ORIGINAL RESEARCH

Occupational exposure to inhaled pollutants and risk of airflow obstruction: a large UK population-based UK Biobank cohort

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ABSTRACT

Background Although around 10% to 15% of COPD burden can be attributed to workplace exposures, little is known about the role of different airborne occupational pollutants (AOP). The main aim of the study was to assess the effect size of the relationship between various AOP, their level and duration of exposure with airflow obstruction (AFO).

Methods A cross-sectional analysis was conducted in 228 614 participants from the UK Biobank study who were assigned occupational exposure using a job exposure matrix blinded to health outcome. Adjusted prevalence ratios (PRs) and 95% CI for the risk of AFO for ever and years of exposure to AOPs were estimated using robust Poisson model. Sensitivity analyses were conducted for never-smokers, non-asthmatic and bi-pollutant model.

Results Of 228 614 participants, 77 027 (33.7%) were exposed to at least one AOP form. 35.5% of the AFO cases were exposed to vapours, gases, dusts or fumes (VGDF) and 28.3% to dusts. High exposure to vapours increased the risk of occupational AFO by 26%. Exposure to dusts (adjusted PR=1.05; 95% CI 1.01 to 1.08), biological dusts (1.05; 1.01 to 1.10) and VGDF (1.04; 1.01 to 1.07) showed a significantly increased risk of AFO, however, statistically not significant following multiple testing. There was no significant increase in risk of AFO by duration (years) of exposure in current job. The results were null when restricted to never-smokers and when a bi-pollutant model was used. However, when data was analysed based on the level of exposure (low, medium and high) compared with no exposure, directionally there was increase in risk for those with high exposure to vapours, gases, fumes, mists and VGDF but statistically significant only for vapours.

Conclusion High exposure (in current job) to airborne occupational pollutants was suggestive of higher risk of AFO. Future studies should investigate the relationship between lifetime occupational exposures and COPD.

Key messages

What is the key question?

- Which occupational airborne pollutant forms are associated with increased risk of airflow obstruction (AFO) and the strength of relationship between risk of AFO with both the level and duration of occupational exposure?

What is the bottom line?

- Exposure to dusts, biological dusts and vapours, gases, dusts or fumes (VGDF) in current work showed a significantly increased risk of AFO as defined by pre-bronchodilator spirometry. High exposure to vapours increased the risk of occupational AFO by 26%.
- Overall, 35% of the AFO cases were exposed to at least one airborne pollutant in their current job, and only 15% of these were exposed to high levels of VGDF. This study suggests that future studies should investigate the relationship between lifetime occupational exposures and AFO.

Why read on?

- This is one of the largest general population studies, which investigates the relationship different occupational airborne pollutant forms by using a job exposure matrix designed for UK population and AFO, defined by objective measurement of lung function.
- The study also investigates the relationship between pollutant exposure levels and their exposure duration with the risk of occupational AFO.

BACKGROUND

Chronic obstructive pulmonary disease (COPD) is a progressive disease characterised by airflow limitation. Although smoking has been recognised as a major cause of COPD; however, a number of studies have indicated that between 10% and 15% of the burden of COPD can be attributed to inhalation of pollutants (vapours, gases and fumes) from the workplace.[1–4]

Although workplace based studies of COPD offer the advantage of having measured personal exposure data for airborne occupational pollutants (AOPs), however, few occupational studies have provided reliable exposure estimates and often are limited to select industry types, processes or specific substances, for example, from coal mining,[5 6] welding,[7] farming,[8] wood working[9] and iron and steel foundry work.[10] Specific substances identified in occupational settings associated with COPD include isocyanates,[11] crystalline silica[12 13] and polyaromatic hydrocarbons present in diesel and asphalt fumes.[14 15]

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With the limited number of work-based studies, it is important to report on the risk of occupational COPD in general populations as they offer the advantage of investigating different pollutant types in a wider range of occupations and industrial sectors while avoiding to some degree healthy worker effects.[16] However, general population studies investigating occupational COPD majority of which are cross-sectional by design have often reported a wide range of risk estimates with inconsistent findings for the same pollutant types. This could partly be due to the relatively small sample size and inclusion of young adults,[17 18] incomplete adjustment for major potential confounders including smoking or differences in the method of COPD diagnosis.[19] Furthermore, few general population studies provide occupational COPD risk estimates by level and duration of exposure. Studies that have investigated cumulative exposure to workplace pollutants typically provide COPD risk estimates for mainly two exposure durations categories, that is, risk estimates for more or less than an arbitrary number of exposure years[20–22] which limits the understanding of exposure-dose relationships. A number of general population studies have reported their findings based on study participants' recall and self-reported workplace exposures.[23–25] Self-reported exposure may result in higher risk estimates for occupational COPD when compared with exposure assigned using expert job exposure matrices (JEMs).[1]

Recently, De Matteis *et al*[26] identified a number of specific occupations with increased risk of COPD in the UK Biobank cohort. The study confirmed high risks of COPD prevalence in occupations such as coal miners, construction workers and industrial process operators (food, drink, tobacco and chemical industries) and importantly identified new occupations such as cleaners. As well as identifying such occupations it is also important to understand the underlying occupational causative agents which can be achieved by applying a general population JEM.

