFA, annual reports 2014, 2018 and 2019.

For data on publications, see chapter 4.

4 Evaluation of the NFA's research

The evaluation panel evaluated the NFA's research by the following dimensions:

Research excellence: the evaluation panel evaluated the research for:

- Output
- Quality
- Impact
- Originality
- Innovativeness and novelty
- Contributions to methodological and theoretical developments
- Dissemination of research results

The quality of the NFA's research was compared to national and international research groups working in the same field.

Specifically, the evaluation panel evaluated:

- Relevance of the research to the NFA's strategy and the Danish work force, and for the specific needs of authorities and workplaces: to what extent the research focused on solving scientifically relevant and prioritized working environment issues; whether the NFA's research topics and project portfolios (funding applications as well as grants) were in line with and prioritized in accordance with overall formal requirements, such as national strategies and the NFA's own strategies and research programs
- Research collaboration: the NFA's development of collaboration and scientific networks with international and national research groups at universities and other research institutions, including private enterprises
- Involvement of society: whether researchers have involved stakeholders and target groups in research
- Funding: to what extent the NFA has succeeded in finding and exploiting new funding opportunities
- Implementation of past recommendations: whether the NFA has followed the recommendations in the latest evaluation report
- Seniors: to what extent issues related to seniors have been included in the research

The evaluation panel examined the NFA's research by a combination of qualitative and quantitative methods. Specifically, the evaluation panel:

- Performed a quantitative analysis of the NFA's production of scientific papers and participation in scientific conferences; of the role the NFA's researchers played in the research behind the publications; and of other researchers' use of papers produced by researchers at the NFA. Many of the variables in these analyses were proxy measures for research quality and gave rise to more questions, which could only be answered by way of interviews with researchers or the management at the NFA
- Examined the publication lists for patterns with regard to research subjects; publication types; and methodologies

- Read the ten papers from each research area, which the NFA considered to be the most important publications published in the evaluation period. The specialist in each research area evaluated he papers for excellence; whether they reported on original research or were reviews or editorials; whether they contributed to development of methodologies; whether they were published in high-impact journals; and what the NFA-researchers' roles were when the studies were performed
- Performed interviews with representatives of junior and senior researchers from each research area and the management

4.1 Analysis of research production and bibliometrics, NFA

4.1.1 Quantitative analyses, methodology

The NFA provided data on original articles and reviews published in international peer-reviewed journals, the journals' impact factors, conference abstracts and other publications.

The publication lists for each research area were extracted by the NFA based on the articles' reporting year so that it followed the NFA's annual report and performance targets.

The NFA stated that *'The Impact Factor (IF) […] is determined by the article's reporting year, i.e. if an Epub article from 2014 (listed in the 2014 list) now appears in the reference as 2015, it is nevertheless the IF for 2014, which is stated in the reference, because 2014 is the publishing year according to NFA's performance targets. In 2015, the IF is added for 2015; in 2016, the IF is added for 2016 etc. In the list of 2019 references, the IF is added for 2018 because 2018 is the most recent IF year given. As the IF typically varies from year to year, it means that articles from the same journal have different IFs according to the specific year of publication in the journal. If it has not been possible to determine the IF for a particular year, the nearest year with a given IF figures in parenthesis on the list. If the IF does not exist, it will appear as IF=N/A (Not Available)*

The impact factor data is collected from the Journal Citation Reports (JCR), a product of Clarivate Analysis, and an authoritative resource for impact factor data.'

Based on the publication lists and impact factor data from the NFA we calculated the number of:

- Original articles and reviews, respectively, in peer-reviewed journals a year as a measure of the scientific output. However, the number of articles published in one calendar year often reflects research performed in previous years
- The number of first authorships, single authorships and last authorships for original articles and reviews, respectively, a year as measures of the contribution by researchers from the NFA. Generally, the first author is assumed to be the author, who has provided the greatest contribution to the article, and the last author may be an experienced researcher, who has supervised the study published in the article. Usually, the other authors will be listed in decreasing order by their contribution to the study

- The total number of authorships from the NFA as a measure of the scientific output from the NFA. This measure takes cooperation with other researchers from the NFA into account unlike a simple calculation of the number of articles
- The NFA-researchers' average share of authorships to articles – a measure which reflects the NFA's researchers' contributions to studies
- The average number of authors/article to provide an measure of possible "authorship inflation"; an increasing number of authorships may reflect that more authors are added to each article rather than an increase in the research performed
- The average impact factor/article to provide a very rough measure of the quality of the articles and thereby of the research performed. The impact factor reflects, how often articles in a specific journal on average are cited by other researchers, providing a simple measure of a journal's impact, and the researchers will try to get their articles published in a journal with a high impact factor. Presumably, journals with high impact factors will receive the best articles and will demand more of their contributors than other journals in order to maintain their high impact factor, and therefore publishing an article in a journal with a high impact factor may indicate that an article is of comparatively high quality

The numbers were calculated for the NFA as a whole and for each research area (see section 4.2-4.5). For several research areas the numbers were so small, that the analyses were very sensitive to small changes in the data, and conclusions must be drawn with caution.

Different research fields may have different publishing traditions. For example, researchers in narrow research fields may have few peers to cite their work, no matter how important the subject is, and therefore their research will be published in journals with low impact factors, despite the importance of the research. Therefore, comparisons across research fields may not be meaningful, and the evaluation focused on the development in the quantitative measures over time in each of the four research fields and for the whole NFA.

The evaluation panel found, that although the impact factor can only constitute a proxy measure of quality, at the present it is the most operational proxy measure available.

The data on reviews etc. from the NFA included not only reviews but also editorials and invited letters to the editor. Therefore, this data is much more difficult to interpret than data on original studies, and the numbers are small and tend to fluctuate markedly. Furthermore, reviews do not constitute original research, so original articles may better reflect the NFA's scientific contribution, but publishing reviews may indicate that researchers have an excellent overview over their subject, and they may be respected by their peers. In the data from the NFA 'invited letters to the editor' typically were responses to a letter to the editor concerning an original article, and therefore the invited letter to the editor did not reflect the same amount of work or the same scientific impact as an original article.

By definition, original articles and reviews are published after a research project is finished or under way (unless the researchers publish their study protocol). Therefore, data on the number of articles

and reviews do not provide a measure of the 'pipeline' of future research. The NFA calculated the number of conference abstracts published in each year of the evaluation period. These number may reflect the number of scientific results which will be published in the near future and therefore ongoing research and research finished recently.

4.1.2 Bibliometric analysis, NFA, total number of publications

Throughout the evaluation period, the yearly number of published articles was higher than in any year in the previous evaluation period (tables 4.1 and 4.2).

Table 4.1: Articles in internationally recognized peer-reviewed journal, 2009-13.

Year	2009	2010	2011	2012	2013	Total	Articles/ year
Number of articles	122	137	150	132	153	694	138.8

Table 4.2: Original articles published in international peer-reviewed journals 2014-19; NFA (total).

	2014	2015	2016	2017	2018	2019	Total	Articles/ year
Original articles in peer-reviewed journals	167	156	162	183	172	193	1.033	172.2
First author-ships	62	50	69	68	81	81	411	68.5
Single author-ships	2	2	2	2	1	3	12	2
Last author-ships	65	69	78	79	89	89	469	78.2
Authorships, NFA	367	381	425	439	471	526	2.609	434.8
NFA's share of authorships	22%	27%	32%	29%	32%	33%	29%	
Authors/article	9.9	9.0	8.1	8,3	8.5	8.3	8.7	
Average impact factor	2.9	3.7	3.3	3.4	3.8	3.7	3.5	

The total number of original articles published a year grew by 15% a year from 2014 to 2019, fluctuating slightly during the evaluation period. In the previous five years the number of articles per year increased by 24% year.

The number of first authorships rose by 31% and the number of last authorships rose by 37%, a development indicating that researchers from the NFA not only published results of more research but also took on greater responsibility and initiative in performing and publishing the research projects.

This interpretation is supported by a growth in the number of authorships from the NFA of 43% during the evaluation period. This growth may reflect an inflationary growth in the number of authorships. However, the number of authors/article was relatively stable in the evaluation period, and the share of the total number of authorships of original articles with at least one author from the NFA grew by more – 50% - indicating that the growth did not reflect authorship inflation.

The average impact factor of the journals, which the NFA's research was published in, tended to increase in the evaluation period, indicating that the quality of the research tended to increase.

Table 4.3: Reviews etc. published in international peer-reviewed journals, 2014-19; NFA, total.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Reviews etc. in peer-reviewed journals	9	8	17	25	34	30	123	20.5
First authorships	2	3	4	10	13	9	41	6.8
Single authorships	0	1	0	2	6	2	11	1.8
Last authorships	3	3	7	13	14	12	52	8.7
Authorships from the NFA	19	14	41	45	58	57	234	39
The NFA's share of authorships	21%	29%	34%	33%	18%	19%	23%	
Authors/article	10.0	6.1	7.1	5.5	9.3	10.1	8.3	
Average impact factor	4.1	3.2	6.3	4.5	4.6	5.8	5.0	

The number of reviews increased over time (table 4.3), but the papers included were heterogenous, making it difficult to interpret the data.

Table 4.4: Conference abstracts 2014-19; NFA, total.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Number of conference abstracts	124	77	129	138	124	141	733	122,2

The number of conference abstracts was markedly higher in the second half of the evaluation period than in the first half – in every year in the second half the number of conference abstracts exceeded the average in the whole evaluation period (table 4.4). We have no explanation for 2015's position as an outlier.

One of the reasons to include the data on conference abstracts was to provide a measure of the 'pipeline' of scientific articles. However, the pattern of conference abstracts closely resembled the pattern of published scientific articles without a time-lag – indicating that the development in the number of conference abstracts was not a valid indicator of the number of future scientific articles. On the other hand, the number of conference abstracts may be viewed as a measure of the researchers' participation in dialogue with other researchers.

4.2 Psychosocial working environment

4.2.1. Key data

According to the psychosocial working environment research group at the NFA, their overall aim is to generate and increase knowledge about the role of the psychosocial working environment for the protection and promotion of health, work ability and well-being of the workforce and thereby contribute to the creation and maintenance of healthy and safe workplaces and a long and productive working life for all workers in Denmark.

Research areas

At the research centre, the psychosocial working environment group strategic areas cover research, application and targeted impact. The first strategic focus is to identify risk factors and protective factors in the psychosocial work environment, i.e. to study if and to what extent factors in the psychosocial work environment cause and prevent incidence of somatic diseases and psychiatric disorders and affect workers' well-being. This includes the examination of mechanisms and pathways that link exposure to risk factors and protective factors with diseases, disorders and well-being including sickness absence. A further aim is to identify vulnerable subgroups, such as older workers or workers with existing chronic health conditions, which are particularly vulnerable to the effects of specific psychosocial work environment factors. Research about this first strategic focus point is primarily conducted using large cohort and register studies and advanced epidemiological designs. The second strategic focus point is to obtain information on how to change the exposure to risk and positive factors in the workplace by designing and testing scientifically based workplace

interventions. This is done in close collaboration with the workplaces. Broadly, the themes covered by the research are:

i. Psychosocial work environment and health
ii. Organization and social relations
iii. Work retention and inclusive workplace
iv. Development of theory and methods

Researchers

The psychosocial work environment group is led by the research director and two professors. In addition, five senior researchers in permanent positions belong to the core group. The number of positions in the core group has been the same over the evaluation period. Externally funded, there are currently 22 post-doctoral researchers, PhD students and research assistants. Further, external professors from the University of Copenhagen and the University of Groningen, The Netherlands, are part-time affiliated with the NFA's psychosocial work environment research group. The staff covers a relatively wide range of disciplines from psychology, sociology, and political science to chemistry, but does not include, e.g., medicine. During the evaluation period, employment was terminated for 22 employees.

Research projects

Both quantitative and qualitative methods were used in the projects, including large-scale cohort studies combining survey data with register data, within-individual designs, workplace intervention studies, semi-structured interviews, participating observations, and the chemical analysis of biological material e.g., biomarkers for circadian disruption.

During the evaluation period, there were over 60 externally funded research projects which included:

1. ***Epidemiological studies on the effects of work-related factors on health and health-related outcomes.*** Characteristics of work environment included major sources of stress as identified in the leading work stress models (e.g., job strain, effort-reward imbalance, emotional demands and long working hours), social relations and conflicts at work (leadership behaviour, workplace social capital, workplace violence and workplace bullying), and type of work (e.g., night shift work, non-standard employment). Outcomes of interest covered a wide range of physical and mental conditions (in particular cardiovascular disease, diabetes, dementia, depression, musculoskeletal disorders and pregnancy-related outcomes), accidents, sickness absence, and labour market participation.

2. ***Intervention studies on the implementation and evaluation of workplace interventions***. The targets of the interventions were manifold, from violence at work, musculoskeletal disorders, stress, well-being, work ability to job insecurity night shift work, return to work, sickness absence, noise, and workplace social capital.

