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Occupational exposure to inhalable agents is associated with reduced work ability: A prospective cohort study in Norway

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Abstract

Background—This study aimed to assess work ability score (WAS) in 2018 based on self-reported data regarding inhalable occupational exposure and data from a northern European job-exposure matrix (N-JEM) recorded in 2013.

Methods—During the 5-year follow-up period of this population-based study, 4423 participants completed a postal questionnaire comprising self-reported questions regarding occupational exposure, work history, and WAS.

Results—Ever, weekly, and daily exposure to vapors, gas, dust and fumes (VGDF) in the last 5 years in 2013 was associated with reduced WAS in 2018. The N-JEM data showed that exposure

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Author Contributions

GK drafted the manuscript and was involved in the study design, data collection, data management, data analyses, and data interpretation. PKH, JK, KT, and AKMF were involved in the study design, data analysis, data interpretation, and critical revision of the manuscript. All the authors approved the final manuscript.

Conflicts of Interest

None declared.

Disclaimer

The findings and conclusions of this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH) Centers for Disease Control and Prevention (CDC). The mention of any company or product does not constitute an endorsement by the U.S. government, NIOSH, or the CDC.

Ethical Considerations & Disclosure(s)

This study was approved by the Regional Committee for Medical and Health Research Ethics of Norway (REC 2012/1665). Informed consent was obtained from all participants.

List of Supplemental Digital Content

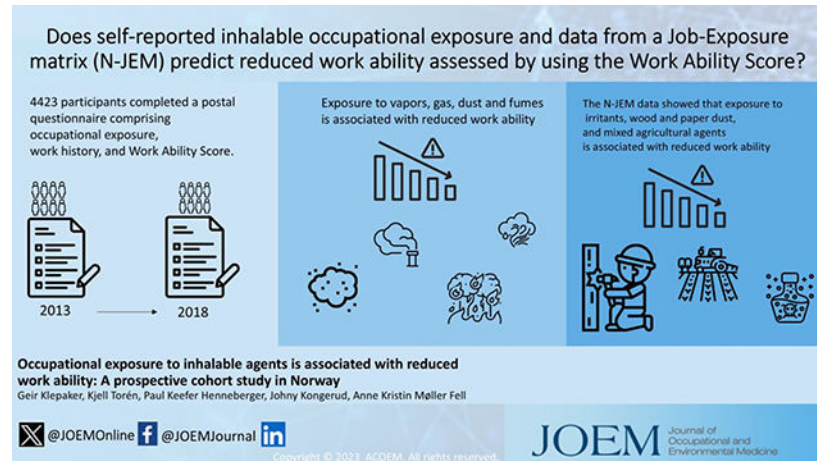
Supplemental Digital Content Tables 1–3

STROBE Checklist

to irritants, wood and paper dust, and mixed agricultural agents were associated with reduced WAS.

Conclusions—Exposure to several occupational inhalable substances is associated with reduced work ability. We recommend reducing inhalable occupational exposure to prevent reduced work ability.

Graphical Abstract



Keywords

Irritants; VGDF; epidemiology; asthma; occupations exposure

Introduction

Occupational exposure to inhalable agents, such as chemicals, vapors, gas, dust, and fumes, is a common occurrence. In Norway, an estimated 23% of workers are exposed to such agents (1). Inhalable occupational exposure is associated with different respiratory diseases, such as asthma, chronic obstructive pulmonary disease (COPD), lung cancer, hypersensitivity pneumonitis, and pneumoconiosis. The population attributable fraction varies from 10% to 30%, depending on the type of exposure and respiratory disease (2). Occupational exposure to inhalable substances is a common, modifiable risk factor and an important contributor to the development of respiratory diseases.