A general population JEM has not been applied previously to a large UK population (with information on occupational and respiratory health data) when investigating occupational COPD.[27] The airborne chemical exposure JEM (ACE-JEM), a general population JEMs, provides exposure estimates for a full range of occupational hazards, that is, vapours, gases, dusts, fumes, fibres or mists (VGDFFiM) where exposures to AOPs were assigned independently of the disease outcome. Although a number of other general population JEMs exists, limited methodological information is available on their development and rules for assigning exposure.

The aim of this study was to apply the general population ACE-JEM to the UK Biobank cohort to understand the relative importance of different AOPs and to improve the identification of jobs and pollutants that are associated with occupational AFO. The specific aims are: (i) the identification of airborne pollutant forms associated with increased risk of AFO, (ii) the estimation of risks of AFO for different pollutant types including vapours, gases, dusts or fumes (VGDF) by level of exposure (low, medium and high) and (iii) an examination of the relationship between duration of exposure to different pollutant forms and AFO.

MATERIAL AND METHODS

Study design and population

The detailed study design and data acquisition process in the UK Biobank study has been reported elsewhere.[26] Overall, 502 649 adults aged 40 to 69 years were enrolled between 2006 and 2010 from 22 health assessment centres by invitation (randomly selected) based on an National Health Service membership sampling framework. The baseline survey included detailed questionnaire on age, sex, lifetime smoking history, current job, doctor-diagnosed asthma and spirometry measurement.

Lung function and AFO outcome definition

Lung function measurement was carried out in 457 282 (91%) participants, the details of which are described elsewhere.[26] No post-bronchodilator lung function measurement was carried out. Participants who had smoked tobacco or used inhalers 1 hour prior to lung function testing were excluded. Airflow obstruction (AFO) was defined as FEV_1/FVC <lower limit of normal (LLN; ie, the 5% lower tail of the normal distribution of average predicted FEV_1/FVC in a reference healthy population).[28] The LLN was used as the diagnostic cut-off because, in comparison to the fixed ratio (FEV1/FVC <70%) approach, it is less likely to be biassed in older ages as it is the case in our study base. We used the term AFO instead of COPD, as no post-bronchodilator measurement or individual clinical assessment was carried out to test the non-reversibility criteria and hence could not differentiate COPD from asthma.

Application of the ACE-JEM to the UK Biobank cohort

The jobs of those currently employed (n=281 247) were coded using the four-digit UK Standard Occupational Classification (SOC), V.2000. The SOC 2000 categorises employment consists of 9 major groups and 353 (four-digit) unit groups. The ACE-JEM was developed by authors (SSS, DF, OPK) for use with the UK SOC 2000 for the period 2000 to 2013.[27] The ACE-JEM assigns exposure to four digits SOC 2000 codes at three level: (i) a binary assignation of exposed/not exposed to VGDFFiM, (ii) assignation of levels (L) of exposure (low, medium and high) and (iii) the proportion of workers (P) likely to be exposed to VGDFFiM in each code. Exposure to aggregate VGDF denotes exposure to any of the four pollutants that is, vapours, gases, dusts or fumes. Those participants exposed to dust were further subgrouped to either biological or mineral dusts and fumes were subgrouped to either diesel fumes or others. The ACE-JEM assigned exposure levels by four semi-quantitative categories: (i) not exposed; (ii) low level of exposure, but above the general occupational background level; (iii) medium level of exposure, 10% to 50% of the UK workplace exposure limit (WEL) and (iv) high level of exposure, >50% of the WEL. The proportions exposed in each SOC code were assigned to four categories: (i) <5% exposed, (ii) 5% to 19%, (iii) 20% to 49% and (iv) ≥50% exposed. The ACE-JEM was applied to the 228 614 UK Biobank participant who were currently employed.