3. ***The development of intervention research methodology, especially within qualitative and mixed methods approaches.***

4. ***The development and implementation of improved measurements***:

- The Danish Psychosocial Work Environment Questionnaire (DPQ)
- New resources with daily information on working hours (DWHD)

- Work-life course cohort studies
- Psychosocial job exposure matrices with annual exposure measurements
- A Danish version of the Karolinska Exhaustion Disorder Scale (KEDS)
- Physiological indicators of stress
- Standardized workplace observations by trained observers
- Workplace recommendations on prevention and management of reduced psychological well-being

The total amount of funds granted during the evaluation period to the research projects was over DKK 90 million. Arbejdsmiljøforskningsfonden (The Danish Working Environment Research Fund) was the most important funding source, providing almost 70% of all external funding received. Three grants were around DKK 4.5 million, 21 grants of DKK 2.0-3.9 million, with the rest being smaller. The largest grants were given to study:

1) The associations of psychosocial work environment with sickness absence and remaining at work
2) Noise acoustics and psychosocial work environment
3) Job exposure matrix analyses of psychosocial factors and healthy ageing in Denmark
4) Working hours, health, well-being and participation

The latter projects were work packages in two large Nordic consortiums funded by NordForsk.

4.2.2 Research collaboration

The research is obviously well integrated in the national and international research community. Nationally, the NFA's psychosocial working environment researchers collaborate actively with the Danish universities and research centres, and the Danish regions. Scientifically, the most important collaborators come from the Department of Occupational and Environmental Medicine, the Bispebjerg University Hospital (at least 45 co-authorised original scientific articles during the evaluation period excluding reviews), and the Department of Public Health, University of Copenhagen (at least 25 articles). Collaboration with the workplaces takes place when designing and testing scientifically based workplace interventions. Within the NFA, the psychosocial working environment researchers collaborate e.g., with the musculoskeletal disorders and physical working environment group (over 20 original articles co-authored by the research group).

A good indicator of the successful and active international collaboration with universities abroad is the important contribution, the psychosocial working environment research group at the NFA has made to many leading international research consortia. This success is built on the high-quality large-scale cohort studies at the NFA combining survey data with register data. The collaboration includes the IPD-Work consortium, the WHO/ILO Joint Estimates of Work-related Burden of Disease and Injury programme, the IARC monography on night shift work, the OMEGA-net, the Horizon 2020 MINDUP research consortium on workplace interventions and mental health, and two NordForsk financed programmes on working hours and on psychosocial work environment and healthy ageing.

Using harmonized data, the international mega studies (consortia) with the NFA psychosocial working environment researchers as partners have produced convincing evidence on the role of chronic stress at work in disease aetiology.

In the Nordic countries, reported collaboration included:

- **Finland**: Finnish Institute of Occupational Health, University of Helsinki, University of Turku, University of Tampere and University of Eastern Finland
- **Norway**: National Institute of Occupational Health (STAMI), University of Bergen and Norwegian University of Science and Technology
- **Sweden**: University of Stockholm, Karolinska Institute, Lund University, Mälardalen University, Umeå University, Malmö University, and University of Gothenburg
- **Iceland**: University of Iceland
- Several university hospitals in the Nordic countries

Elsewhere in Europe collaboration included universities and research institutes from Belgium (KU Leuven), France (Sorbonne University, Paris), Germany (University of Düsseldorf), Netherlands (University of Rotterdam, University of Groningen), and United Kingdom (University of Sheffield, Kings College, University College of London, Queen Mary University of London). Other countries in Europe included Austria, Estonia, Ireland, Italy and Spain.

Countries outside Europe included Australia (e.g., Deakin University, University of Melbourne, Monash University), Canada (University of Alberta), China (Fudan University), Japan, USA (Cleveland State University, The City University of New York, University of California, University of North Carolina).

4.2.3 Scientific output and dissemination of research results

The scientific output was on a high level in the evaluation period. The unit published 302 original articles in peer-reviewed international journals, or on average 50 articles/year, between 2014 and 2019 (Table 4.5). Reflecting the active scientific collaboration, there were on average 8.6 authors per article and the NFA's share of authorships was 27%, with the first authorship in a little less than 20% of the articles, and the last authorship in 20% of them. The average impact factor of the journals, the articles were published in, was 3.5. Of the articles, 10 were published in very-high-impact journals (IF$\geq$10) (a total of 30 articles were published in journals with IF$\geq$5). Success in high-impact journals was largely due to international collaboration in the IPD-WORK consortium: half of all IF$\geq$5 articles and 70% of the very-high-impact articles were from this large and very productive consortium. The NFA researchers were the lead authors of one article published in a very-high-impact journal, and two articles published in journals with 5<IF<10. They have also published several systematic reviews (at least four with meta-analysis) and at least 12 study protocols related to their projects.

Table 4.5: Original articles published in international peer-reviewed journals; Psychosocial working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Original articles in peer-reviewed journals	67	38	43	49	46	59	302	50.3
First authorships	26	6	13	12	25	22	104	17.3
Single authorships	2	2	1	0	0	3	8	1.3
Last authorships	24	12	18	15	25	24	118	19.7
Authorships, NFA	126	65	90	107	131	177	696	116.0
The NFA's share of authorships	23%	15%	29%	23%	35%	38%	27%	
Authors/article	8.3	11.2	7.1	9.6	8.1	7.9	8.6	
Average impact factor	2.9	4.9	2.9	3.5	4.0	3.2	3.5	

According to the psychosocial working environment research group, the knowledge obtained in the research areas is also made available through public dissemination and the development of scientifically based tools with the aim to implement a healthy and safe psychosocial working environment based on scientific knowledge for all employees.

4.2.4 Excellence

The high level of epidemiological research has been reached due to the establishment and excellent utilization of large cohorts of Danish employees. The unit has had a major role in developing and establishing these cohorts and has actively used them in research. The most important cohorts were:

1. Danish Work Environment Cohort Study (DWECS): Surveys in 1990, 1995, 2000, 2005, 2010. About 10,000 people were approached in each round, about 4,000 with repeated measurements. Aimed to be representative of the Danish workforce. Linked to registers. This cohort has been completed and survey data is not collected any longer. However, the participants can still be followed in registers (hospitalization for somatic and psychiatric disorders (with ICD codes), death, retirement, sickness absence, and prescription drug purchases (ATC codes, including psychotropic medication)

2. Work Environment and Health in Denmark study (WEHD, in Danish: Arbejdsmiljø og Helbred): Survey data were collected in 2012, 2014, 2016 and 2018. The plan to collect data in 2020 has been cancelled. WEHD is much larger than DWECS, there are about 20,000 to 30,000 respondents at each round. Like DWECS it aims at being representative of the Danish workforce. There is also a special sampling of employees from selected small, medium and large companies. Taking rounds 2012, 2014, 2016, 2018 together, the cohort includes more than 80,000 respondents from all kinds of job groups. Those who responded in 2012 were contacted in 2014 again (about 10,000 with measurements in 2012 and 2014) and again in 2016 (about 8,000 with measurements in 2012 and 2014). Additionally, those who participated for the first time in 2016, participated again in 2018, giving another 10,000 with two measurements. About 20,000 have had at least two measurements. For these people, it is possible to use a pseudo-trial design (i.e., a design where researchers can analyse if onset of exposure at the second measurement will predict subsequent health impairment in participants healthy at the second measurement). After 2018, WEHD has been taken away from the NFA to the Danish Working Environment Authority (Arbejdstilsynet). According to the NFA researchers, it looks likely that they will not continue with the WEHD sample, but instead start with a new survey and a new cohort in 2021. If so, the old WEHD can only be followed up in registers in the future

3. Job exposure matrix analyses on healthy aging in Denmark (JEMAD): About 1.6 million individuals, aged 30 to 59 years in the year 2000. Register study, exposure measured annually with JEMs that are age, sex and job group specific. Yearly updates of the exposure, in principle as long as information on the job group of the participants can be drawn from the register. https://pubmed.ncbi.nlm.nih.gov/32202306/

4. Danish Work Life Course Cohort Study (DaWCo): A register cohort with about 950,000 individuals, aged 15 to 30 years at baseline, followed from their first entry into the labour market (inception cohort). Register study, exposure measured annually with JEMs that are age, sex and job group specific. Yearly updates of JEM as long as long as it can be calculated from the register. https://pubmed.ncbi.nlm.nih.gov/31727648/

The NFA psychosocial working environment group listed 10 selected peer-reviewed journal articles with the NFA first authorship for the international evaluation, considering various criteria such as:

i. Originality of the research and methodical innovation
ii. Citation record of the article and impact factor of the journal
iii. That the collection reflected the diversity of the research activities in the psychosocial work environment area
iv. Scientific and societal impact

The articles illustrated well the breadth of the excellence the psychosocial research group covers. One study used original harmonized data from 14 cohort studies with over 120,000 participants, and another a life-course approach in the Danish total population register data, to examine the association between psychosocial working conditions and depression (Madsen IEH et al. 2017; Svane-Petersen et al. 2019). Up to 150,000 of The Danish Labour Force Survey respondents were

followed to investigate the association between long working hours and stroke (Hannerz H et al. 2018). Other examples of the usage of excellent Danish register data were a study on the contribution of income and work stress to the association between education and cardiovascular disease in 1.6 million Danish employees (Framke E et al. 2019), and a study to examine the association of work shifts and hospital requiring injury utilizing high-intensity payroll data from the Danish Working Hour Database with a sophisticated within persons design (Nielsen HB et al. 2019). Multistate data and life table approaches were used to examine the impact of depressive symptoms on work-life expectancy (Pedersen J et al. 2019). Finally, quasi-experimental, within-subject crossover study designs have been utilized, e.g., to examine psychophysiological outcomes under real-life exposure conditions (Jensen MA et al. 2016), as well as experimental designs, e.g., in a process evaluation of the implementation of the Danish Return-To-Work-Program trial in 21 Danish municipalities (Aust B et al. 2015).

During the evaluation period, a new survey tool, the Danish Psychosocial Work Environment Questionnaire (DPQ), was developed by the psychosocial working environment research group (Clausen T et al. 2019, Scandinavian Journal of Work, Environment & Health). The DPQ is based on a comprehensive revision and extension of widely used earlier questionnaires, that NFA developed and launched in the late 1990s (COPSOQ-I) and mid 2000s (COPSOQ-II), and has been used in the cohort studies so far. The aim is the same: to monitor and study the psychosocial working environment factors, health, and well-being in Danish workplaces. The new tool has been suggested to the national Danish work environment monitoring.

The cohorts have information on psychosocial working environment over decades, and the cohort members have been linked to national health registers. Brilliant usage of total population register data, possible only in the Nordic countries, is another major strength. These high-quality data have made it possible to apply sophisticated counterfactual epidemiological methods with which causal inference can be derived from observational settings. Examples of such methods are fixed-effect method (controls for all measured and unmeasured time-invariant confounders), the usage of directed acyclic graphs (DAGs) to select confounders as well as pseudo-trials (a design that mimics trials in observational settings). One large cohort has been used to study the associations between specific ways of scheduling night shift work (e.g., number of consecutive night shifts) and incidence of disease and accidents. In another, psychosocial job exposure matrices have been developed and used on the Danish population registers allowing the researchers to perform work-life course cohort studies examining the role of psychosocial working conditions.

The partnership in the international mega studies, made possible by high-level data combined with high-level epidemiological research in the psychosocial working environment group, resulted in clinical guidelines and policy statements:

1. **The WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury** (Descatha et al. Environment International 2020; Li et al. Environment International 2020). Evidence for the effect of exposure to long working hours on stroke and ischaemic

heart disease was derived from three articles with researcher(s) from the NFA psychosocial working environment group as co-authors (Kivimaki,... Rugulies et al. Lancet 2015; Kivimaki,...Rugulies et al. Lancet Diabetes Endocrinology 2015; Virtanen,...Rugulies et al. BMJ 2015)

2. **National Occupational Research Agenda (NORA) for Cancer, Reproductive, Cardiovascular, and Other Chronic Disease Prevention (CRC).** National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, 2017. Evidence was derived from a correspondingly co-authored article (Kivimaki,... Rugulies et al. Lancet 2015)
3. **European Guidelines on Cardiovascular Disease Prevention in Clinical Practice** (European Heart Journal 2016) and **Updated Recommendations for Primary Prevention of Cardiovascular Disease in Women** (J Am Coll Cardiol 2020). Evidence on the role of work stress was presented in a co-authored article (Kivimaki,... Rugulies et al. **Lancet** 2015)
4. Another indicator of the very high research impact of this collaboration is **Altmetric Top 100 in the World research impact ranking #12** (Kivimaki,... Rugulies et al. Lancet 2015) (http://www.altmetric.com/top100/2015/9)

4.2.5 Evaluation and recommendations

The research from the psychosocial work environment group shows:

- A high level of originality of the research and methodical innovation compared to similar national and international research groups
- A good citation record of the articles and impact factor of the journals
- Diversity of the research activities in the psychosocial work environment group
- High scientific impact

No doubt, the psychosocial working environment group has provided major contributions to the Danish occupational health research and the knowledge obtained is highly relevant for the Danish working environment. The high level of the research has also enabled an important contribution of the research group to many leading international research consortia, making it possible to have a role in preparing clinical guidelines and policy statements worldwide.

The research is relevant for the specific needs of authorities and workplaces. The researchers have sufficient knowledge, systematics and methods to involve stakeholders and target groups in research. For example, mastery of workplace interventions (implementation and evaluation) offers key insights into the role of processual and contextual factors, as well as their effects on health-related outcomes.