The concept of work ability can be defined as “How good are workers at present and in the near future, and how able are they to do their job with respect to work demands and health and mental resources?”(3). Measuring work ability is complex; however, the Work Ability Index (WAI) is a validated and reliable instrument that has been used in epidemiological studies. Previous studies have shown that a low score predicts future work disability and may help identify employees who require support to improve their work ability (3). The WAI is not a static measure and is influenced by age, health status, weight, and level of physical work (4). The complete WAI battery is a comprehensive instrument that is inconvenient for large surveys; therefore, shorter questionnaires have been developed (5). One such questionnaire is the Work Ability Score (WAS), where the participants are

asked to grade their current work ability on a scale from 0 (“I cannot work at all”) to 10 (“My work ability is at its best right now”). The WAS has been shown to quite effectively represent the entire WAI (4). In a study of health care workers, respiratory diseases were associated with reduced work ability measured using the WAS, with an odds ratio (OR) of 2.11 (95% confidence interval [CI], 1.77–2.51), compared with healthy employees (6). To our knowledge, no studies have assessed whether exposure to inhalable agents, such as vapors, gas, dust, and fumes (VGDF), can predict future reduced work ability.

Therefore, the main aim of this study was to use self-reported data on inhalable occupational exposure and data from the asthma-specific northern European job-exposure matrix (N-JEM) to assess work ability after 5 years measured with the WAS. Second, we assessed whether physician-diagnosed asthma modified the effect estimates.

Methods

Study population

The Telemark Study is a population-based survey that began in 2013 and was sent to a random sample of 50,000 individuals aged 16–50 years living in Telemark County, Norway. Of these individuals, 48,142 were eligible, and 16,099 responded (response rate: 33 %) by mailing back the postal questionnaire (7). In 2018, all the respondents were invited to complete the questionnaire again. However, 414 subjects could not be traced or were excluded because of illness (n=3) or language problems (n=1, this person was not detected in 2013 as the questionnaire was filled out and might have had help filling in the questionnaire.). A total of 7952 subjects (response rate: 51%) responded in 2018. Subjects who were unemployed in the past 12 months in 2013 or who did not answer questions about the frequency of VGDF exposure or their occupation in 2013 were excluded. Additionally, all participants with reduced WAS (< 8 points on a scale of 0–10) in 2013, those who did not fill in the question on VGDF exposure or gave sufficient information so they could be assigned an ISCO-88 code, and those who had not completed the WAS question in 2013 or 2018 were excluded (n=3529). This resulted in a final study population of 4423 participants (Supplemental Digital Content, <http://links.lww.com/JOM/B778>).

Questionnaire

The questionnaire included questions regarding occupational exposures, past and current work titles, industry of employment in free text, physician-diagnosed asthma, WAS, and possible confounders. The questionnaire was based on the European Community Respiratory Health Survey questionnaire (8) and a questionnaire from a similar study from Sweden (9).

Exposure variables

VGDF exposure was defined as an affirmative answer to the question, “Have you ever been exposed to vapors, gas, dust or fumes at work?” All exposed participants in 2013 were subsequently asked to classify their average exposure in the past 5 years into one of the following categories: “Daily, for large parts of the working day,” “Daily, but for short periods,” “Weekly,” and “Less often.” In the present study, “Daily, for large parts of the

working day” and “Daily, but for short periods” were merged into one category. Participants who did not select any of these categories were considered unexposed over the last 5 years.

The participants’ work titles from their self-reported work histories were classified by a trained research assistant using the 1988 International Standard Classification of Occupations (ISCO-88) coding system. We used the asthma-specific N-JEM to assess the participants’ inhalable occupational exposure based on their self-reported jobs in 2013 (10, 11). A few job titles (n=39) specific to industries in Telemark County were added to the N-JEM. The N-JEM is based on expert assessment by occupational hygienists and defines an occupation as exposed based on the assumption that at least half of the workers with this specific ISCO-88 code have a high probability of being exposed to irritants or allergens. The participants can be exposed to multiple exposures based on the allocation by the N-JEM. All specific exposure categories comprising more than 1% of the total study population were included in the analyses. The N-JEM data were collapsed into six main exposure groups: high molecular weight (HMW) agents, low molecular weight (LMW) agents, irritating agents, accidental peak exposures to irritants, uncertain or low exposure, and unexposed reference groups.