Statistical analysis

Poisson regression models with robust SEs was used to calculate both crude and adjusted prevalence ratios (PRs) for the association between AFO and exposure to different airborne pollutants (including VGDF). The reference group for each pollutant was a 'clean group': not exposed to any of the pollutants (VGDFFiM). The models were adjusted for sex, age (5 years categories), lifetime smoking exposure (ever, pack years and years since cessation of smoking) and participant recruitment centre (proxy for socioeconomic status). We carried out correction of p value for multiple testing using Holm-Bonferroni method.(Holm, 1979 #20649) The data were also analysed for the level of exposure (low, medium and high) and duration of exposure (in quartiles with the lowest quartile as a reference group) for each pollutant types. Stratified analyses were carried out for those who did not report a doctor's diagnosis of asthma and also smoking status

Table 1 Distributions of exposure to pollutants from the ACE-JEM by SOC major groups: Number exposed (exposed as per cent of total in each SOC group) and proportion of individuals with AFO in each SOC group

	Major group code*									
Pollutants	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
N (%)	40 314 (17.6)	53 618 (23.5)	41 202 (18.0)	34 333 (15.0)	16 935 (7.4)	13 843 (6.1)	7650 (3.3)	10 095 (4.4)	10 624 (4.6)	**228 614**
Vapours	5455 (13.5)	7007 (13.1)	12 847 (31.2)	0 (0)	5399 (31.9)	6196 (44.8)	0 (0)	1321 (13.1)	4544 (42.8)	42 769
Gases	343 (0.9)	7145 (13.3)	10 989 (26.7)	0 (0)	3997 (23.6)	1861 (13.4)	82 (1.1)	7081 (70.1)	2298 (21.6)	33 796
Dusts	7727 (19.2)	9693 (18.1)	13 397 (32.5)	0 (0)	14 749 (87.1)	5836 (42.2)	0 (0)	3951 (39.1)	6140 (57.8)	61 493
Fumes	8591 (21.3)	1999 (3.7)	6064 (14.7)	621 (1.8)	7036 (41.5)	346 (2.5)	179 (2.3)	8342 (82.6)	3503 (33)	36 681
Fibre	7050 (17.5)	0 (0)	1164 (2.8)	0 (0)	9987 (59)	0 (0)	0 (0)	960 (9.5)	1257 (11.8)	20 418
Mists	5393 (13.4)	1610 (3)	10 612 (25.8)	0 (0)	4910 (29)	2806 (20.3)	0 (0)	1308 (13)	3234 (30.4)	29 873
Biological dusts	2056 (5.1)	6109 (11.4)	10 340 (25.1)	0 (0)	4853 (28.7)	5231 (37.8)	0 (0)	1595 (15.8)	2850 (26.8)	33 034
Mineral dusts	7530 (18.7)	5727 (10.7)	5272 (12.8)	0 (0)	10 058 (59.4)	947 (6.8)	0 (0)	3277 (32.5)	3913 (36.8)	36 724
Diesel fumes	2645 (6.6)	1066 (2)	3945 (9.6)	621 (1.8)	1142 (6.7)	346 (2.5)	179 (2.3)	6284 (62.2)	2502 (23.6)	18 730
VGDF	9102 (22.6)	10 100 (18.8)	17 343 (42.1)	621 (1.8)	16 034 (94.7)	7184 (51.9)	179 (2.3)	10 095 (100)	6229 (58.6)	76 887
Total AFO (%)	3165 (7.9)	4467 (8.3)	3516 (8.5)	3052 (8.9)	1647 (9.7)	1308 (9.5)	787 (10.3)	1039 (10.3)	1308 (12.3)	**20 289**

1=managers and senior officials, 2=professional occupations, 3=associate professional and technical occupations, 4=administrative and secretarial occupations, 5=skilled trades occupations, 6=personal service occupations, 7=sales and customer service occupations, 8=process, plant and machine operators, 9=elementary occupations.
*SOC 2000 main group.
ACE-JEM, airborne chemical exposure JEM; AFO, airflow obstruction; JEM, job exposure matrix; SOC, UK Standard Occupational Classification; VGDF, denotes exposure to vapours, gases, dusts or fumes.

(never-smokers and ever-smokers separately). The interaction effect between smoking status and occupational exposures was assessed. We also carried out an analysis using a bi-pollutant model by including one other pollutant at a time to understand the robustness of association between a single pollutant and the health outcome (AFO) when a second pollutant is controlled for, among both smokers and never-smokers. The bi-pollutants model over multi-pollutant model was preferred due to presence of high collinearity between the airborne pollutant exposures. All analyses were conducted using Stata V.13 (StataCorp, 2013, Stata Statistical Software: Release 13, College Station, Texas: StataCorp LP)

RESULTS

Out of 281 247 participants 228 614 were currently employed and assigned a four-digit SOC code. The mean age was 53 years and 48% were men. Fifty-seven per cent were never-smokers and 11% reported a doctor's diagnosis of asthma.