Right now, the funding comes from governmental/public agencies and private not-for-profit funds but, importantly, not from the workplaces (if the intervention studies were to be funded by the workplaces, there would be a major concern of a conflict of interest). The Danish Working Environment Research Fund has been the most important funder, covering almost 70% of all external funding received. The grants have been $\leq$ DKK 4.5 million. The active international

collaboration in the IPD-Work consortium, the WHO/ILO Joint Estimates of Work-related Burden of Disease and Injury programme, the IARC monography on night shift work, the OMEGA-net, and the Horizon 2020 MINDUP research consortium has opened new funding opportunities, e.g., from NordForsk.

The 2014 evaluation report recommended integration of the accident and safety-research(ers) in the psychosocial group. This has not been done.

A main focus of the research group has been to identify vulnerable subgroups, such as older workers or workers with existing chronic health conditions, which are particularly vulnerable to the effects of specific psychosocial work environment factors. Moreover, early retirement and work-life expectancy have been a focus of the research, recently also questions related to extended working life and health and health-related behaviours in retirement transition. These issues are also studied in collaboration with other NFA groups, e.g., professor Lars Andersen from the musculoskeletal group is very much focused on retirement and post retirement.

There is a strong focus on what the research group calls applied research and there is sometimes the suspicion/the concern that high quality epidemiological research published in international peer-reviewed journals is more basic science than applied science. It should be strongly emphasized that high quality psychosocial epidemiological research, using large datasets and registers and linking large surveys to registers, is crucial for the NFA. The international peer-review processes are necessary for guaranteeing high quality and independent research, which is very different from the type of data analyses stakeholder organizations can do.

Moving WEHD from the NFA to the Danish Working Environment Authority poses a potential risk to the possibilities of maintaining high-level international collaboration in the future. To maintain an important contribution to the research field both nationally and internationally, the new WEHD should be a very large cohort which represents the workforce, with repeated measures at least bi-annually covering both work environment, non-work psychosocial exposures and confounders/mediators (including health risk behaviours). It is a key issue for future success to be able to assess exposures repeatedly, both for implementing a working-life course perspective and for conducting emulated trials that help to understand how onset and removal of an exposure affects health outcomes (which would inform potential intervention studies). Having repeated measures of the same individuals is also a key for understanding and evaluating the effects of interventions at the national level (including legislation or activities conducted by the Danish Working Environment Authority).

It will be important, that the NFA collaborates very closely with the Danish Working Environment Authority about surveillance, and the WEHD, and that the NFA, as an independent research organization, is responsible for doing research with the data. This implies that research activities should be at the NFA and that a clear distinction between the NFA and the Danish Working

Environment Authority is important, and that there should be funding possibilities for the NFA for doing such analyses.

Increasing the utilization of direct objective measures from the individual in research would be an important step forward in psychosocial epidemiology. This has already started in the collaboration with other units in the NFA; especially with the musculoskeletal group on retirement and working beyond retirement (with Lars Andersen) and the DOSES study measuring physical and psychosocial workload objectively (with devices and by highly standardized workplace observations by trained observers (with Andreas Holtermann). There are initial plans about collaboration with the chemical research group on cardiovascular disease (considering the importance of small participates for cardiovascular events). Finally, collaboration with a new research group on working environment economics, for which the NFA just recently got funding, gives an opportunity to include economical aspects into psychosocial research topics.

Serious consideration should be given to develop research on the effects of climate change on employee health and health-related risk factors. So far, this has been a neglected area.

4.3 Musculoskeletal disorders and physical working environment

4.3.1 Key numbers

Research areas

Musculoskeletal disorders (MSDs) are one of the priority areas in the national work environment strategy and have been one of the selected research areas of the NFA during the whole evaluation period 2014-2019. Through research on MSDs and physical working environment, the NFA wants to create knowledge that contributes to healthy and safe workplaces, where workers avoid work-related MSDs and maintain high work ability.

The research of the group is strategically prioritized into three key themes, which may overlap:

1) Mechanical work factors that can increase the risk for occurrence and aggravation of MSDs, sickness absence, and early withdrawal from work
2) Means to prevent, manage and rehabilitate MSDs and its consequences, such as sickness absence, in Danish workplaces
3) Focus on employees at particular risk for MSDs, sickness absence and early withdrawal from work (short education, high physical work demands and low resources, such as low physical capacity)

In addition, the research group has defined four subthemes across the three research themes.

a) '*Positive ergonomics*' covers, how work can be organized so that it in itself promotes health and physical work capacity, and includes "the Goldilock principle", i.e., how to design productive work so it becomes "just right" for workers with physically demanding work, as well as workers with sedentary work
b) '*New technologies*' covers both the development of new technologies and the use of existing technologies in data collection, data analyses, and interventional studies, and includes

methods for objectively measuring exposures during work and leisure time in large number of workers. The research group is one of the most prominent globally in this field, and collaborates with several groups internationally

c) '*Research to practice*' covers implementation research and the involvement of relevant stakeholders in the development of interventions, recommendations, and practical tools, and includes a national campaign and participatory intervention projects, using randomized controlled trials (RCTs) and "the Goldilock principle". The number of intervention projects of high quality is impressing internationally and show promising results, and the research group wants to upscale them and extend the methodology to more industries and eventually to all workplaces
d) '*Seniors*' covers push and stay factors for labour market participation among older workers, and includes the importance of the work environment. The research group makes use of large surveys, combined with national register data, and results from the studies have contributed to the national debate on prolonging working life

Researchers

The research group is led by a research director and two professors. All three met with the evaluation panel, and were engaged and enthusiastic about their research. The two professors came to the NFA in 2008. Their current contracts as professors last until February 2021, and they are in the process of applying for prolongation.

At the end of 2019, the research group had 24 employees. In addition to the two professors, the group had four permanently employed senior researchers (three of these took their PhD in the group in 2015), and one senior researcher who retired in 2020, as compared to only two senior researchers at the last evaluation. The recently retired senior researcher will not be replaced, motivated by the need for flexibility. Additionally, the group had one physiotherapist (retiring in 2020), two researchers (both contracts ending primo 2021), two postdocs (contracts ended 12-2019 and 02-2020), four PhD students (3 completing in 2020, 1 in 2022), and eight research assistants (three contracts ended 12-2019). In addition, 43 employees ended their contracts during the evaluation period; two of these had long employments (a senior researcher for nearly 13 years, a bioanalyst for 34 years). Most had shorter employments (from 3 months to a few years), and included 4 researchers, 4 postdocs, 3 PhD students, 3 project coordinators, 2 occupational therapists, 23 research assistants, 1 academic assistant and 1 candidate of medicine.

There seems to have been a high turnover of employees, relative to the size of the group, as compared to the other research groups. The Musculoskeletal group had 24 employees at the end of 2019 (ratio terminated/employed 43/24 = 1.8). The corresponding numbers for the Chemical group were 42 vs. 43 (ratio 1.0), for the Psychosocial group 31 vs. 22 (ratio 0.7), and for the Accident group 8 vs. 2 (ratio 0.3). A total of 24 of those who ended their employment in the Musculoskeletal group were research assistants, who often have short employments, while eight were employed at the end of 2019 (ratio 3.0). However, the Psychosocial group also had many research assistants in 2019 (9), but fewer (11) who ended their contracts in the period (ratio 1.2). The high turnover of employees and few

researchers on permanent contracts might be a problem for the continuity of the work of the research group.

The employees of the group are quite young. When two older employees retire in 2020, the two professors will be the oldest, both in their 40s (43 and 46 years, respectively, in 2019), and all the rest below 40 years, including the four senior researchers, as compared to 50% below 40 in the 2008 evaluation of this group. The professors and senior researchers of the Chemical group are described as rather young, however, the age of the corresponding researchers of the Musculoskeletal group is about 10 years lower and, therefore, very young. The lack of seniority and possibly less diversity in educational background (mostly focused on physical exercise/training at the individual level) and job experiences could possibly represent a limitation of the research focus of the group.

Guest researchers

Eight international PhD students have been associated with NFA during the evaluation period, from Spain, Brazil, Belgium and Iran, respectively, as well as a bachelor student (from the Netherlands) and two master students (from Sweden and Germany). Based on supplementary information from NFA, also senior guest researchers or guest professors have been affiliated with the research group.

Current research projects

There has been a total of 73 "active research projects", led by researchers of this group during the evaluation period (2014-2019), of which 46 with external funding, as counted by the project numbers. However, some projects are listed with more than one project number, due to funding from separate sources or additional funding for prolongation of the project, so the number of unique projects is lower. The two professors have been PIs of 28 of the 73 projects (15 and 13, respectively), while 24 are led by the four current Senior Researchers in the group and a previous Senior Researcher (resigned in 2018), and three projects by researchers at the unit "Work environment epidemiology (Data and Analyses)". At the end of 2019, 32 of the 73 projects were still ongoing, while five ended on that date. More than half (39 of 73) are listed with "co-finance". In addition to projects led by researchers of this group, they collaborated on projects led by researchers outside this research group.

The total amount granted the research group through external funding in the evaluation period was DKK 76.7 million, with The Danish Working Environment Research Fund as the most important funder, covering 83% (DKK 63.8 million) of all external funding received. The second largest external funder was TRYG Insurance (DKK 6.3 million), followed by the Independent Research Fund Denmark (DKK 2.6 million; the only group at the NFA receiving money from this funder), and the European Union (DKK 2.2 million). The "success rate" was on average 35% of applied amounts.

Two external grants have been around DKK 4.5 million, funding *the TOY project*, a participatory ergonomic intervention aiming at reducing physical exertion and musculoskeletal pain among

childcare workers, and *the Goldilock Work Principle*. Eight grants have been DKK 3.0-3.9 million and eleven grants in the range of DKK 2.0-2.9 million, with the rest being smaller.

The research group started testing out hypotheses in intervention projects in 2005, first with physical exercise in the workplace among office workers, and later in different workplaces, and found effect on pain and work ability. The intervention studies have also included a national campaign (2010-2015), which aimed to increase research-based knowledge about musculoskeletal pain and work, and found changes in attitudes, more among those who knew the campaign. Recently, they have developed participatory intervention projects, including also ergonomics and technical measurements, in different industrial sectors, such as construction, hospitals, eldercare and supermarkets, using randomized controlled trials (RCTs) and "the Goldilock principle".

Several projects in the evaluation period have been intervention projects, focusing on physical and ergonomic interventions, as well as organizational and psychosocial interventions, and lately with participatory methodology and Stepped-Wedge structure (a type of RCT), to reduce bias. Another important topic has been prolonging a healthy working life for senior workers, also with several projects, some based on survey and registry data.

4.3.2 Research collaboration

Research collaboration, international and national, including private enterprises

Many national and international collaborations and networks are listed in the documentation from this research group. In addition, they collaborate with other researchers at the NFA, particularly with the Psychosocial research group. Psychosocial factors may contribute to MSDs, and collaboration between the two groups is therefore warranted. The two professors are co-authors (usually separately) on about 30 original publications in international peer-reviewed journals listed in the prepared documentation from the Psychosocial research group, and also listed by Musculoskeletal group. The number of joint articles was highest in the last two years of the evaluation period (6 in 2018 and 11 in 2019), and the first year (7 in 2014), thus, it is difficult to judge whether collaboration between the two groups has increased during the period. It is also not clear whether they actually are involved in projects across the groups, or only on selected publications. One of the professors also had three joint publications with the Accident group. In addition, employees of the Work environment epidemiology (Data and Analyses) group co-authored some of the publications from the MSD research group. The professors were not co-authors of publications from the Chemical research group, but ten publications with one of the employees listed in this group. A small proportion (7 %) of the 384 original publications listed had no authors from the MSD group.

Nationally, they collaborate with several researchers, particularly at the University of Southern Denmark and the University of Copenhagen, but also at Aarhus University and Aalborg University, as well as university hospitals. These collaborations have often resulted in a number of scientific publications, including 40 publications with Professor Karen Søgaard (Department of Sports Science and Clinical Biomechanics, University of Southern Denmark), 12 publications with Professor Pascal

Max Madeleine (Department of Health Science and Technology, Aalborg University) and 12 with Associate Professor Mette Aadahl (Department of Public Health, University of Copenhagen). The two professors at the unit hold positions as adjunct professors at Aalborg University and the University of Southern Denmark, respectively.

International collaboration includes the following research institutions in the Nordic countries:

- **Finland**: Finnish Institute of Occupational Health, University of Tampere and University of Turku.
- **Norway**: National Institute of Occupational Health (STAMI), Norwegian University of Science and Technology (NTNU), Norwegian School of Sport Sciences, Oslo Metropolitan University (OsloMet), Østfold University College and University of Nordland.
- **Sweden**: University of Gothenburg, Lund University, Karolinska Institute, Umeå University, Uppsala University and University of Gävle.

Collaborating research institutions in other European countries included Belgium (Ghent University, Université Libre de Bruxelles), Germany (BAuA, University of Wuppertal), Italy, Netherlands (incl. Netherlands Organisation for Applied Scientific Research (TNO), National Institute for Public Health and the Environment, and a couple of universities), Spain (several universities), United Kingdom (Health and Safety Executive (HSE) Science and Research Centre, and several universities). Research collaboration with countries outside Europe include Australia (several universities), Brazil, Canada, Chile, China, Iran, Qatar, Thailand, and USA (National Cancer Institute and several universities). International collaborations have also often resulted in scientific publications, including publications with top-level international researchers in the field.