Outcome variable

To assess work ability, we used the first question of the WAI (12). This question is referred to as the WAS (12). The participants were asked to grade their current work ability on a scale from 0 (“I cannot work at all”) to 10 (“My work ability is at its best right now”). The WAS categorizes work ability into normal (score ≥ 8) and reduced (score < 8) (13). Previous studies have demonstrated a strong association between the WAS and results of the entire WAI questionnaire (4, 13).

Background and adjustment variables

Smoking status in 2013 was classified into the following categories: daily smokers, occasional smokers, and former smokers, in case of an affirmative answer to one of the following questions: “Do you smoke every day (also applies if you only smoke a few cigarettes or cigars or light a pipe every day?),” “Do you smoke occasionally (not every day, but on weekends, parties, or similar)?,” and “Did you use to smoke?,” respectively. If an individual did not answer any of the three questions, it was defined as missing data, and those with three negative responses were categorized as never-smokers. Self-reported age and sex were confirmed using Norwegian National Population Registry data.

The WAS is influenced by physically demanding work (14); therefore, we adjusted for the variable “Have you had physically strenuous work (such that you have been out of breath and sweaty)” in 2012 and 2013. Asthma was defined as an affirmative response to the following question: “Has a physician ever diagnosed you with asthma?”

Statistical analyses

Logistic regression models of WAS in 2018 (dichotomous variable: [normal/reduced]), were adjusted for age, sex, and smoking status in 2013 in a first model, and then with the addition of asthma in 2013, WAS in 2013, and physically strenuous work in the last 2 years

in 2013 as adjustment variables in a second model. The first model included traditional and well-known confounders. In the second model WAS score in 2013 was included to mediate a regression to mean effect. Further, asthma was included as it is can be affected by occupational exposure and influence the work ability score, and strenuous work was included in the model as several studies have shown that heavy, strenuous work may have a large effect on work ability. The main N-JEM categories were mutually adjusted for in the regression models. Any possible interactions between asthma and exposures were assessed using interaction terms (asthma $\times$ exposure). The adjusted models were stratified according to physician-diagnosed asthma in 2013. Missing answers regarding physician-diagnosed asthma in 2013, VGDF exposure, or current strenuous work were recorded as absence of asthma, VGDF exposure, or strenuous work, respectively, whereas missing data on smoking were not included in the regression models. We determined the odds ratio (OR) and 95% CIs using logistic regression models.

Results

From 2013 to 2018, the WAS in 478 of the 4423 participants (11%) changed from normal to reduced. The mean WAS was 9.45 (SD, 0.77) in 2013 and 8.99 (1.53) in 2018. Table 1 shows baseline characteristics of the study population. The study population comprised a majority of women (57%), and approximately half (52%) the participants were in the oldest age category of 41–50 years. The mean participant age in 2013 was 38.7 years with a standard error of 8.8. Regarding smoking status, 11% of participants smoked daily, 9% smoked occasionally, 23% were past smokers, and 57% were never-smokers. Nine percent of the participants had physician-diagnosed asthma.

Table 2 shows the unadjusted and adjusted associations between reduced WAS in 2018 and exposure to VGDF in 2013 as well as the collapsed exposure groups. Ever exposure to VGDF was associated with reduced WAS in 2018 (OR, 1.24; 95% CI, 1.01–1.55). Weekly and daily exposure to VGDF in the last 5 years in 2013 was also associated with reduced WAS in 2018 (OR, 1.43; 95% CI, 1.02–2.02 and OR, 1.88; 95% CI, 1.42–2.50, respectively). Exposure to irritants was associated with reduced WAS (OR, 1.46; 95% CI, 1.15–1.86). No statistically significant interactions were observed between asthma and exposure (data not shown).