The ACE-JEM was applied to the 228 614 current job titles to determine exposure profiles for the different pollutant forms (VGDFFiM) and to estimate the level and duration of exposure. Of the nine main SOC groups; the highest number of study participants assigned as exposed to dusts were for the main groups 5 (skilled trades occupations). Participants from the main groups 6 (personal service occupations) and 8 (process, plant and machine operators) had the highest number of participants which were assigned as exposed (using the ACE-JEM) to vapours and fumes, respectively (table 1).

There was a wider variation in number assigned as exposed to the different airborne pollutants (including VGDF) for each of nine main SOC groups (table 1). The majority (>90%) of the study participants in SOC groups 5 (skilled trade occupations) and 8 (process, plant and machine operators) were assigned as exposed to VGDF whereas only 2.3% were assigned as exposed to VGDF for participants in SOC group 7 (sales and customer services occupations). Of the total study participants, 33.7% (n=77 027) were exposed to at least one airborne pollutant. Of these the majority (72%) were assigned as exposed to more than one pollutant (online supplementary table S1).

Of the 228 614 study participants, 8.9% (n=20 289) had AFO (table 1). The proportion of individuals with AFO ranged from 7.9% in SOC group 1 (managers and senior officials) to 12.3% in SOC group 9 (elementary occupations). For study participants with AFO, 31.6% (7218) were exposed to at least one pollutant and among those exposed, 86.6% were exposed to multiple airborne occupational pollutants (online supplementary table S1). Higher proportions of those with AFO were exposed to dusts (28.3%) and vapours (19.2%) whereas only 9% of AFO cases were exposed to fibres and diesel fumes (table 2). AFO cases exposed to mineral and biological dusts were 15.2% and 16.7%, respectively (table 2). There was a strong positive correlation between dusts and vapours and a moderate positive correlation between the following pairs of the main pollutants; gases and dusts, dusts and fibres, vapours and mists, fibres and dusts (online supplementary table S2).

After adjustment, there were significantly increased risks of AFO associated with exposure to dusts (OR 1.05; 95% CI 1.01 to 1.08), biological dusts (1.05; 1.01 to 1.10) or VGDF (1.04; 1.01 to 1.07), however, after correction for multiple testing the results were statistically not significant (table 2). Following stratified analysis for never-smokers, the findings for all pollutants were null (table 3). Among those with no history of asthma, adjusted risk estimates were significantly increased for all pollutants except for mists and fibres. Exposure to VGDF increased the risk by 7% (PR=1.07; 1.03 to 1.11) (table 3). Following correction for multiple testing the increased risk due to exposure to mineral dusts, total fumes and diesel fumes were statistically not significant.

AFO risk estimates for different levels of exposure (low, medium and high) for each AOP are shown in table 4. The majority (>70%) of AFO cases were assigned as being exposed to low level of different pollutants including VGDF. Table 4 shows significant increases in risk estimates for high exposure to vapours (1.26; 1.15 to 1.38), fumes (1.26; 1.03 to 1.54), VGDF

Table 2 Prevalence ratios (95% CI) for risk of AFO defined as FEV_1/FVC <LLN for exposure to occupational pollutants in the UK Biobank cohort overall (n=228 614)

Pollutant	Healthy exposed (n=208 325) %	AFO cases (n=20 289) (%)	Crude PR (95% CI)	Adjusted PR (95% CI)*
Vapours	38 866 (18.7)	3903 (19.2)	1.06 (1.02 to 1.10)	1.03 (0.99 to 1.07)
Gases	30 661 (14.7)	3135 (15.5)	1.08 (1.04 to 1.12)	1.04 (1.00 to 1.08)
Dusts	55 748 (26.8)	5745 (28.3)	1.08 (1.05 to 1.12)	1.05 (1.01 to 1.08)
Biological dusts	29 941 (14.4)	3093 (15.2)	1.09 (1.05 to 1.13)	1.05 (1.01 to 1.10)
Mineral dusts	33 341 (16.0)	3383 (16.7)	1.07 (1.03 to 1.11)	1.03 (0.99 to 1.07)
Fumes	33 282 (16.0)	3399 (16.8)	1.07 (1.04 to 1.11)	1.02 (0.98 to 1.06)
Diesel fumes	16 902 (8.1)	1828 (9.0)	1.13 (1.08 to 1.19)	1.04 (0.99 to 1.09)
Fibres	18 604 (8.9)	1814 (8.9)	1.03 (0.98 to 1.08)	0.98 (0.93 to 1.03)
Mists	27 211 (13.1)	2662 (13.1)	1.03 (0.99 to 1.08)	1.01 (0.97 to 1.06)
VGDF	69 682 (33.5)	7205 (35.5)	1.09 (1.06 to 1.12)	1.04 (1.01 to 1.07)
VGDFFiM	69 809 (33.5)	7218 (35.6)	1.09 (1.06 to 1.12)	1.04 (1.01 to 1.07)