In addition, researchers from the group have been part of different project groups and networks, including *SELFBACK Consortium* (2016-2020, funded by Horizon 2020) and PEROSH networks on *Wellbeing and Work* and *Prolonging Working Life* and Other PEROSH network collaborators. PEROSH (Partnership for European Research in Occupational Safety and Health) comprises 14 European Occupational Safety and Health (OSH) institutes and support collaboration projects between the institutes, although not financially, so expenses have to be covered by the participating institutes themselves.

4.3.3 Scientific output and dissemination of research results

The number of original articles from this group increased during the previous evaluation period (annual average 2009-2013: 30 articles), and continued to increase in the beginning of this evaluation period, from 49 in 2014, to a stable level of 66-73 per year in 2016-2019 (Table 4.6). The total number of articles during 2014-2019 was 384 (annual average: 64 articles). On the other hand, an increase in the number of first and last authorships, from 24 and 26, respectively, to a maximum in 2017, 38 and 43, respectively, was followed by falls. The total number of NFA authorships and the NFA's share of authorships rose in the beginning of the evaluation period, to a maximum in 2016 (196 authorships and 49%, respectively), followed by major fluctuations in the number of

authorships and a fall in the NFA's share of authorships (annual average 172 authorships and 41%, respectively).

The NFA's research in this field was published in journals with still higher impact factors in the evaluation period, from an average of 2.4 in 2014 to 3.6 in 2019 (except 2017: 2.4). Of the 384 original articles, 96 (25%) were published in journals with impact factor of at least 3, of which 23 with impact factor higher than 5, but only six with first author from the research group.

Many of the articles are published in occupational health journals or public health journals, and some in other specialised journals, on e.g. sports, rheumatology or cardiology.

Table 4.6: Original articles published in international peer-reviewed journals. Musculoskeletal disorders and physical working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Original articles in peer-reviewed journals	49	58	66	68	73	70	384	64
First authorships	24	28	33	38	35	29	187	31.2
Single authorships	0	0	0	0	0	0	0	0
Last authorships	26	37	41	43	42	37	226	37.7
Authorships, NFA	119	177	196	175	195	170	1.032	172
The NFA's share of authorships	39%	49%	49%	41%	37%	34%	41%	
Authors/article	6.2	6.2	6.0	6.2	7.1	7.1	6.5	
Average impact factor	2.3	2.6	2.8	2.4	3.0	3.6	2.8	

Of the 384 articles, six were published in very-high-impact journals (impact factor > 10), but only one with first author from the research group (an editorial on the physical activity paradox). The main topics of the other five articles were cardiorespiratory fitness, physical fitness, living alone, mortality and chronic obstructive pulmonary disease, and one on anthropometric measurements, which may not be the main priority research areas of the research group.

The number of review articles etc. also seemed to increase during the evaluation period, from one in 2014 and 2015, to 6-8 each year in 2017-2019, with number of NFA authorships also increasing, from one to 11-12 per year (Table 4.7). The number of conference abstracts fluctuated strongly through the evaluation period, between 11 and 31 per year, the average number was 23 (Table 4.8).

Table 4.7: Reviews etc. published in international peer-reviewed journals. Musculoskeletal disorders and physical working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Reviews etc. in peer-reviewed journals	1	1	0	6	8	6	22	3.7
First authorships	0	0	0	1	4	1	6	1.0
Single authorships	0	1	0	2	1	0	4	0.7
Last authorships	1	0	0	2	3	3	9	1.5
Authorships from the NFA	1	1	0	9	12	11	34	5.7
The NFAs share of authorships	17%	100%	-	38%	15%	20%	21%	
Authors/article	6.0	1.0	-	4.0	10	9.0	7.5	
Average impact factor	1.1	-	-	2.0	5.4	2.2	3.1	

Table 4.8: Conference abstracts. Musculoskeletal disorders and physical working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Number of conference abstracts	31	11	29	14	29	24	138	23

4.3.4 Excellence

The research group on MSDs and physical working environment has increased its contribution to Danish occupational health research during the evaluation period. The researchers have extended their research, from focusing on individual-level interventions and exercise programs, to

participatory intervention projects, including ergonomics and technical measurements, as well as organizational and psychosocial factors. Self-reported ergonomic exposures are inaccurate, and the group has developed methods for objectively measuring exposures during work and leisure time, on many workers. They are probably at the forefront globally in this field, and collaborate with several groups internationally. They have also developed their study designs, with participatory methodology and Stepped-Wedge structure, to reduce bias. The number of intervention projects of high quality from this research group is impressing, considering the size of the research group. Few other groups, if any, have performed so many work-place intervention studies targeting MSDs. The researchers also combine objective exposure measurements with registry-based outcome data, e.g., on sickness absence, to study effects of ergonomic exposures and workload, without using self-report data, which is a major strength. In addition, they combine survey data from large cohorts of Danish employees with registry-based outcomes and have, e.g. explored theoretical models of reasons for leaving or staying in working life.

The NFA musculoskeletal and physical working environment group listed ten publications from the evaluation period, which they consider to be the most important contributions to research in the area, all with first authorships. The publications illustrate well the excellence of the research group and include original research articles, some based on survey and register data, as well as an evaluation of a national campaign, an editorial, a discussion paper, practical guidelines and a cohort profile. The selected publications clearly demonstrate the excellence and breadth of their research, both in terms of topics and methods.

Several prospective studies have combined survey and/or measurement data with Danish register data, and some good examples were selected.

One of these (Andersen et al. 2019) studied the influence of physical and psychosocial working conditions on the risk of disability pension among 4699 healthy female eldercare workers, followed for 11 years. This study was done in a collaboration between researchers from the Musculoskeletal, Psychosocial and Work environment epidemiology groups, exploiting different competences within the NFA.

Another study (Andersen et al. 2016) examined the prospective association between physical workload (8 specific physical exposures, as well as the number of exposures) and long-term sickness absence. Exposure factors are often analysed separately, but this study shows the importance of looking at combined exposures.

The *SeniorWorkingLife* Study (Andersen et al. 2019) investigates “push” and “stay” mechanisms for labour market participation among older workers, such as factors conditioning retirement intentions, also based on survey and register data, comparing employees with sedentary and physically demanding work and different occupational groups. The study tested theoretical models and mechanisms influencing retirement decisions in an excellent way.

One publication (Jørgensen et al. 2019) is a cohort profile of the *Dphacto* cohort (The Danish Physical Activity Cohort with Objective measurements), a research database with objective measurements of physical activity and postures of 1087 workers from manufacturing, transportation and cleaning sectors (both blue-collar and white-collar workers), with prospective follow-up, including repeated text messages, questionnaire and national registers. The paper also gives an overview and baseline information. Several publications are expected from the follow-up of the cohort.

The group has examined the effect of interventions, both at the national level and at the workplace level.

One study (Andersen et al. 2018) evaluated the effect of a national campaign (2010-2015), which aimed to increase research-based knowledge about musculoskeletal pain and work among public sector employees, through questions to random samples at baseline and at four later time points.
Another study (Rasmussen et al. 2015) investigated the effectiveness of a workplace multifaceted intervention, consisting of participatory ergonomics, physical training, and cognitive-behavioural training for low back pain among 594 nurses' aides from eldercare workplaces, with a pragmatic stepped wedge cluster randomised controlled trial (RCTs).

Another RCT (Sundstrup et al. 2014) examined the effect of workplace strength training on work ability among 66 slaughterhouse workers with upper-limb chronic pain and work disability, randomly allocated to 10 weeks of either strength training at the workplace or usual care ergonomic training.

RCTs are considered the gold standard in research, and Intervention studies using RCTs are often difficult to perform in workplaces, and very resource demanding. These studies show, in excellent ways, that it is possible.

Some publications discuss central questions in relation to work exposures and MSDs, important to understand the relationships and prevent work-related MSDs.

An editorial (Holtermann et al. 2018) discusses reasons for "the physical activity health paradox", i.e. why physical activity at work may not give the same health benefits as leisure time physical activity, reflecting several papers on the topic by the authors, including international prominent public health researchers.

A discussion paper (Holtermann et al. 2019) presents the *Goldilocks principle*, that envisions how to design productive work so it becomes "just right", and promotes health and physical capacity of the workers, instead of using the traditional approach, by reducing high physical demands or taking time away from productive work (e.g. exercises during work hours).

A paper (Holtermann et al. 2017) based on a collaboration project between 13 PEROSH institutions, led by the NFA, gives practical guidance for researchers and practitioners to appropriately assess sedentary behaviour at work and presents an overview of characteristics of wearables and factors to consider for sedentary behaviour assessment. The paper received the "Best paper award 2017" for Applied Ergonomics.

4.3.5 Evaluation and recommendations

The research of the MSDs and physical work environment group is innovative and holds high quality, when compared to similar national and international research groups. The group has developed methods for objectively measuring ergonomic exposures and intervention projects of high quality. MSDs are very common in the population and one of the priority areas in the national work environment strategy and a selected research area of the NFA. The research group has extended their research during the current evaluation period, from a more individual-level focus to a stronger focus on combinations of work environment factors of importance for the prevention of MSDs. Their research is therefore focused on solving scientifically relevant and prioritized working environment issues, with potentially high social impact.

MSDs lead to economic and other consequences for employers and society, as well as for individuals. Thus, the research activities of the group are highly relevant for authorities and workplaces. The researchers have sufficient knowledge, systematics and methods on how to involve stakeholders and target groups in research. Their research activities, in particular intervention projects, are carried out in collaboration with workplaces and stakeholders.

MSDs are prioritized, both nationally and by the NFA, and the research topics and projects of the group, focusing on MSDs or seniors, are very well in line with NRCWE's research strategies.

The group has succeeded in getting external funding for a number of projects, with The Danish Working Environment Research Fund being the largest funder, covering 83% of external funds in the period, followed by TRYG Insurance. The researchers are involved in national and international scientific networks, including a couple of PEROSH projects (which do not fund research) and a project funded by Horizon 2020.

The group's implementation of recommendations from the latest evaluation

"Give more emphasis to factors and interventions at the organizational level that can explain biomechanical exposures and related outcomes."

The previous evaluation described that there had been large changes in focus of the NFA's research on MSDs and physical exposures, from biomechanics and work physiology to emphasis on "individual-targeted interventions (exercise programs), mainly for the purpose of reducing musculoskeletal pain, and on epidemiological studies of associations between biomechanical exposures and different outcomes". It was recommended to give more emphasis to factors and

interventions at the organizational level that can explain biomechanical exposures and related outcomes, in addition to the individual-focused approach, which dominated both intervention studies and epidemiology in the group. It was also commented that the explicit relationship of the research with the strategic priorities of the NFA was not thoroughly transparent.

A focus on individual-level interventions and exercise programs seems to contradict the mission and vision of the NFA, which focus on the working environment, as expressed in the strategy documents. However, the group has developed its research and interventions much during the current evaluation period, particularly on ergonomics and exposures, from looking at one exposure at a time, which has usually been common, to see them in relation to other exposures, which gives more opportunities for intervention. The focus is now more on how to organize work and on participatory interventions. Thus, the research group has followed the recommendation to give more emphasis to factors and interventions at the organizational level that can explain biomechanical exposures and related outcomes.

"Clarify and define the organizational structure of the NFA regarding exposure factors and outcomes."
The previous evaluation commented that "some priorities pertain to occupational exposures while others are described in terms of outcomes" and recommended "that the NFA clarify and define their organizational structure", and that one alternative could be "to organize projects according to exposure factors, (…) possibly combined with type of outcomes in a matrix structure".

The name of the research program was previously just *musculoskeletal disorders*, but changed in 2015 to *musculoskeletal disorders and physical working environment*, possibly following these recommendations. The change of the name also seems to reflect a stronger focus of the group on the working environment, not only the physical working environment, but also organizational and psychosocial aspects. Causes of MSDs are multifactorial and research and interventions focusing only on physical/mechanical/ergonomic factors for several decades have not succeeded in reducing these disorders very much. Therefore, a wider approach seems warranted. Collaborating with other research groups at the NFA, in particular the Psychosocial research group, would also be an advantage, and was recommended in the previous evaluation, and a bilateral exchange program was suggested. Several publications with authors from both research groups show that there is some collaboration between them.

"More clearly formulate the interpretation of the area "musculoskeletal disorders"."
The previous evaluation recommended initiating discussions of the NFA research in the context of the national 2020 priorities, and particularly more clearly formulate its interpretation of the area "musculoskeletal disorders", whether they allow for any effects of physical (in)activity to be studied, including, e.g., cardiovascular health or diabetes, which does not very clearly relate to the 2020 strategy.

In the last half of the evaluation period, there seems to have been fewer articles on cardiovascular health or diabetes, with first or last author from this research group, compared to the first half. This may indicate a stronger focus, and greater awareness and adherence to the national priorities that governs the NFA's strategy and work.

Cardiovascular health or diabetes may also be work-related and therefore relevant study outcomes for the NFA. The Psychosocial group studies these outcomes in relation to psychosocial and organizational factors, including shift work.

"Develop a strategy of whether to perform controlled experiments or not."
The previous evaluation recommended a clear strategic choice of whether to invest resources in building functional laboratories for controlled experiments and method development, or whether to instead engage in collaborations stimulating other groups to investigate issues of interest to the NFA using laboratory-based research designs. The research group appears to have chosen the latter, using experimental research designs and collaborating with other experts for developing technical equipment for accurate measurements of exposures.