Table 3 shows the different specific exposures derived from the N-JEM, with reduced WAS in 2018 as the outcome variable. In the present study, exposure to wood and paper dust (OR, 1.81; 95% CI, 1.04–3.14) and exposure to mixed agricultural agents (OR, 2.24; 95% CI, 1.00–4.97) were associated with reduced WAS. An increased estimate was observed for exposure to welding fumes (OR, 2.05; 95% CI, 0.94–4.48), but did not reach statistical significance. Other exposures assessed in 2013 were not associated with reduced WAS in 2018. No statistically significant interactions were observed between asthma and exposure (data not shown).

In Table 4, the results related to the exposure to VGDF and main exposure groups are stratified by physician-diagnosed asthma. In the stratum showing results for those without asthma, weekly (OR, 1.47; 95% CI, 1.03–2.10) and daily exposure (OR, 1.92; 95% CI,

1.43–2.58) to VGDF, as well as exposure to irritants (OR, 1.41; 95% CI, 1.07–1.86) was associated with reduced WAS. For participants with asthma, ever exposure (OR, 2.35; 95% CI, 1.24–4.42) and daily exposure to VGDF (OR, 3.45; 95% CI, 1.56–7.61) was associated with reduced WAS. Exposure to high-molecular-weight chemicals and irritants resulted in higher, but not statistically significant, estimates for participants with asthma compared to those without. Interaction analyses showed no statistical significant interactions between asthma and inhalable exposures on WAS.

As a sensitivity analysis we assessed subjects with reduced WAS in 2013 (n=585) and found that age was an important predictor of WAS in 2018; older age was associated with continued reduced WAS, whereas younger age was associated with improved WAS in 2018. A statistically non-significant trend of individuals exposed to VGDF continuing to have reduced WAS in 2018 was also observed (data not shown). In the case of N-JEM and more specific exposures, we lacked the power to fit the regression models.

Discussion

In the present study, self-reported exposure to VGDF was associated with reduced WAS, and there was a trend towards further reduction as exposure increased. Exposure to irritants was also associated with reduced WAS when the N-JEM data was analyzed. When assessing the specific exposure variables derived from the N-JEM, we found that exposure to wood and paper dust and mixed agricultural agents were associated with reduced WAS. There was an indicated association with exposure to welding fumes, but it did not reach statistical significance. The estimates were higher in subjects with asthma than in those without asthma but followed a similar pattern and interaction analyses showed no statistically significant results. This suggests that asthma does not modify the association between inhalable exposures and reduced WAS.

Previous studies have found that psychosocial factors, such as poor management and job satisfaction, and high physical demands, such as increased muscular work and poor ergonomic conditions, are work-related factors associated with reduced work ability (14). Results regarding the association between the type of work and level of work ability are conflicting (15). Several respiratory diseases, such as asthma, as well as respiratory symptoms, are associated with inhalable exposures (16, 17). Patients with these diseases also report reduced work ability, and this may indicate that inhalable occupational exposure could be a risk factor for reduced work ability. To our knowledge, no other studies have assessed on inhalable occupational exposure as a risk factor for reduced work ability by assessing specific exposures or by using the N-JEM or any others JEMs.

Other studies have shown that VGDF exposure is associated with an increased risk of respiratory disability (18). In a previous study from the Telemark study, carpenters and joiners, gardeners, welders, and agricultural workers were among the occupations with a higher risk of job change because exposures during work affected their breathing (20). In addition, exposure to irritants has been described as a risk factor for developing asthma (21). Further, occupational peak exposure to gases in the pulp mill industry has been reported to be a potent factor responsible for job change and respiratory work disability (22). These

findings are consistent with our findings, indicating that VGDF exposure may affect work ability.