The n (%) in columns 2 and 3 are the total number for each category and percentages of total in each category.
Adjusted for sex, study centre (22 categories), age (5 years categories) and lifetime smoking exposure (ever, pack-years and year since quitting).
Reference group for each pollutant individuals in jobs with no exposure to any of the pollutants (clean group).
Healthy=non-AFO cases.
*All the p values obtained from adjusted model were statistically not significant after multiple testing.
AFO, airflow obstruction; LLN, lower limit of normal; PR, prevalence ratio; VGDF, vapours, gases, dusts or fumes; VGDFFiM, vapours, gases, dusts, fumes, fibres or mists.

(1.14; 1.08 to 1.22) and medium exposures for gases (1.14; 1.01 to 1.29) and dusts (1.14; 1.07 to 1.22) particularly for mineral dust (1.11; 1.04 to 1.18). However, these results were statistically not significant among never-smokers (table 4) except for high exposure to vapours (1.23; 1.05 to 1.43).

Stratified analysis in ex-smokers suggests that the risk of AFO was significantly higher among those exposed to vapours, gases, dusts, biological dusts, mineral dusts, fumes, diesel fumes, fibres, mists and VGDF (online supplementary table S5). The risk remained significantly higher after correction for multiple testing.

AFO risk estimates associated with each pollutant and the respective duration in current job (online supplementary table S3) did not show significant increase in risk of AFO with exposure duration following further adjustment. This was also the case for never-smokers.

There was no evidence of association between different airborne occupational pollutants and AFO when the data were analysed using bi-pollutant models except for dust when adjusted for fibres (online supplementary table S4). Similarly, no evidence of association was found in the bi-pollutant models among never-smokers (online supplementary table S4).

DISCUSSION

With a sample size of 228 614 UK Biobank and approximately 77 000 participants (34%) assigned as exposed to workplace inhalants, this is one of the largest studies investigating potential

Table 3 Prevalence ratios (95% CI) of AFO risk spirometry defined as FEV_1/FVC <LLN among non-asthmatics and never-smokers for exposure to occupational pollutants

	Non-asthmatics only			Never-smokers only		
Pollutant	Healthy exposed	AFO cases	Adjusted PR (95% CI)	Healthy exposed	AFO cases	Adjusted PR (95% CI)
Vapours	35 269	2881	1.06 (1.02 to 1.11)*	22 459	1759	0.99 (0.94 to 1.04)
Gases	27 903	2303	1.07 (1.02 to 1.12)*	17 579	1429	1.02 (0.97 to 1.08)
Dusts	50 818	4242	1.08 (1.04 to 1.12)*	31 239	2473	1.01 (0.96 to 1.06)
Biological dusts	27 081	2275	1.08 (1.03 to 1.14)*	17 662	1441	1.03 (0.97 to 1.09)
Mineral dusts	30 616	2493	1.06 (1.01 to 1.12)	17 936	1351	0.97 (0.91 to 1.03)
Fumes	30 501	2507	1.06 (1.0 to 1.11)	17 239	1318	0.98 (0.92 to 1.04)
Diesel fumes	15 549	1352	1.07 (1.0 to 1.14)	8567	680	1.0 (0.93 to 1.09)
Fibres	17 114	1348	1.02 (0.96 to 1.09)	9669	654	0.87 (0.80 to 0.95)*
Mists	24 721	1940	1.03 (0.98 to 1.08)	15 478	1170	0.96 (0.91 to 1.02)
VGDF	63 597	5313	1.07 (1.03 to 1.11)*	38 172	3023	1.01 (0.97 to 1.05)

PRs (95% CI) for exposure to pollutants and AFO risk (defined as FEV_1/FVC <LLN) were calculated using a Poisson model with robust variance.
Adjusted for sex, study centre (22 categories), age (5 years categories) and lifetime smoking exposure (ever, pack-years and year since quitting).
Reference group for each pollutant individuals in jobs with no exposure to any of the pollutants (clean group).
Healthy=non-AFO cases.
*Adjusted p values were significant after correction for multiple testing.
AFO, airflow obstruction; LLN, lower limit of normal; PR, prevalence ratio; VGDF, vapours, gases, dusts or fumes.