"Develop further collaborations with groups outside Scandinavia."
The research group has extensive collaborations outside Scandinavia, judged by the list of collaborations and joint publications. The previous evaluation also suggested investing resources in a running program for inviting guest researcher(s) or post doc(s) to perform research at the NFA. It does not appear from the documentation that this has been done, but some PhD students from other countries have stayed as visitors for shorter or longer periods.

"Decide priorities for future research into noise and its effects."
The previous evaluation recommended the NFA to decide how to maintain the knowledge base required in the National strategy 2020 (performing in-depth research or only monitoring research from other groups). Research into noise and its effects has not been prioritised in the current evaluation period.

"Seniors" is one of four subthemes across the three key themes of this research group, and the documentation prepared for the evaluation panel, demonstrates its importance, including specific projects, such as the *SeniorWorkingLife* study and the PEROSH project *Prolonging working life*. They have performed several epidemiological studies by merging data from existing and/or newly formed cohorts with high-quality national registers containing information on labour market participation. Results from these studies have contributed to the national societal debate on prolonging working life, recently in relation to an upcoming reform about differentiated state pension age.

Suggestions for recommendations

The research group on MSDs and physical work environment has developed their research during the evaluation period, from focusing on individual-level interventions and exercise programs, to participatory intervention projects, including ergonomics and technical measurements, as well as organisational and psychosocial factors. It is recommended to continue developing the focus on work environment factors and workplace interventions of relevance to MSDs, in accordance with the mission and vision of the NFA, in collaboration with other research groups at the NFA, and in interplay with the strategy processes at the NFA. Greater diversity in age and background of permanently employed senior researchers could be an advantage in this process.

This research group is mainly focused on health outcome, MSDs, and the relevant physical exposures, while the other groups are mainly organised according to exposures (psychosocial, chemical, safety culture; although "occupational accidents" is an outcome for the Occupational Accident and Safety Culture research group, it is not a health outcome, but could be considered an intermediate variable to the health outcome "injuries"). Occupational psychosocial and organisational factors are important risk factors for MSDs, as well as for combinations/interactions with other exposures. There is, and should be, considerable collaboration between the research groups. It is difficult to judge whether such collaboration has increased and whether senior researchers of one group are actually involved in projects of other groups, however, this is recommended to ensure that relevant knowledge, across the research groups, is available all through the project, from the start of planning the project.

The research group often presents the results of their studies adjusted for gender. There are usually gender differences in MSDs, and possibly in effects of exposures and interventions. Adjusting for gender may obscure important effects and differences, therefore gender-stratified analyses are recommended, whenever possible. Citing colleagues in occupational health research: "Although gender-sensitive practices may be difficult to operationalize in some cases, they enrich the scientific quality of research and should lead to better data and ultimately to well-targeted prevention programs." We will recommend the research group to follow this advice.

Collaboration with universities (including teaching) often seems to be with focus on sports. It is recommended to strengthen collaboration with occupational (and public) health researchers and academic institutions.

4.4 Occupational accidents and safety culture

4.4.1 Key data

Research areas

The Accident and Safety Culture research group has defined its objective as to generate scientifically based knowledge that is relevant for promotion of safety and health of the workforce and thereby contributing to the creation and continuation of safe and healthy workplaces and a long and productive working life for all workers in Denmark. The Danish government prioritized the reduction

of occupational accidents during the evaluation period and it is included in the national 2020 action plan for the improvement of health and safety at work. The Accident and Safety Culture research group's overall goals and methods fit well with the national 2020 action plan and Danish governments' prioritization. The National Research Centre for Work environment strategy 2017-2020 states that Accident and Safety Culture strives to create knowledge on how organizations' ability to predict and adapt to changing risk situations, can be developed through a proactive approach to security. Now, in the years 2020-21, when the Covid-19 pandemic is affecting all countries and workplaces, it is a very relevant and timely goal to support workplaces on providing safe working environment and building resilience.

At the beginning of the evaluation period the research group developed research and acquired funding for projects that addressed digitalisation, how to translate research to practise, and developing and evaluating policy initiatives. The research area is organized in four main themes which are connected to each other:

- Aetiology (contributing factors to accidents)
- Intervention (prevent accidents and promoting safety and health)
- Resilience (ensure long-term, sustainable initiatives)
- Research to practice / knowledge transfer and exchange

During the evaluation period, the group has increased the use of survey and register data.

Even though the group is rather small, it has consolidated its activities and operates effectively. One way this shows, is that it has a very active collaboration with other research areas at the centre. With this internal collaboration the group can and has increased the impact and extent of its research goals. Good internal collaboration also ensures that there should not be any unintentional overlap in activities of research areas.

Researchers

The research group includes eight persons and is headed by research director Henriette Bjørn Nielsen, who is also the research director of the psychosocial working environment area. The research group includes three senior researchers, one researcher, one postdoc, one PhD student and two research assistants. Additionally, by the end of 2019, the research group has had two academic assistants, whose employment ended by November 2018.

The research group size is rather small, but it has operated effectively during the evaluation period.

Guest researchers

During the evaluation period the Accident and Safety Culture research group had two guest professors from USA and Canada.

Current research

There were 31 projects with external funding during the evaluation period and total external funding was over DKK 23 million and on average DKK 750,000 per project. In addition to externally funded/co-funded project there has been six projects funded by the NFA itself. Over 70% of externally funded projects were funded by The Danish Working Environment Research Fund - generally the largest projects. Other external grants were smaller and occasional, so the research group depended on The Danish Working Environment Research Fund for continuation of research projects. The risk of losing funding possibilities is likely not very high, due to the group's good fit on funder scope, but search for alternative research funding possibilities would be something to investigate, e.g., EU funding opportunities.

The foci of the group followed its main research area themes:

1) Aetiological studies, such as risk and safety among young workers, working hour arrangements, nanotechnology, zero accident vision, safety climate and the role of safety coordinators in establishing safety in construction projects, digitalisation of work and of OSH-promotion initiatives
2) Intervention studies such as development and evaluation of a toolbox training method in construction; development of a safety observation app, improving apprentice safety in small construction firms
3) Resilience studies regarding safety culture and leading indicators, and zero accident vision
4) Research to practice (R2P), theoretically and methodological development, research to practice in accident prevention and in OSH-promotion efforts at the working place

The research group has increased the use of survey and register data in the projects.

4.4.2 Research collaboration

The research group is active and cooperative in research and expert collaboration both nationally and internationally. At a national level it had active partnership projects with Occupational Medicine, Herning Hospital and Accident Analysis Group, Department of Orthopaedic Surgery, Odense University Hospital, Odense. National collaborations and networks include:

- Aalborg University, Centre for Youth Research; Sociology
- Aarhus University: Department of Psychology
- Copenhagen University: Anthropology, Public Health
- Herning Hospital, Department of Occupational Medicine
- Odense University Hospital, Department of Occupational Medicine
- Odense University Hospital, The Accident Analysis Group, Department of Orthopaedic Surgery, Odense
- University of Southern Denmark, Institute of Clinical Research, Odense
- Roskilde University: Department of Communication and Arts
- Roskilde University, Centre for Working Life Studies (Arbejdslivsstudier)
- Teamarbejdsliv (consultancy and research activities)
- University of Southern Denmark, Department of Technology and Innovation

Internationally collaboration has been made with a Nordic group working on risk and safety among young people. There is a partnership between Herning, NFA and Göteborg University on safety in construction work, and there is also an international partnership about evaluating safety interventions (the SIPAW REVIEW). Researchers were in a close collaboration with PEROSH regarding the Vision Zero research, which involved seven research institutes in the EU. International connections include, among others, STAMI, Norway; FIOH, Finland; Occupational and Environmental Medicine, Uppsala University Hospital, Sweden; CIOP-PIB, Poland; DGUV, Germany; HSL, UK; Prevent, Belgium; TNO, Netherlands; PEROSH; Institute for Work and Health, Canada, NIOSH, USA; NIVA.

4.4.3 Scientific output and dissemination

The group's researchers have been active with dissemination on national and international level. The Accident and Safety Culture research group has developed a Safety Observer app for use in measuring safe and healthy working environments and it is available for download for mobile devices.

The scientific output has remained at a quite stable level during the evaluation period if 2014 is not considered. In the previous period the group (although the circumstances were different) published 27 articles which is very similar to the 28 articles published in the present period. On average the group published 4.7 original articles in peer-reviewed journals per year. The NFA's share of authorships was on average 44%, the first authorship on average 35%, and last authorship on average 53% of the articles. In both first and last authorships a good positive trend can be seen through the evaluation period, but due the small sample size conclusions are difficult to draw. The research group has compensated for its relatively small size by relying on and developing extensive national and international collaborations with complementary research fields and researchers. The group has a good internal collaboration with NCRWE's other three research lines.

Table 4.9: Original articles published in international peer-reviewed journals; Occupational accidents and safety culture.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Original articles in peer-reviewed journals	0	4	5	6	7	6	28	4.7
First author-ships	0	0	1	2	4	3	10	1.7
Single author-ships	0	0	0	1	0	0	1	0.2
Last author-ships	0	1	2	4	5	3	15	2.5
Authorships, NFA	0	5	12	15	23	12	67	11.2
The NFA's share of authorships	-	29%	39%	47%	56%	36%	44%	
Authors/article	-	4.25	6.2	5.3	5.9	5.5	5.5	
Average impact factor	-	2.2	2.3	2.8	3.2	3.0	2.7	

The average impact factor of journals, which articles from the NFA were published in, was quite stable in the evaluation period – especially when the small numbers are considered. There were no articles in so called very-high-impact journals (impact factor >10). However, the journals, which the articles were published in, were high quality journals of the research area. During the evaluation period the research group had four review articles published.

Table 4.10: Conference abstracts; Occupational accidents and safety culture.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Number of conference abstracts	9	18	10	24	6	25	92	15.3

The number of conference abstracts fluctuated a lot during evaluation period, but the average annual number of conference abstracts for the group was 15.3 abstracts which is good, when considering the size of the group, and the researchers have contributed actively to international scientific discussions.

4.4.4 Excellence

The Occupational Accidents and Safety Culture group has reached a high level of safety research by sound research strategy choices, that have also followed the needs observed in society/workplaces. The group has a long history on developing the Safety Climate concept, measurements, and practical questionnaires for use by OSH experts. The NOSACQ-50 questionnaire is widely used internationally, and the group has demonstrated innovativeness by developing a reduced form of the questionnaire. The group's activities on Vision Zero and proactive safety started earlier that in most similar type research organizations, thereby demonstrating an understanding of the relevance and timeliness of the research themes. The group has also excelled in research on young workers and their specific safety needs and measures. The group has a very good methodological and theoretical strength and know-how in using mixed-methods research which is important for the safety research area.

Examples of the excellence of the NFA Occupational accidents and safety culture group in research include, for example:

- A study on toolbox-training method process evaluation at construction sites in Denmark. The study included the whole process starting from the development of the training to the evaluation of the results. Toolbox methods are commonly used in many countries, but there is not much research on the effectiveness of these participatory techniques. Results indicated that these methods are adaptable to the construction safety culture in Denmark to successfully improve OSH dialogue among foremen and other parties at construction sites. The study also had a positive impact on the group's international expert collaboration
- Taking small enterprises as a study subject with implementation of an integrated approach. This was a case study on metal and wood processing industries. Small businesses are very important as employers and for national economy, but research on small enterprises is very challenging. They also often lack formal safety management and have limited resources on development of safety. The study showed, that the integrative approach is possible in small enterprises and confirmed the importance of the management commitment
- Research on improving apprentice safety in small enterprises is a good example of, how the group's study focus targets important groups of small enterprises and young people entering working life.

Both groups are very relevant from an OSH perspective. The study results support the organizational approach as a apprentice's injury prevention strategy

- A cross-sectional study among 15,000 workers of the general working population demonstrated the usefulness analysis of occupational safety climate to foresee the risk and injuries at work. The questions were part of 2012 Danish Work Environment and Health study and are based on the NOSACQ-50 questionnaire (Kines et al) in reduced form. The study found, that the short version of the questionnaire can be used by OSH professionals to assess the safety climate in an easy and cost-effective way. The study also found, that younger people are more likely to experience safety climate problems and accidents at work

- A register based cross-over study on shift work and risk of injuries illustrates the group's good research collaboration both within institute and with national partners. The study utilized data from the Danish Working Hours Database and the National Patient Register by linking their data. The study supports the evidence of higher risks of occupational injuries during evening shifts and after quick returns, which can be used at workplaces in shift planning
- A multinational study on implementation of Zero Accident Vision in 27 companies in Europe is a good example of international research collaboration and of research on themes that are about to become global topics in working life. The research and especially working life activities on Vision Zero have increased significantly since the article was published. The study was a good example of the mixed-methods approach and it systematically studied the implementation of Vision Zero in enterprises. The study confirmed, that Vision Zero committed companies often have other important 'zero' goals along with accident prevention
- A good example of a qualitative study on safety practices of small construction companies from the employee perspective. The data were from a multi-case study of ten small companies involving work crews of 1-2 persons. The study showed that from the employee perspective the general approach to safety was positive even though it rarely had an explicit focus. The study also found that safety generally was not a topic for communication, and it was not viewed as a common responsibility

There are also other good examples:

- A mixed-method approach using qualitative (survey) and quantitative (safety observations) research methods was used to explore, if OSH risk perception, behaviour and exposure to violence and threats differ among worker groups and across work shifts at emergency departments
- A register-based study as a nice example of well-defined study protocol and using large data from the Danish version of the European Labour Force Survey and national health registers to study the link between long working weeks, night work, and risk of accidental injuries
- A qualitative study of construction workers' practices of using and relating to their bodies at work

4.4.5 Evaluation and recommendations

The research of the Occupational Accidents and Safety Culture shows

- A high level of quality and originality when compared to similar national and international research groups
- Research topics/projects that address the Danish working environment's needs
- Well thought-out strategic focus points for the group's activities

The research area clearly constitutes a major contribution to the Danish occupational safety research, and the research results are highly relevant to the Danish working environment. The group is focused on solving scientifically relevant and prioritized working environment issues, and it has good contacts to enterprise-level stakeholders to understand the needs of workplaces. The group has also prioritized the top five high-accident-risk sectors in its research along with multi-sectoral studies. The high quality of the research has also led to international appreciation and cooperation in different activities.