In our study, exposure to wood and paper dust was associated with reduced WAS assessed 5 years later. A large majority of the 104 participants in this exposure category were carpenters, builders, or other construction workers (90%), and only two participants had a job title associated with exposure to paper dust. In another Norwegian study using the same question to measure work ability, 12% of the total population reported reduced work ability (1). Among construction workers, 16–18% reported reduced work ability. These results indicate that construction workers may be at a higher risk of developing reduced work ability than other workers. In a large Dutch cross-sectional study of construction workers, researchers concluded that highly physically demanding jobs and psychosocial and physical work-related factors were the most important factors associated with work ability (23). They also reported a negative association between pulmonary problems and work ability, but when the indicators were included in the regression models, the explained variance increased by only 0.2%. The limited influence of respiratory problems was thought to be caused by the healthy worker effect, as the study population did not include participants receiving long-term disability benefits or those who had changed jobs because of health problems, leading to a likely underestimation of the effects of respiratory problems on work ability.

In the present study, increased exposure to VGDF was associated with reduced WAS in both individuals without and with asthma. This indicates that this exposure may affect all workers. The estimated ORs were higher in the participants with asthma than in those without asthma; however, not all effect estimates were statistically significant, as one might have expected. This may be because the group of participants with asthma comprised those with all types of asthma, including those with childhood asthma without symptoms in adulthood, and not just those with occupational asthma. This and the relatively small number of exposed subjects with asthma may have contributed to the lack of statistically significant associations between WAS and more well-known exposures, such as HMW agents, in subjects with asthma.

The measurement of work ability is complex. The complete WAI battery is a comprehensive instrument that is inconvenient for large surveys; therefore, shorter questionnaires have been developed (5). The WAS have been shown to effectively represent the entire WAI (4). In a study comparing the WAI to other instruments, the WAS exhibited poorer discriminating properties for detecting the absence of long-term sickness and correctly identified 74% of non-manual laborers and 72% of manual laborers, while the complete WAI battery identified 79% and 82%, respectively (5). Based on two large samples and on using other questionnaires, such as the WAI, Ebener and Hasselhorn concluded that the WAS could be used in occupational health research surveys (24).

The WAS can also be influenced by several other factors, both occupational and non-occupational; however, our questionnaire did not contain all possible risk factors that were previously found to be associated with reduced WAS (14). We did have data on body mass index (BMI) and regular physical activity during leisure time, but including these variables in the regression models had minimal effects on the estimates and associations (data not

shown). Psychosocial factors, such as a lack of autonomy at work and high mental work demands, have been shown to influence work ability; however, we did not have information on these factors (14).

Work ability is not a static measure; those with reduced WAS in 2013 could have increased their work ability by 2018 and then be considered to have normal work ability. In the current study, 10% of individuals with reduced WAS in 2013 had a normal WAS in 2018. We found that age was an important predictor of WAS in 2018, and a statistically non-significant trend showing that individuals who were exposed to VGDF continued to have reduced WAS in 2018. This might indicate that cessation of exposure to inhalable agents improves work ability and that younger age is a positive predictor of reduced WAS. As an alternative approach, we analyzed WAS as a continuous score and calculated the change in WAS between 2018 and 2013 (See Tables, Supplemental Digital Content 1–3, <http://links.lww.com/JOM/B779>). We compared the group with a negative change to those with no change or a positive change. The results of these analyses showed somewhat lower effect estimates but a similar pattern, except that statistically significant results were not observed in the case of exposure to wood and paper dust (OR, 1.14; 95% CI, 0.78–1.67) but were observed in the case of exposure to cleaning chemicals (OR, 1.63; 95% CI, 1.08–2.45). These analyses showed that participants with reduced WAS at baseline experienced less subsequent reduction in work ability than those with normal WAS. Exposure had a greater effect in individuals with normal WAS and asthma than in those with reduced WAS and asthma, possibly because the latter group was more likely to benefit from interventions, such as being provided a disability pension or reduction of exposure.