Table 4 Prevalence ratios (95% CI) of AFO risk defined as FEV_1/FVC <LLN for level of exposure to occupational pollutants in the UK Biobank cohort overall (n=228 614) for overall and non-smokers

		Overall category			Non-smoker category		
Pollutant	Exposure level	Healthy exposed	AFO cases	Adjusted PR (95% CI)	Healthy exposed	AFO cases	Adjusted PR (95% CI)
Vapours*	Low	30 485	2885	1.00 (0.96 to 1.04)	18 243	1412	0.98 (0.92 to 1.03)
	Medium	5338	574	1.05 (0.97 to 1.15)	2701	199	0.95 (0.83 to 1.08)
	High	3043	444	1.26 (1.15 to 1.38)	1515	148	1.23 (1.05 to 1.43)
Gases*	Low	28 085	2841	1.03 (0.99 to 1.07)	16 256	1318	1.02 (0.96 to 1.08)
	Medium	2283	256	1.14 (1.01 to 1.29)	1197	100	1.05 (0.87 to 1.28)
	High	293	38	1.26 (0.92 to 1.72)	126	11	1.12 (0.63 to 1.98)
Dusts*	Low	42 126	4146	1.02 (0.99 to 1.06)	24 520	1938	1.0 (0.96 to 1.05)
	Medium	8021	965	1.14 (1.07 to 1.22)	4056	335	1.06 (0.95 to 1.18)
	High	5601	634	1.07 (0.99 to 1.16)	2663	200	0.97 (0.85 to 1.11)
Biological dusts*	Low	26 794	2740	1.05 (1.01 to 1.1)	16 040	1318	1.03 (0.98 to 1.09)
	Medium	1253	134	1.04 (0.88 to 1.23)	706	48	0.90 (0.68 to 1.18)
	High	1894	219	1.09 (0.96 to 1.25)	916	75	1.03 (0.83 to 1.28)
Mineral dusts*	Low	22 323	2061	0.98 (0.93 to 1.03)	12 582	921	0.94 (0.88 to 1.01)
	Medium	9418	1110	1.11 (1.04 to 1.18)	4620	372	1.03 (0.93 to 1.14)
	High	1600	212	1.18 (1.03 to 1.35)	734	58	1.02 (0.79 to 1.30)
Fumes*	Low	27 044	2687	1.0 (0.96 to 1.05)	14 160	1063	0.96 (0.90 to 1.03)
	Medium	5496	617	1.09 (1.0 to 1.18)	2693	218	1.05 (0.92 to 1.19)
	High	742	95	1.26 (1.03 to 1.54)	386	37	1.18 (0.86 to 1.60)
Diesel	Low	15 251	1665	1.04 (0.99 to 1.10)	7647	607	1.0 (0.92 to 1.09)
	Medium	1651	163	1.02 (0.87 to 1.20)	920	73	1.01 (0.81 to 1.27)
	High	–	–	–	–	–	–
Fibres†	Low	15 635	1460	0.96 (0.90 to 1.01)	8283	549	0.86 (0.78 to 0.93)
	Medium	2614	310	1.08 (0.96 to 1.21)	1222	94	0.98 (0.80 to 1.19)
	High	355	44	1.16 (0.87 to 1.53)	164	11	0.87 (0.49 to 1.55)
Mists*	Low	20 707	1898	0.97 (0.93 to 102)	12 137	897	0.94 (0.88 to 1.0)
	Medium	3014	291	1.0 (0.89 to 1.12)	1567	113	0.93 (0.78 to 1.12)
	High	3490	473	1.22 (1.12 to 1.34)	1774	160	1.15 (0.99 to 1.34)
VGDF*	Low	51 163	5123	1.03 (0.99 to 1.06)	28 919	2293	1.01 (0.96 to 1.05)
	Medium	9375	949	1.01 (0.95 to 1.08)	4806	358	0.97 (0.87 to 1.07)
	High	9144	1133	1.14 (1.08 to 1.22)	4447	372	1.07 (0.97 to 1.18)

Adjusted for sex, study centre (22 categories), age (5 years categories) and lifetime smoking exposure (ever, pack-years and year since quitting).
Reference group for each pollutant individuals in jobs with no exposure to any of the pollutants (clean group).
Healthy=non-AFO cases.
*P trend for adjusted PR significant for overall.
†P trend for adjusted significant for non-smokers.
AFO, airflow obstruction; LLN, lower limit of normal; PR, prevalence ratio; VGDF, vapours, gases, dusts or fumes.