The research is relevant for the specific needs of authorities and workplaces. The researchers have sufficient knowledge, systematics and methods on how to involve stakeholders and target groups in research. For example, the group reports, that the research on young workers work safety has influenced on strategic priorities on the Working Environment Council. The group's research in most cases involves workplaces, and the group is putting more emphasis on interventional studies which deepen stakeholder involvement further. The group's approach with research-to-practice also makes it possible to transfer the results of scientific research much faster to benefit the stakeholders at workplaces and authorities.

The NFA strategy 2017-2020 states, that the Occupational Accidents and Safety Culture research area strives to create knowledge on how organizations' ability to predict and adapt to changing risk situations can be developed through a proactive approach to security. The NFA prioritizes research that can:

1) Shed light on the background and causes of occupational accidents
2) Clarify which specific measures or interventions can help to improve the safety climate and culture at Danish workplaces
3) Investigate how a high and long-term level of safety can be maintained under flexible and dynamic conditions

The group's research topics and projects are very well in line with NFA's research strategy and contribute strongly to it.

During the evaluation period over 70% of externally funded projects were funded by The Danish Working Environment Research Fund and they are generally also the largest projects of the group. In general, there is a small number of scientific financing opportunities for occupational safety research. The group's research focus has a good fit to the national research funders. However, search for alternative research funding possibilities would be something to investigate, e.g., EU funding opportunities.

The group has good scientific networks with important research groups at universities and other research institutions in Denmark and abroad.

The 2014-evaluation commented on a lack of focus of the research group at that time. This has changed, as the group now has well thought-out strategic research focus points and priorities. The 2014-evaluation recommended to recruit a professor, who can combine solid quantitative expertise in accidents, safety measures, and human error, with the safety management topics. The NFA has tried to recruit a professor with these competences but was not successful. Instead, it has had two visiting professors during the evaluation period and added one senior researcher to the group. This recommendation has not been followed, but it is still a valid recommendation for the future even if a professor for this specialized field is difficult to find. In general, the NFA should consider, how it may advance its personnel on researchers' career paths, where a professor position should also be

possible to reach. The 2014-evaluation also noted, that research is managed by a project organization, but the panel considered that the institute would benefit from a more clear and transparent presentation of its organizational structure, research programs, and within these research programs, research lines. The NFA has followed this recommendation by organizing four research programs, and different research lines within the programs.

The issues related to seniors have been included in research projects as a part of normal activities, but the issues have not constituted a focus of the research. For example, in wellbeing in the elder care sector research this question was approached by looking at new technology lifts etc. to prevent accidents and musculoskeletal disorders.

The Occupational Accident and Safety Culture research group and its work is organized efficiently, and the research area is important to the NFA's mission and strategy. However, we suggest, that increasing the personnel in this group should be taken into consideration and thus increasing the impact and scope of research to better accommodate the research strategy and stakeholder expectations. The 2014-evaluation also recommended to open a professor position in the group, and this is still a valid recommendation for the future.

The current Covid-19 epidemic has shown, that there is a need to study and provide practical solutions of megatrends that change our environment, workplaces, and societies. The group's strategic focus points already include the necessary elements, and it is suggested, that the group considers, how effects of climate change, pandemics etc. could be included in the group's future research plans, if they are not already there.

4.5 Chemical working environment

The aim of the research at the Chemical working environment unit is to mitigate current and emerging issues for the chemical work environment in Denmark. The research at the unit spans a wide field ranging from physical-chemical and microbial characterization, release and exposure measurement, toxicological evaluation, to risk assessment and risk management.

4.5.1 Key data

Research areas

The unit for the Chemical working environment addresses exposures that are extremely diverse in structure and composition, e.g., air-borne particles, bioaerosols, gases, and fluids, that are taken up by the body via different routes, and accordingly cause many and diverse health effects that can be both local and systemic. Apart from measuring exposure and toxicity, research at the unit also includes investigation of mechanisms and pathways linking exposure to diseases. Parts of the research support standard and guideline development and regulation. Research at the unit is performed using different types of scientific studies, from *in vitro* cell studies, advanced experimental animal studies, human field studies in close collaboration with the workplaces, to large cohort and register studies with advanced epidemiological designs.

In the evaluation period, the research within the Chemical working environment unit was organized in three areas:

- *Nanosafety*. Research in particle characterization, exposure assessment, toxicology, and nanoparticle risk assessment and risk management
- *General toxicology*. Addresses e.g., the toxicology of spray products, indoor air climate and toxicity of prenatal exposures to chemicals
- *Microbiology and bioaerosol exposure*. Microorganisms and their inflammatory components were studied at workplaces and characterized

Nevertheless, it has not been possible to perform this evaluation according to this organization and accordingly it has been performed at the unit level. The reasons for this are that

1) There are strategy documents for the nanosafety and microbiology areas but not for general toxicology (and nor for the whole unit)
2) The documents provided by the unit have not been grouped according to this organization

Researchers

The research unit comprises appr. 40 employees including professors, senior researchers, postdocs, PhD-students, and technicians and is headed by a director of research. The unit is organized as a matrix organization where all projects have a project leader, who refers to the director of the research unit. The unit included in December 2019 one professor, one professor MSO and one affiliated professor (affiliated by 12.5%). One professor and three senior researchers have left the unit during the evaluation period and two new senior researchers have been hired: one working with general toxicology and one with nanosafety. One senior researcher leads the microbiology and bioaerosol exposure group.

By the end of 2019, apart from the three professors mentioned above, there were eight senior researchers, four researchers, six postdocs, two PhD students, two research assistants and nine technicians, and ten from other professions (including animal caretakers, research and academic assistants and consultants) working at the unit. This number has increased slightly from the previous evaluation period. No guest researchers are listed, but some of the researchers are affiliated to the

NFA, including one of the professors. The professors (54 and 55 years of age) and the senior researchers (average age 48.5 years) are rather young.

Research projects

The research unit lists 80 research projects during the evaluation period. Almost all research funding is external and gained in competition with other research institutions. The main funding bodies include The Danish Working Environment Research Fund and the EU, of which the unit has been particularly successful in obtaining funding from the latter. The success rate is overall impressive with 25.6% as the lowest and 79,30% as the highest. The success rates were for years 2018 and 2019 60% and 65.5%, respectively, which suggest stable high external funding for the years to come.

The Nanosafety research area has been the research area within the unit with the largest contribution in terms of international projects, scientific output, and funding. It has been very successful in obtaining grants from national and international (mainly EU) funding bodies. Twice, the unit has obtained special national funding (The Danish Working Environment Research Fund) for the Danish Centre for Nanosafety (2012-2019). During the evaluation period, the unit has been a partner in 16 EU-projects, mainly in the Nanosafety area, and coordinator for one large EU project. The General toxicology lists the largest number of projects, but the overall funding is lower than for the Nanosafety area. The Microbiology and bioaerosol exposure group list the lowest number of projects and the lowest external funding.

Since the evaluation in 2014, the Nanosafety research has broadened its research to other particles such as process generated ultrafine emissions from diesel engines and airplanes and workers' exposure to PCB. The unit works to maintain its competences during the change. Due to the large number of different chemicals, it has been necessary to adapt the intensity of the research to the resources available each year, and subjects like organic chemicals and noise are not prioritized currently.

4.5.2 Research collaboration

Links to international research have been very strong during the evaluation period by several means:

1) As partners in large Nordic and European Horizon 2020 projects
2) As experts in groups (e.g., PEROSH, NEG, ICOH) for criteria documentation

The international collaboration includes research and publication collaborations as well as collaborations on preparation of guidelines, and criteria and exposure limits. The collaborations involve universities and institutes in (some examples in brackets): Finland (Finnish Institute of Occupational Health), Norway (National Institute of Occupational Health; Norwegian Institute of Public Health), Sweden (Lund University, Uppsala University), Germany (Helmholtz Centrum, BfR), United Kingdom (Institute of Occupational Medicine, Heriot-Watt University), Poland (University of Warmia and Mazury), Turkey (Yeditepe University), Italy (Tor Vergata University), the Netherlands (TNO for Life, RIVM), Canada (Health Canada), Austria, France (French National

Research Institute for Agricultural Research, INRA), Belgium (CODA CERVA), Spain (Institute of Environmental Assessment and Water Research - Spanish Research Council, Compultense University), Switzerland (Swiss Federal Laboratories for Materials Science and Technology), China (Chang'an University), Japan (Tokyo University of Science) and USA (Boston University, School of Public Health; Duke University).

There is also collaboration within networks (e.g., Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals, NEG; PEROSH Exposure group; EU Nanosafety cluster, and Stoffenmanager's International Scientific Advisory Board). Indeed, the international collaboration is impressive.

National collaboration is carried out with several Danish universities and institutes (DTU; the universities of Copenhagen, Aarhus, Aalborg and Southern Denmark; College Metropol, and the Ramazzini Center), Copenhagen University Hospital (e.g., the hospitals of Bispebjerg and Gentofte - e.g., the National Allergy Center) and the university hospitals in Odense, Aalborg and Aarhus.

The extent of international and national collaboration is corroborated by co-authorships of scientific articles. Thus, nearly all of the 318 original articles published in international journals for 2014-2019 have one or more co-authors from outside the NFA. The international collaboration has increased during the evaluation period.

There are extensive collaborations with private consultancy firms (COWI, FORCE, and DHI) and industry through national and international research projects with external funding. The research unit has collaboration with the Danish authorities, primarily The Danish Environmental Protection Agency; the "Advisory Board for Hygiene" as well as the different networks (IDA, Network Indoor Air); the Municipality of Copenhagen; other Danish stakeholders, including industry, unions, the Danish Working Authorities; the EU; OECD, and occupational health professionals.

4.5.3 Scientific output and dissemination

The scientific output in the evaluation period is extensive and impressive. The unit lists 318 original articles in peer-reviewed international journals with an average of 53 articles per year (Table 4.11). About one third of the original articles have the first author from the unit and one third has the last author from the unit. There are 17 articles published in very-high-impact (IF>10) peer-reviewed international journals during the period. Four of these articles emanate from the Nanosafety research area, one is a comment, one is a review article, and two are original research papers. Two articles involve the General toxicology area, of which one is a review paper. Three papers aim to identify genetic susceptibility factors for different types of cancers. Four articles address exposure to airway irritants and risk of lung toxicity and lung disease, whereas three focus on biological characteristics and risk of lung function decline and/or asthma. There is one article (Ørby et al. 2019) of those articles in very-high-impact journals where an author from the NFA is senior author, and one paper (Bornholdt et al. 2017) with shared first authorship. For two out of the seventeen papers

there are more than one co-author from the NFA, i.e., the large majority of the high-impact papers represent international collaborations where the NFA is not the PI of the research.

Table 4.11: Original articles published in international peer-reviewed journals; chemical working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Original articles in peer-reviewed journals	51	55	48	60	46	58	318	53
First authorships	12	16	12	16	17	27	100	16.7
Single authorships	0	0	1	1	1	0	3	0.5
Last authorships	15	19	17	17	17	25	110	18.3
Authorships, NFA	122	133	127	142	122	167	813	135.5
The NFA's share of authorships	15%	23%	22%	24%	24%	27%	22%	
Authors/article	16	11	12	10	11	11	12	
Average IF	3.56	4.08	4.50	4.50	4.12	4.43	4.20	

There was no clear trend in the number of original articles published in peer-reviewed scientific journals over time. The numbers of first and last authorships were comparatively stable, although the numbers were very high in the last year in the evaluation period compared to the rest of this period. There was a tendency to an increase in the number and share of authorships. Again, the last year in the evaluation period constituted an outlier. The comparatively low share of authorships in the first year of the evaluation period reflected, that one of the articles was a paper with 298 authors including a single author from the NFA. The average number of authors for each article was stable over time except for the first year with the article with 298 authors. This finding indicates, that there was no or very little inflation in authorships – the increase in the number of authorships most likely reflected growing contributions from the NFA. The small and fluctuating number of review articles and their heterogeneity made it difficult to interpret the data (Table 4.12). The year 2017 constituted an outlier with 17 papers including 16 reviews and a letter to the editor. The average IF/year was 4.20 for original research articles and higher for review articles: 6.14.