Strengths and limitations

The important strengths of this study are the prospective design and relatively large sample of individuals from the general population. Furthermore, few exclusion criteria were used, which likely reduced selection bias. Possible limitations are the low response rate at baseline and the large proportion of individuals who were lost to follow-up in 2018. This may introduce bias, but both non-response and loss to follow-up have been assessed in other parts of the Telemark study (7, 27). These studies show that estimates of exposures as risk factors for respiratory symptoms were not affected by loss to follow-up (27). Although the possibility cannot be entirely ruled out, we do not suspect that non-response or loss to follow-up substantially altered the estimates of the associations found in this study; however, they might have altered the prevalence estimates.

Self-reported information was used in this study. Nevertheless, validated questions and questionnaires from other large epidemiological studies were used, which may have improved response accuracy. However, they may still have introduced random errors or recall bias. Self-reported VGDF exposure was demonstrated to be useful for assessing occupational exposure in epidemiological studies and to be moderately sensitive compared to VGDF exposure assessed using a JEM (28). The additional use of the N-JEM to assess occupational exposure is a strength of this study as it translates job histories into specific exposures in a systematic way, thereby reducing recall and misclassification bias (29).

A limitation of this study is the lack of questions assessing a wider range of physician-diagnosed conditions, such as mental illness and musculoskeletal diseases, and assessing specific exposures, such as organizational and psychosocial factors, as well as the relatively small numbers of responders in some of the exposure categories.

In conclusion, our findings indicate that inhalable exposures might affect work ability, and efforts to reduce these exposures have the potential to prevent loss of work ability and future disability. Our study showed that exposure to VGDF, irritants, mixed agricultural agents, and wood and paper dust was associated with reduced WAS. The estimates were higher in individuals with asthma than in those without asthma, but they followed a similar pattern and there were no statistically significant interaction. In future studies, we recommend including more data on organizational and psychosocial work exposure in the analyses, as well as exposure to VGDF, to better assess the importance of different factors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data Availability

Data supporting the findings of this study are available on a limited basis upon request from the corresponding author. The data are not publicly available because of privacy and ethical restrictions.

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Clinical Significance

Our study showed that different types of inhalable occupational exposures affected work ability. Reduced work ability is associated with of absence from work, disability, and a reduced health-related quality of life. We recommend reducing occupational exposures to prevent loss of work ability and implementing measures to improve work ability.

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Learning Outcomes:

After reading this article, readers will be able to:

- Acknowledge that exposure to VGDF, irritants, mixed agricultural agents, and wood and paper dust was associated with reduced WAS.
- Give advice to patients with asthma regarding possible higher risk for reduced WAS as compared to those without asthma.
- Inform patients and corporations about the importance of reduction of inhalable exposures to prevent the loss of work ability and future disability.

Table 1.

Baseline characteristics of the study population

Variable	N (%)	N (%) in the category with reduced WAS in 2018 (score <8)
Age category in 2013		
16–30	890 (20.1%)	85 (10%)
31–40	1245 (28.1%)	112 (9%)
41–50	2288 (51.7%)	281 (12%)
Sex		
Female	2529 (57.2%)	309 (12%)
Male	1894(42.8%)	169 (9%)
Smoking in 2013		
Never	2523 (57.0%)	216 (9%)
Past	991(22.4%)	118 (12%)
Occasionally	401 (9.1%)	45 (12%)
Daily	490 (11.1%)	95 (19%)
Missing	18 (0.4%)	-
Physician-diagnosed asthma in 2013		
No	4026 (91.0%)	420 (10%)
Yes	394 (9.0%)	58 (15%)
“Have you had physically strenuous work (so that you have been out of breath and sweaty)” in the last 2 years in 2013		
No	3205 (72.5%)	303 (10%)
Yes	1218 (27.5%)	175 (14%)

WAS, work ability score

Table 2.