occupational contribution to measured AFO using a general population job exposure matrix, especially in the UK. Exposure was assigned to current jobs using the ACE-JEM, which assigns exposure to six different individual pollutant types, and the aggregate VGDF. The highest proportion of UK Biobank participants were exposed to dusts (27%), followed by vapours (19%) and fumes (16%). Of the 20 289 cases of AFO, 7205 (35%) were exposed to VGDF. Adjusted risk estimates for AFO remained significant for exposure to dusts, biological dusts and VGDF but on multiple testing exposure to these pollutant in current job were not significant. Importantly, highest risk estimates were associated with either high or moderate exposure levels (daily/weekly) to vapours, fumes and dusts. There was no significant increase in risk of AFO by duration (years) of exposure in current job.

There was significant variation in number of study participants assigned as exposed to different pollutant types across the nine standard major SOC 2000 groups. For example none of the study participants were assigned as exposed to dusts for SOC groups 4 (administrative and secretarial occupations) and 7 (sales and customer service occupations) but over 50% were exposed to dusts for SOC group 5 (skilled trades occupations) and 9 (elementary occupations). However the number of AFO cases among study participants did not differ hugely for different SOC groups for example, 8.9% for SOC group 4 (administrative and secretarial occupations) and 10.3% for SOC group 8 (process, plant and machine operators). This suggests the need to investigate previous (lifetime) exposures, socioeconomic status as well as current occupational exposures for chronic disease such as AFO.

The increased risk of 4% for exposure to VGDF is slightly lower than published in a recent systematic review (1.07; 95% CI 0.92 to 1.25).[1] This review also showed that risk estimates for VGDF are higher for studies with self-reported exposure to VGDF (1.91; 95% CI 1.72 to 2.13) and for JEM based studies with physician defined COPD (1.19; 95% CI 1.10 to 1.30) when compared with spirometry defined COPD. Another recent systematic review of COPD and exposure to airborne pollutants[2] reported a much higher risk estimate for VGDF (1.43; 95% CI 1.19 to 1.73) probably because it included both JEM based and self-reported estimates for VGDF exposure. The significant increased risk of COPD with exposure to biological dusts is consistent with other studies[3 29–31] although a systematic review, which was limited to ALOHA JEM studies, reported no association between exposure biological dusts and COPD.[3] Of the different pollutant forms encountered in the workplace settings, our study suggests a significant positive association of AFO with exposure to aggregate VGDF, dusts and its subfraction including mineral and biological dusts. However, it is not clear if the sources of the different types of mineral and biological dust shows differential risk to AFO.

Restricting analysis to never-smokers, no significant increased risks of AFO were associated with exposure to any single or combined airborne pollutants suggesting that residual confounding associated with smokers. We also found significant interaction for smoking status and airborne pollutants. The results following interaction suggest exposure to fibres and mists has positive interaction with smoking on the airflow obstruction whereas the results from VGDF and VDDFFiM became statistically insignificant after including the interaction term. The relationship between level (daily/weekly) of exposure and AFO risk was not consistent for all pollutants but showed significant increased risk for high level of exposure to VGDF. However, no significant association was found between exposure to VGDF and AFO risk for non-smokers again possibly due to residual bias. When the analysis excluded participants who self-reported diagnosis of asthma, significantly increased risks of AFO were associated with exposure to all pollutants except mists and fibres.

Initially, we limited our analyses to the risks associated with exposures to single pollutants, (with the exception of VGDF), which is a general approach adopted in all COPD general population epidemiological studies that use JEMs to assign exposures to job titles. In this study gases, dusts and biological dusts showed an increased risk when assessed as independent pollutants. However, the bi-pollutant model only showed increased risk for dusts when adjusted for fibres. The attenuation in the AFO risk could also be due to the moderate correlation between different airborne pollutants but future studies need to consider in more detail the influence of co-exposures to pollutants for different job types. We did not use more than two pollutants at a time in the model as many of these pollutants are multicollinear.