Table 4.12: Reviews etc. published in international peer-reviewed journals; chemical working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Reviews etc. in peer-reviewed journals	5	4	9	11	17	11	57	9.5
First authorships	1	1	1	4	5	3	15	2.5
Single authorships					4	1	5	0.8
Last authorships	2	2	1	7	4	3	19	3.2
Authorships from NFA	15	7	20	19	21	19	101	16.8
The NFAs share of authorships	25%	26%	26%	28%	13%	16%	20%	
Authors/article	12	6,8	8,4	6,1	9,8	11	9,1	
Average IF	5.19	3.40	7.78	5.41	4.78	9.49	6.14	

The unit encourages PhD students to publish before they finish their PhD, to publish in open-access and high-impact journals. Apart from this, the unit has not presented a specific publishing strategy. Nevertheless, it should be stressed, that the unit often publishes comprehensive articles rather than many smaller publications from each project. A comprehensive article (in vitro+animal study+measurement if the workers + risk assessment) is an example of the very high impact papers published (Bornholdt et al. 2017).

Researchers working with chemical working environment have participated in scientific conferences, both national and international, and the number of conference abstracts was markedly higher in the second half of the evaluation period than in the first half.

Table 4.13: Conference abstracts; chemical working environment.

	2014	2015	2016	2017	2018	2019	Total	Average/ year
Number of conference abstracts	38	28	48	58	51	51	274	46

The highest number of presentations (oral or poster) listed is from 20179 (n=58) of which the majority were oral presentations. It is not clear, if any of the presenters were key note speakers.

4.5.4 Excellence

Research quality

The unit of Chemical working environment is a strong player in Danish occupational health research. The scientific productivity measured by peer review papers is at a high level, amounting to over 50 papers annually. The ability to successfully respond to national and international competitive research calls, together with acceptance of papers in high-ranking journals, probably is the best quantitative indicator of scientific innovation and originality. Judged by this metric the unit is doing very well.

Here follow examples of the high research quality of the NFA chemical work environment unit:

Nanosafety research area

Researchers at the unit have, by numerous *in vitro* and experimental animal experiments, identified biological mechanisms of action of toxicity for various nanoparticles. For example:

- In a review (Saber et al. 2014), based on a collaboration between the NFA, University of Copenhagen and Health Canada, the authors suggest, that particle-induced pulmonary acute phase response is the causal link between particle inhalation and cardiovascular disease. They base this hypothesis on mice studies from the NFA and others, where the acute phase response was examined in different tissues after particle exposure, as well as from human controlled exposure studies (such as chamber studies).
- In a joint study with University of Copenhagen, DTU and Health Canada, researchers from the NFA identified gene transcription start sites and enhancers responding to pulmonary carbon nanotube exposure *in vivo* (Bornholdt et al., 2017; ACS Nano, impact factor 13.709). This is a comprehensive paper, which by combining particle characterization, *in vitro* and *in vivo* experiments with state-of-the-art methods for genetic and bioinformatic analysis of gene regulation, provide mechanistic insights of MWCNT action in lung tissue. This study builds highly on the expertise in nanoparticles exposure and toxicity as well as use of the animal facility at the NFA.
- Furthermore, the NFA has performed in-depth characterization of the physicochemical properties of nanoparticles that have resulted in better prediction of nanoparticle toxicity. For example, the researchers have shown in a study of ten different multi-walled carbon nanotubes (MWCNT), that the physicochemical properties predict pulmonary inflammation and genotoxicity in mice (Poulsen et al 2016). The results are important, as they not only provide mechanistic data on what drives the toxicity of different MWCNT, but they may also contribute to, by safe-by-design manufacture, safer MWCNT, thereby minimizing adverse effects
- The NFA has performed occupational exposure assessment and evaluated risk management for nanoparticles. As an example, the NFA together with DTU evaluated six Control Banding (CB)-based tools, which were developed in order to assess and manage the potential risks associated with occupational exposure to nanomaterials (Liguori et al. 2016)

General toxicology area

Acute inhalation toxicity is rather common after inhaling aerosolized impregnation products. But how to predict which products result in toxicity? Traditionally, animal experiments have been used. These cause suffering of the animals, and they are time-consuming and expensive. In an elegant study, the authors used an *in vitro* method, based on lung surfactant inhibition, that they have developed, to predict acute inhalation toxicity and compared the results with a mouse inhalation bioassay (Sørli et al. 2017). This *in vitro* method is as a very promising tool to screen for acute inhalation toxicity for products that are used at workplaces and in the general environment.

In a collaboration between the NFA and several national partners, the exposure to polycyclic aromatic hydrocarbons and their toxicity was evaluated for firefighters. This is a complex field study, where the exposure was measured by air measurements, dermal and urinary biomarkers, and biomarkers of effect (genotoxicity, inflammation) in blood as well as lung function were measured. The results are important for risk assessment of working as a firefighter.

Microbiology and bioaerosol research

In a study on the organic dust toxic syndrome, bacterial and fungal communities were characterised in dust causing this syndrome and in reference dust not causing the syndrome (Madsen et al. 2015). By advanced mass spectrometry analysis, sequencing, and enzyme activity assays, a shift in the microbial community was shown in aerosol samples that cause organic dust toxic syndrome relative reference samples. The results of this study can be used to identify species, that can be used for surveillance of the working environment and in turn, to prevent the organic dust toxic syndrome.

Uhrbrand and co-authors (2017) evaluated the risk of being exposed to airborne harmful microorganisms, including noroviruses, at a type of hospital wastewater treatment plants with novel wastewater treatment technology. The risk of airborne exposure to pathogenic bacteria and noroviruses from the air emission of the plant to surroundings was found to be very low. This type is important for evaluating if novel technology prevents bioaerosol-related disease.

Impact

Societal impact of the research unit has been achieved by providing scientific health-based evidence for three nanomaterials and diesel exhaust particles; heading the development of a new CEN standard on nanomaterial dustiness testing; developing a new CEN standard for 'Measurement of biological agents'; initiating new CEN standard for measurement of endotoxin from bacteria and the development of three OECD Guidance Documents on dissolution, surface chemistry, and dustiness. Furthermore, based on the NFA's uncovering of the mechanism and evaluation of the toxicity of impregnation spray products, the Danish EPA prohibited the sale of certain products in Denmark and in the EU under the REACH regulation.

4.5.5 Evaluation and recommendations

Overall, the evaluation committee considers the quality of the research and the research output to be excellent or very high in all three research areas of the unit, when compared to similar national and international research groups. The unit shows a high level of originality and has developed a very broad and state of the art methodological platform (omics, genetics, biomarkers, *in vitro* and experimental *in vitro* and *in vivo*, field studies and registers). The research has scientific impact. It should be stressed, that the unit shows very high diversity in research activities reflecting the often very complex chemical work environment.

The activities are generally highly relevant, in that they address important (old and new hazards) or potential occupational health issues. The anchorage with the rest of the society, including stakeholders, is generally good or very good. The researchers have sufficient knowledge, systematics and methods on how to involve stakeholders and target groups in research.

Resources seem to be applied in accordance with national strategies, the NFA's strategic prioritization and research programs. One aspect peculiar to toxicology (according to the unit) is, that funding sources' interest in specific substances change suddenly, meaning that the unit's focus areas must change as well, necessitating a high degree of flexibility. At the same time, it should be emphasized, that the unit needs to have a very general expertise in order to meet the demands of a rapidly changing society and environment and to handle acute exposures. Accordingly, the unit is vulnerable to loss of specific competences. It is thus important to keep both in-depth knowledge as well as a broad know-how, and not only to focus on what the stakeholders want or need for a short-term period.

It is too early to evaluate, whether the unit can manage to obtain as much funding from Horizon Europe as it did from Horizon2020. The committee has the impression, that in the current evaluation period networking has been sufficient for fundraising purposes. The links to international research has been reinforced during the evaluation period which is promising for future applications to the EU and to Nordic funding bodies.

The earlier evaluation strongly recommended that the NFA, given the ending of the special funding from the Danish Working Environment Research Fund for nanosafety research, needs to develop a strategy for what to come after. The unit has addressed this recommendation since it has managed to get renewed special funding from the Danish Working Environment Research Fund for nanosafety, as well from several large EU projects.

The earlier evaluation recommended that the NFA in more depth addressed relevant work tasks and workplaces for exposure to nanoparticles, workers' exposure, toxicological risk assessment and risk management. In 2014-2019 every year several articles were published on these topics.

The earlier evaluation strongly recommended that the NFA develops and strengthens the Microbiology and Bioaerosol Exposure group. It is not clear, whether this recommendation has been followed. There are no new senior positions in the group or clear strategic funding presented from the NFA.

The earlier evaluation strongly recommended that the NFA develops a strategy for occupational toxicology, including all three areas (nanosafety, microbiology/bioaerosols, general toxicology). This recommendation seems partly to have been followed during the new evaluation period and more emphasis has been put on aspects of general toxicology as well as other particles than particles covered by nanosafety. New focus areas have been identified or strengthened, e.g., reproductive toxicology and inhalation toxicology, which is reflected in the external funding for general toxicology. The focus on indoor air climate and noise has been reduced. It is not clear if the competence needs, recruitment and resource allocation have been sufficiently addressed.

Seniors have to some extent been included in the research at the unit. The epidemiological research has mainly focused the role of occupational exposures during pregnancy (chemicals and stress) for foetal development and offspring health later in life. The unit also analyses how exposure to different agents can affect the ageing by different biomarkers that reflect ageing and resilience. The unit has contributed to the NFA's report "Seniorers arbejdsmiljø og helbred".

The aims with the research are not well expressed for the whole unit. For the current evaluation, there are strategy documents for Nanosafety and for Microbiology but not for General toxicology, and no overall for the unit as an entity. In order to strengthen the unit, it is encouraged to develop a strategy for the whole unit, it may be diverse and with different topics in the different research areas, but a common strategy may increase collaboration within the unit and with different external collaboration partners as well as the use of infrastructures. Upscaling and downscaling the unit's capacity in relation to funding is a major challenge. It may be difficult for the unit to allocate resources efficiently due to a large share of external funding provided for specific purposes - this problem appears to become even bigger in the future. A common strategy may help.

This strategy should preferably include how to address new challenges in the work environment: e.g., novel technologies and materials in the working environment can lead to exposure to new hazardous chemicals, and there are increased risks for some chemical and microbial exposures and in turn diseases due to climate change. Further, it is important to develop a strategy for how to address acute exposures – can funding within the institute be quickly allocated to research on an acute and alarming situation?

The working environment is currently under a massive change due to new types of work tasks and occupations, changes in the working organization and digitalization. At the same time old and known risk factors may be forgotten. It is therefore recommended that there is a focus on the general

toxicology area, otherwise the unit will be less prepared for new emerging risks and may lose competence to handle old risks.

It is very important to secure and develop the existing knowledge and expertise at the NFA and not only maintain knowledge and front-line expertise in areas that stakeholders ask for. It is well-known that stakeholders often do not know which problems exist or do not want to acknowledge serious problems at work.

The Microbiology and Bioaerosol Exposure group has a clear and relevant strategy, students particularly at the bachelor level, a strong stakeholder involvement, an anchoring in practical workplace problems, and good media coverage. This paves the way for a significant impact on workplace improvements. We therefore recommend that the NFA considers an enlargement of the staff (senior scientist) in the field of microbiology/bioaerosols. It should be noted that the unit of Chemical Working Environment has lost one full professor and one full senior researcher during the evaluation period. At the same time, the external funding for the unit is high.

The funding for nanosafety may be reduced during the coming years. In order to maintain the competence in toxicology in terms of manpower, it is therefore important that the funding for other areas, General toxicology and Microbiology, is increasing, which at least for General toxicology seems to be the case. On the other hand, one could expect that the Microbiology area will increase in number of projects and funding due to the strong livestock agriculture and crop production in Denmark, an increased focus on the role of microorganisms – including viruses such as Sars-CoV2 - for our health, and increasing industries, such as waste management.

It is recommended to develop the network between the PhD and post doc students at the unit and within the NFA to strengthen the training in occupational medicine, and build a career network for the future.

It is recommended to increase the synergy of research resources at the units by working together on methodological issues, e.g., biomarkers, big data, and multiple exposures (exposome).

5 Teaching performed by researchers at the NFA

The NFA's mission is defined as: "we perform research, teach, disseminate and advice authorities in order to contribute to a health and secure working environment in Denmark."

Teaching can be divided into:

1) Teaching and supervision of younger researchers, PhD candidates
2) Teaching at graduate and undergraduate level at universities and other institutions
3) Medical doctors and others in the field

The amount granted to education in the funds from the state (Finansloven) has decreased from DKK 8.0 million in 2014 to 6.2 in 2019. This seems to concern education of researchers, PhD candidates, at the NFA. Teaching at universities and other institutions outside the NFA is paid for by those.

The ambition is to have, on average, five PhDs graduating annually from the centre, which the NFA has well surpassed during the evaluation period. The supervision of PhDs is covered in the four sections on the research units. The number of PhD projects supervised fluctuated over the years between 22 and 27 with a slightly increasing trend, 23 in 2014 to 25 in 2019. The number of finalised PhDs has decreased since 2014 from 16 in 2014 to 10 in 2019, se table 5.1.