Both crude and adjusted results for the main groups of agents derived from the N-JEM and self-reported exposure to VGDF obtained from the logistic regression models showing OR (95% CI) with WAS in 2018 as the dependent dichotomous variable; normal (WAS score ≥ 8) vs reduced (WAS score < 8)

Exposure variable	N-yes (% of total study population)	Unadjusted	Adjusted for smoking in 2013, age, sex OR _{adj} (95% CI)	Adjusted for smoking in 2013, age, sex, asthma in 2013, WAS score in 2013, and current strenuous work in 2013 OR _{adj} (95% CI)
<u>Occupational Exposures: Self-reported</u>				
VGDF-ever	2063 (46.6%)	1.28 (1.08–1.52)	1.43 (1.20–1.72)	1.24 (1.01–1.53)
VGDF-never	2239 (50.6%)	Ref	Ref	Ref
VGDF-seldom	1116 (25.2%)	0.85 (0.66–1.10)	0.97 (0.75–1.27)	0.90 (0.68–1.19)
VGDF-weekly	458 (10.4%)	1.51 (1.11–2.04)	1.83 (1.33–2.52)	1.43 (1.02–2.02)
VGDF-daily	610 (13.8%)	2.21 (1.72–2.83)	2.43 (1.87–3.16)	1.88 (1.42–2.50)
<u>Occupational Exposures: Assessed with N-JEM*</u>				
High molecular weight substances	466 (10.5%)	1.22 (0.92–1.64)	1.11 (0.82–1.50)	1.09 (0.80–1.48)**
Low molecular weight substances	224 (5.1%)	1.09 (0.72–1.66)	1.14 (0.74–1.75)	0.96 (0.61–1.50)**
Irritants	955 (21.6%)	1.57 (1.27–1.94)	1.79 (1.42–2.24)	1.46 (1.15–1.86)**
Peak exposure	98(2.2%)	1.51 (0.86–2.64)	1.79 (1.01–3.17)	1.55 (0.86–2.91)**
Uncertain/low	345 (7.8%)	0.86 (0.60–1.25)	0.99 (0.68–1.45)	0.995 (0.67–1.48)**
Unexposed	2568 (58.1%)	Ref	Ref	Ref**

* Based on occupation in 2013

** Mutually adjusted in one model.

WAS, work ability score; OR, odds ratio; CI, confidence interval, N-JEM, northern European job-exposure matrix; VGDF, vapors, gases, dust, and fumes

Table 3.

Both crude and adjusted results for specific exposures derived from the N-JEM obtained from logistic regression models showing OR (95% CI) with WAS in 2018 as the dependent dichotomous variable; normal (WAS score ≥ 8) vs reduced (WAS score < 8)