Significantly higher risks were found with high levels of exposure to the following pollutants; vapours, dusts, mineral dusts, fumes, mists, VGDF but on multiple testing, the results became statistically not significant for current exposures. However, for never-smokers only high exposure to vapours showed a significantly increased risk. We carried out a sensitivity analysis by not adjusting pack-years in the model as 15% of the smokers did not provide information required to calculate pack-years. The risk estimates increased in the ever-smoker group when only the smoking status (and not pack-year) was adjusted for suggesting the importance of pack-years in estimation of risk estimates for occupational COPD. Sadhra *et al* in their systematic review[1] also reported a higher risk estimate for VGDF and COPD (based on spirometry) when compared with medium and low exposure to VGDF unlike Alif *et al* (2016) who reported no increased risk to biological dusts but a significantly increased risk for low exposure to mineral dust but surprisingly not for high exposure.[3]

One of the main strengths of this study is that this is to our knowledge the largest general population study on occupational contribution to AFO with more than 225 000 study participants from a wide range of occupational sectors. A further strength is that AFO cases were defined using objective measurement of lung function with the LLN criteria. As well as adjusting for common confounders, sensitivity analyses were conducted for non-asthmatic and never-smokers, which strengthen the reliability of the reported finding. A further strength of the study is that in addition to investigating the role of different pollutants, we also explored the association between exposure level and duration to different pollutants. We provided estimates after multiple testing in the analyses and found that the risks associated with some pollutant metrics, such as the very commonly used combination of VGDF, remained significant even after adjustment for covariates in the whole participants (not never-smoker only).

There are a number of limitations associated with the use of a JEM in exposure attribution. In addition to these, discussed below, the generalisability of our findings to other populations, and indeed to the UK working population, may be adversely influenced by the initial response rate to recruitment into UK Biobank. The risk estimates were adjusted for centre/location as a proxy for socioeconomic status. However, we cannot completely rule out residual bias, for instance, individuals with blue collar jobs are more likely to smoke, have less favourable lifestyles factors (diet intake) and more likely exposed to other environmental pollutants. The study participant may also not representative of the UK for the number workers in different occupational groups. For many jobs and work environments, the possibility of co-exposures to air pollutants exists. For example, wood workers may be exposed not only to dusts but also to vapours from glues, adhesives and paints. Thus, where analysis is conducted using the ACE-JEM to attribute exposure to a single pollutant type (eg, dusts) then the results may be influenced by interaction with co-exposures, which was examined to some extent when the data were analysed using bi-pollutant models and also interaction term used with smoking. However, this approach of investigating the effects of single exposures is consistent with the application of other general population JEMs that estimate exposure to broad class of pollutants, rather than specific substances, as is the case with workplace based JEMs. Other limitations of the study is that data is based on current job collected at baseline interview for those still in work that is, susceptibility to healthy worker effect which is likely to result in an underestimation of the true occupational COPD risk and no post-bronchodilator measures were performed. For instance individuals in major groups 4 (administrative and secretarial occupations) and 7 (sales and customer service occupations) had higher prevalence of airflow obstruction than expected given their exposure to air borne pollutant is likely to low. This may be explained by higher exposures to air borne pollutant in previous jobs. Hence the importance of estimating life occupational exposure with reference to airflow obstruction.

The ACE-JEM, like other general population JEMs, assigns exposure to standard occupational codes and not specific jobs. A major limitation of JEMs is the possible misclassification introduced due to variability of exposure within the job titles.

This is particularly important where the self-reported job title is composed of many job tasks with high variability in exposure between the different tasks and material used/handled. A number of SOC codes cover a range of jobs and work environments, which thus introduces uncertainty when assigning exposures to individual jobs. This issue will inevitably lead to exposure misattribution. Despite these limitations the ACE-JEM assign exposures cover the full range of jobs and is developed using set of priori rules and definitions hence it is most efficient and consistent method available for estimating exposures in population studies when the only information available form study participants is job title and industry that is, avoiding bias introduced through self-reported exposures.

Furthermore, in this study exposure to pollutants is assigned to current job held by study applicants, that is, UK Biobank participants. For this population it shows that of those who are exposed to airborne pollutants the majority are exposed to low levels. It is reasonable to assume that those diagnosed with COPD (irrespective of its cause) may then move (in later life) in to jobs where exposure to pollutants is lower than in their previous jobs. This raises the question whether the risk estimate for COPD can be reliability evaluated based level of exposure in current job. For this reason, future studies need to compare risk estimates for both current and lifetime exposure to different pollutants in workplace settings.

In summary, we applied the ACE-JEM to the cross-sectional UK Biobank data. Exposure to various pollutants, and combination of pollutants as assessed by the JEM at an individual SOC code level, were associated with an increased risk of AFO in the overall population. These effects were most marked for exposures attributed to dusts, biological dusts and the aggregate VGDF, however, stratified analyses suggested interaction with smoking. High exposures in current job to vapours increased the risk of AFO. Employers should therefore consider suitable risk assessments to prevent exposures to harmful inhaled pollutants where appropriate, and actions from these assessments might include respiratory health monitoring where workers are routinely exposed to these airborne pollutant forms particularly where there is evidence of high exposure to either vapours, gases, dusts or fumes.

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