The NFA wishes to contribute to education at universities by:

1) Supervising students writing theses at bachelor, master, and PhD level
2) Participating in teaching
3) Qualifying researchers to become adjunct professors or associate professors at universities
4) Education of consultants (speciallæger) in occupational medicine (this fourth point was added in the strategy for 2018)

The researchers at NFA teach to a limited extent at university courses in Denmark, mostly single lectures, which makes good sense, since the course often will have broader perspectives. The number of master theses supervised varied (between 18 and 36) with a decreasing trend. More teaching at universities would probably generate more supervision tasks with the possibility to recruit PhD candidates, but since the resources at the NFA are limited, this is probably not a priority. The researchers have also been active in NIVA courses, where they have taught several times during the evaluation period. The centre does not have an ambition to increase teaching.

In the strategy from 2014, it was stated, that the NFA should investigate the possibility of contributing to continuing education of advisors and other professionals in working environment (arbejdsmiljøprofessionelle). From 2016 it was stated as a task to be performed. Since 2014, the NFA has, in collaboration with Danish Association of Occupational Health and Safety Consultants, contributed with teaching at four annual seminars. The NFA has also participated in the annual work environment conferences. The target group for these conferences is professionals in working environment.

Education of specialists (speciallæger) in occupational medicine which was mentioned in the strategy from 2018 has not been performed. It has not been possible to find funding for it. One could expect the regions to be interested in promoting that activity.

Table 5.1: PhDs finalised

	2014	2015	2016	2017	2018	2019	Total
Psychosocial	8	3	3	1	2	3	20
Accidents		1		2	1		4
Chemical	4	3	2	5		5	19
Musculoskeletal		5	3	3	2	2	15
Cross disciplinary	4	1	1	1	2		9
Total	16	13	9	12	7	10	67

6 Discussion

6.1 Scientific output and quality

The scientific output of the NFA is very high in numbers of scientific articles in international peer reviewed journals, also in journals with high impact factors, considering the number of researchers at the centre. Furthermore, the number of original articles published increased, as did authorships, first and last authorships, and the impact factor of the journals. There is no tendency during the evaluation period to an increase in number of authors per article as a way to increase the number of authorships. The scientific quality (originality of research and validity and reliability of methods) is very good to excellent.

The previous evaluation panel recommended the centre to prioritise publishing more comprehensive articles rather than a high number of articles, as they may contribute more to the advancement of knowledge. A recommendation we endorse, well knowing that the request from funders and management may be for high numbers, which are more easily measured than high quality. The researchers seem to have published more comprehensive articles, as an example can the articles from the IPD-consortium be mentioned.

One could consider to use more qualitative performance indicators to get a better evaluation of the quality of the research.

6.2 Relevance of research

When evaluating relevance, a question is of course 'relevance to whom?' We looked at it from the perspective of the employees. The research at the NFA is highly relevant as it is dealing with important work-related health and safety issues in Denmark and elsewhere. To maintain the existing strong expertise and to be prepared for future challenges in the working environment, we would recommend to strengthen the microbiology, general toxicology and occupational safety areas. It is also important for the centre to maintain the strong collaboration with clinical occupational medicine.

6.3 Dissemination of knowledge

Another evaluation panel is looking at dissemination of the NFA's research in the Danish society; we look at the scientific dissemination. Scientifically, both through articles and conference presentations, the dissemination is very satisfying. The researchers do also participate in education outside the centre. This could be done to a larger extent, both to provide students and practitioners with relevant and up-to-date knowledge and to recruit researchers. However, financing is not provided for that. Nevertheless, it seems that the centre is capable of attracting young, qualified researchers, even with the low educational activity of the centre.

The centre shall inform the Ministry of Employment when it is about to publish research results, which may cause public interest. The ministry shall only be informed, it has no say concerning the design of the studies or the interpretation of the results of the studies.

6.4 National and international networking and collaboration

The researchers at the NFA have extensive networks and research collaborations with researchers in Denmark, Europe, and other countries, which indicates that they are, also internationally, considered to be well qualified researchers worth collaborating with. The international collaboration seems to have increased and quite a few international PhD students visit the centre. We recommend that the NFA continues along this path and maintains the fruitful collaboration with other research institutions, maybe with more senior researchers visiting the NFA and researchers from the centre visiting other research institutions.

6.5 Financial situation

Some of the research fields studied have been very good at attracting external funding, not least from The Danish Working Environment Research Fund, but also from the EU and other sources. External funding's share of the total spending has continuously increased during evaluation period from 27% to 39%, from DKK 32 million to DKK 47 million, which is impressive. Government funding has been decreasing during a number of years, but these cuts have stopped in 2020. Still the NFA will to a large extent depend on external funding, which creates problems for planning and retaining qualified researchers and maintaining the expertise of the centre.

In order to retain qualified researchers and a preparedness to deal with new issues in the working environment, it is crucial that the centre has a considerable share of stable government funding and more permanent senior positions.

6.6 Future challenges to the health, safety and productivity of the Danish workforce, the issue of seniors

All research fields to a larger or smaller extent address the challenges of an ageing workforce. New technologies and other global megatrends will present both challenges and opportunities, of which many are difficult to foresee, but which underline the need for a scientific preparedness among the researchers within these areas.

6.7 Summary: general conclusions and recommendations

The quality of the research at the NFA is high to excellent, and the publication record in international peer reviewed journals is impressive, considering the size of the staff. The researchers are very good at combining survey and register data, as well as combining human studies with experimental studies, *in vitro* and *in vivo*. There seems to be an increasing collaboration between the units to solve complex working environment problems, which is highly encouraged.

The centre's research is organised along either exposure, or outcomes, or both. This might be a good solution provided the research is also organised along themes connecting research from the different groups. More collaboration between PhD students in different units and research areas could be an advantage, they seem to be more confined to their research group, than more senior researchers.

The need for qualified research about work environment has increased due to changes in the working conditions. These changes include changing contents of many jobs due to digitalisation and other technological developments, changing ways of organizing work and businesses, and challenging demographic changes in all Western countries. There is a great need for assembling groups of scientists, who know and understand Danish working life, as exists at the NFA, and who can produce research at a high, international scientific level, collaborating across disciplines, acknowledging that processes determining health, performance and behaviour, are almost always multifactorial. This underscore, that it is important to have several disciplines in one place, and that they collaborate across the groups. A hub is needed to dissect the complex interplay between not only different occupational, but also environmental, and individual factors that contribute to disease. Moreover, there is a need for a hub with competence in gathering and maintaining a general knowledge base in all fields of significance to work and health in order to provide advice and detect new potential exposure risks. We find, that the NFA has fulfilled these needs in an excellent way and highly recommend continued funding by the ministry. It should be strongly pointed out, that high quality research is crucial for achieving the goals of the NFA. The international peer-review processes are necessary for guaranteeing high quality and independent research.

Serious consideration should be given to developing research on the effects of climate change on employee safety, health, and work-related risk factors. So far, this has been a neglected area.

The NFA is under huge pressure to increase external funding. As the external funding rate is already high, further increasing the funding might be difficult. A way to ensure more funding for keeping up the high standard of research, if the direct government funding cannot be increased, The Danish Working Environment Research Fund could, as suggested by the previous panel, reserve a percentage of its funds to unspecified research at the NFA.

We have learnt that the centre has received funding for a research group in working environment economics. This is a great achievement, and we hope it will be a part of the good cooperation between groups at the centre, but it should not endanger funding for other research areas.

In our interviews, we noticed, that the researchers and the management seemed to agree that the goal of the NFA should be to provide research, which could benefit the working environment in making it less hazardous to health by eliminating risks. But they did not seem to align totally on the means. The management emphasised the roles of stakeholders, employees, employers, the ministry etc., in defining the tasks of the NFA. The researchers emphasised, in addition, the need for high quality in stakeholder-initiated research based on developed theories and advanced methods, and

the need of more independent research in order to identify problems in the work environment, which the stakeholders were not necessarily aware of. The Covid-19 pandemic has illustrated that research, performed without an immediate use in mind, has made society better prepared to tackle the disease. The situation is the same in research dealing with the work environment.

Although it is important for researchers to listen to, what the stakeholders say, to understand the key and burning issues, the research should be independent of special interest, committed to find the truth, also if the truth might not be popular with all stakeholders.

7 Summary in Danish: Sammenfatning af evalueringen af NFA 2014-2019

NFA's videnskabelige produktion er på et meget højt til fremragende niveau, når det kommer til antallet af publikationer og publikationer i tidsskrifter med en høj impact factor. Antallet af publikationer er vokset i løbet af evalueringsperioden, og andelen, der har NFA-forskere som første- og/eller sidsteforfattere, steg. Den videnskabelige kvalitet, forskningens originalitet og metodernes validitet og pålidelighed, er meget god eller fremragende. Forskerne er gode til at kombinere dels spørgeskema- og registerdata, og dels observationelle studier med eksperimenter, både *in vivo* og *in vitro*. Det interne samarbejde mellem de forskellige forskergrupper ser ud til at vokse, hvilket er meget hensigtsmæssigt, da arbejdsmiljøproblemer ofte er komplekse, så udforskningen af dem kræver brug af flere forskellige kompetencer. Mere samarbejde også mellem PhD-studerende fra de forskellige områder kunne være en fordel.

Forskningen er særdeles relevant, idet den beskæftiger sig med væsentlige arbejdsmiljøproblemer. For at NFA kan fastholde den store og brede ekspertise anbefaler vi, at centret styrker særligt områderne mikrobiologi, generel toksikologi og arbejdsrelateret sikkerhed. Vi foreslår også, at NFA prioriterer at videreføre og udvikle det stærke samarbejde med den kliniske arbejdsmedicin. Vi anbefaler, at NFA udvikler forskning i effekterne af klimaforandringerne på arbejdsrelateret sundhed og risikofaktorer. Dette er hidtil blevet forsømt.

NFA's forskere har udstrakte og stærke netværk og samarbejdsrelationer med forskere i Danmark og en række andre lande. En del udenlandske PhD-studerende har været tilknyttet NFA som gæsteforskere, mens gæsteforskerophold på et mere seniort niveau på og fra NFA ser ud til at være sjældne.

Flere forskningsområder har været endda særdeles gode til at tiltrække ekstern finansiering, især fra Arbejdsmiljøforskningsfondet, men også fra EU og andre kilder. Den eksterne finansiering er steget fra 27 til 39 % af NFA's budget, dvs. fra 32 til 47 mio. kroner, hvilket er imponerende. Den statslige grundbevilling til NFA og dermed forskningen er faldet såvel absolut som relativt. Den store afhængighed af ekstern finansiering kan skabe problemer med at fastholde kvalificerede forskere og ekspertise på NFA. Vi finder det afgørende for fastholdelsen af forskningens niveau, at en høj andel af NFAs finansiering kommer i form af en stabil, offentlig grundbevilling, og at der oprettes flere seniore faste forskerstillinger.

Der er en udtalt forventning om, at NFA's forskere øger den eksterne finansiering. Størrelsen og andelen af eksterne midler er allerede stor, og det kan blive svært at øge den yderligere. En mulighed, som det foregående evalueringspanel pegede på, er, at hvis den direkte statsfinansiering ikke kan øges, kan der afsættes en fast andel af Arbejdsmiljøforskningsfondets midler til frie forskningsmidler til NFA.

Vi har fået oplyst, at NAF har fået en bevilling til at oprette en enhed for sundhedsøkonomi, hvilket vi lykønsker centret med. Vi håber, at det vil udvikle sig et godt samarbejde med de andre enheder på centret, og anbefaler stærkt, at det ikke kommer til at få negative økonomiske konsekvenser for de andre forskningsområder på NFA.

Alle forskergrupper beskæftiger sig mere eller mindre med udfordringen med den aldrende arbejdsstyrke. Nye teknologier og andre overordnede globale udviklingstendenser, som ikke altid kan forudses, understreger nødvendigheden af et videnskabeligt beredskab, herunder at man fastholder et bredt spektrum af kompetencer. Det understreger igen behovet for samarbejde mellem forskergrupperne, og at NFA fastholder et højt kompetenceniveau inden for alle de områder, det dækker nu. Det er afgørende, at arbejdet med arbejdsmiljøet bygger på uafhængig forskning af høj kvalitet, hvilket international fagfællebedømmelse af publikationer fra en uafhængig specialiseret forskningsinstitution som NFA kan være med til at sikre.

I vores interviews noterede vi, at der var enighed mellem ledelsen og forskerne, om at NFA's mål er at udføre forskning på højt niveau, som gavner arbejdsmiljøet ved at reducere sundhedsrisici. Det fremgik dog, at der ikke var helt enighed om midlerne. Ledelsen fremhævede interessenternes (ansatte, arbejdsgivere, ministeriet mv.) rolle, når det gjaldt fastlæggelsen af NFA's forskningsopgaver. Forskerne betonede nødvendigheden af høj kvalitet i den forskning, som udføres på initiativ af interessenter, baseret på udviklingen af teorier og avancerede metoder, og desuden behovet for mere uafhængig forskning, hvor forskerne kan identificere arbejdsmiljøproblemer, som interessenterne ikke nødvendigvis er opmærksomme på. Covid-19-pandemien har synliggjort, at forskning, som ikke sigter mod umiddelbar anvendelighed, har gjort samfundet bedre forberedt på at håndtere krisen. Det samme gælder for arbejdsmiljøforskning.

Det er vigtigt, at forskerne lytter til, hvad interessenterne kan sige om afgørende og aktuelt højt prioriterede emner, men forskningen skal være uafhængig af særinteresser og opsat på at nå frem til sandheden, også når sandheden ikke altid er velset hos alle interessenter.