Exposure variable	N-yes (% of total study population)	Unadjusted	Adjusted for smoking in 2013, age, sex OR _{adj} ; (95% CI)	Adjusted for smoking in 2013, age, sex, asthma work in 2013 OR _{adj} ; (95% CI)
Occupational Exposures: Assessed with N-JEM *				
Animal agents	65 (1.5%)	0.40 (0.12–1.27)	0.44 (0.13–1.41)	0.30 (0.09–1.00)
Mold	58 (1.3%)	0.78 (0.31–1.95)	0.85 (0.34–2.14)	0.54 (0.21–1.42)
Latex	324 (7.3%)	1.21 (0.86–1.71)	1.03 (0.72–1.46)	1.10 (0.76–1.59)
Pharmaceuticals	253 (5.7%)	1.35 (0.93–1.96)	1.17 (0.80–1.71)	1.33 (0.89–1.98)
Acrylates	84 (1.9%)	0.87 (0.41–1.81)	0.96 (0.46–2.03)	0.83 (0.38–1.79)
Epoxy	67 (1.5%)	0.66 (0.27–1.66)	0.74 (0.29–1.88)	0.54 (0.21–1.39)
Diisocyanates	94 (2.1%)	0.98 (0.51–1.91)	1.15 (0.58–2.26)	0.91 (0.40–1.63)
Other reactive agents	77 (1.7%)	1.38 (0.73–2.64)	1.30 (0.68–2.50)	1.34 (0.63–2.44)
Cleaning agents	816 (1.9%)	1.77 (1.00–3.11)	1.54 (0.87–2.74)	1.50 (0.93–2.72)
Wood and paper dust	104 (2.4%)	1.88 (1.13–3.12)	2.40 (1.42–4.07)	1.81 (1.04–3.14)
Inorganic dust	274 (6.2%)	1.18 (0.82–1.72)	1.44 (0.97–2.14)	0.96 (0.63–1.45)
Welding fumes	48 (1.1%)	1.92 (0.93–3.99)	2.21 (1.05–4.65)	2.05 (0.94–4.48)
Metal working fluids	57 (1.3%)	1.56 (0.76–3.20)	1.94 (0.93–4.04)	1.50 (0.70–3.22)
Exhaust	445 (10%)	1.21 (0.90–1.63)	1.23 (0.91–1.67)	1.10 (0.80–1.52)
Environmental tobacco smoke	82 (1.9%)	1.15 (0.59–2.24)	1.31 (0.67–2.56)	1.16 (0.57–2.33)
Mixed agricultural agents	41 (0.9%)	2.34 (1.11–4.95)	2.57 (1.17–5.25)	2.24 (1.00–4.97)

* Based on occupation in 2013 Statistically significant findings (p < 0.05) are bolded.

Only exposures reported by more than 1% of the study population were assessed.

WAS, work ability score; OR, odds ratio; CI, confidence interval, N-JEM, northern European job-exposure matrix

Table 4.

Associations (OR) between reduced WAS as a dichotomous variable (WAS score < 8) in 2018 and exposures to main groups of agents derived from the N-JEM and self-reported exposure to VGDF stratified by physician-diagnosed asthma in 2013

Exposure variable	No asthma in 2013 (n=4026)		Asthma in 2013 (n=397)	
<u>Occupational Exposures: Self-reported</u>	n= (% of total stratum)		n= (% of total stratum)	
VGDF-ever	1860 (46%)	1.19 (0.96–1.47)	203 (51 %)	2.35 (1.25–4.42)
VGDF-never	2054 (51%)	Ref	185 (47%)	Ref
VGDF-seldom	1019 (25%)	0.82 (0.61–1.10)	97 (24%)	1.84 (0.87–3.91)
VGDF-weekly	404 (10%)	1.47 (1.03–2.10)	54 (14%)	1.88 (0.67–5.08)
VGDF-daily	549 (14%)	1.92 (1.43–2.58)	61 (15%)	3.45 (1.56–7.61)
<u>Occupational Exposures: Assessed with N-JEM**</u>				
High molecular weight substances *	423 (11%)	1.10 (0.78–1.55)	43 (11%)	2.17 (0.93–5.07)
Low molecular weight substances *	207 (5%)	0.92 (0.58–1.48)	17 (4%)	0.80 (0.16–4.12)
Irritants *	865 (22%)	1.41 (1.07–1.86)	90 (23%)	1.80 (0.88–3.69)
Peak exposure *	93 (2%)	1.21 (0.63–2.33)	5 (1%)	4.83 (0.67–34.8)
Uncertain/low exposed *	315 (8%)	1.15 (0.75–1.77)	30 (8%)	0.91 (0.25–3.36)

* Adjusted for each other in one model

** Based on occupation in 2013

Statistically significant findings (p <0.05) are bolded.

Logistic regression models showed ORs (95% CI) stratified by physician-diagnosed asthma, adjusted for age, sex, current strenuous work in 2013, WAS in 2013, and smoking in 2013.

WAS, work ability score; OR, odds ratio; CI, confidence interval, N-JEM, northern European job-exposure matrix; VGDF, vapors, gases, dust, and fumes