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## Cohort Profile – The Copenhagen Airport Cohort

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**Cohort Profile – The Copenhagen Airport Cohort**

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**Abstract**

*Purpose:* Copenhagen Airport Cohort 1990-2012 presents a unique data source for studies of health effects of occupational exposure to air pollution (ultrafine particles) and manual baggage handling among airport employees. We describe the extent of information in the cohort and in the follow-up based on data linkage to the comprehensive Danish nationwide health registers. In the cohort, all information is linked to the personal identification number that also is used in Denmark Statistics demographic and socio-economic databases and in the nationwide health registers.

*Participants:* The cohort covers 69 175 men in unskilled positions. The exposed cohort includes men in unskilled jobs employed at Copenhagen Airport in the period 1990–2012 either as baggage handlers or in other outdoor work. The reference cohort includes men in unskilled jobs working in the greater Copenhagen area.

*Findings to date:* The cohort includes environmental GPS measurements in Copenhagen Airport, information on job function/task for each calendar year of employment between 1990 and 2012, exposure to air pollution at residence, average weight of baggage lifted per day and lifestyle. By linkage to registers, we retrieved socio-economic and demographic data and data on health care contacts, drug subscriptions, and incident cancer, and mortality.

*Future plans:* The size of the cohort and the completeness of the register-based follow-up enhance a more accurate assessment of the possible health risks of occupational exposure to ultrafine particles and manual baggage handling at airports than in previous studies. We plan to follow the cohort for the incidence of ischemic heart diseases, stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease, and further for associations between heavy manual baggage handling and musculoskeletal disorders.

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9 *Registration:* The Danish Data Protection Agency approved the study (Journal no: 2012-41-  
10 0199).

### 11 12 **Strengths and limitations of this study**

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15 • The size of the cohort and the completeness of the register-based follow-up enhance a  
16 more accurate assessment of the possible health risks of occupational exposure to  
17 ultrafine particles and manual handling at airports than in previous studies
- 18  
19 • The cohort included detailed information on employment for each year
- 20  
21 • The register-based follow-up by linkage to the various Danish, nationwide, health and  
22 population registers ensure an almost complete follow-up
- 23  
24 • Self-reported descriptive data on lifestyle factors were collected among a sample
- 25  
26 • The main limitation is the impossibility to control for confounders variables such as  
27 smoking and other lifestyle factors
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### 37 **Introduction**

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39 In Copenhagen Airport the ground personnel perform tasks such as aircraft fuel tanking,  
40 security, aircraft parking and towing and baggage handling (1). These tasks are often  
41 performed in a working environment with high exposure to air pollution, including high levels  
42 of ultrafine particles (UFP) (diameter  $\leq 100$  nm) (2). Furthermore, the tasks of baggage  
43 handlers include daily heavy lifting of, on average, up to 4–5 tonnes of luggage (3).  
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9 In 2010 the Danish Centre for Environment and Energy at Aarhus University measured high  
10 number concentrations of particles in open air at Copenhagen Airport. These results showed  
11 an average number of 38 600 particles (6–700 nm in diameter)/cm<sup>3</sup>, and about 90% of the  
12 measured particles were UFP(2)). Employees working on the apron at Copenhagen Airport  
13 were exposed to a number concentration of UFP between 12 000 and 37 000 particles/cm<sup>3</sup> (4).  
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15 The number concentration was two–three times higher than measured at the kerbside in a  
16 traffic loaded street in Copenhagen City Centre during the same period (2).  
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26 Particulate air pollution has been associated with increased risk of ischemic heart diseases and  
27 various cancerous diseases (5-7). Previous studies have shown that particulate air pollution  
28 increases the risk of hospital admissions due to chronic obstructive respiratory disease (8, 9).  
29 Diesel exhaust, which is one of the most prevalent sources of particulate air pollution in urban  
30 environments, has also been found to have convincing evidence for carcinogenicity (9), mainly  
31 based on occupational exposures in miners (10, 11). There is, however, uncertainty regarding  
32 occupational exposures to particulate air pollution and risks of health problems (12), and to  
33 our knowledge only two studies have investigated UFP exposure among employees at civil  
34 airports and adverse health effects, and only based on self-reported data (13, 14).  
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48 It is well documented that the majority of baggage handlers are exposed to a high workload  
49 with daily heavy lifting in often awkward positions, and report a high prevalence of  
50 musculoskeletal disorders (15), especially lower back, neck and knee disorders (16-18).  
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9 However, these studies rely on self-reported data about musculoskeletal disorders in small  
10 samples, without the inclusion of a reference group, and the estimation of exposure was only  
11 based on seniority in the occupation and hours per week loading and unloading aircraft (16,  
12 17).

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19 At present, no previous study has analysed the health effects of occupational exposure to UFP  
20 and/or to manual lifting among airport employees utilising data in a large cohort with  
21 complete and long follow-up. The Copenhagen Airport Cohort includes a unique source of  
22 information for occupational epidemiological studies of health effects of high exposure to air  
23 pollution and manual baggage handling with follow-up information based upon linkage to the  
24 Danish nationwide registers. Hence, we present the magnitude of information included in the  
25 cohort study and some preliminary data.  
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### 36 **Cohort description**

#### 37 **Location**

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39 Copenhagen Airport is located 8 km from the city centre of Copenhagen and is the largest  
40 airport in Denmark, with approximately 22 000 employees working in different companies. In  
41 2015, the total number of international and domestic flights was slightly above 254 000. The  
42 apron is the area at the airport where aircrafts are parked, unloaded and loaded, refueled or  
43 boarded (4).  
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### Population and sample size

The cohort comprises men in unskilled jobs employed at Copenhagen Airport in the period 1990–2012 either as baggage handlers or in other outdoor work on the apron. We created a reference cohort of men in unskilled jobs working indoors at Copenhagen Airport and of men in unskilled jobs working in the greater Copenhagen area without any previous employment at Copenhagen Airport.

We only included men, as there were few women working as baggage handlers or employed in outdoor work at Copenhagen Airport.

From company employment registers and the union membership registers, we obtained a complete occupational history for each person concerning both present and former employment (Figure 1).

Company registers included the two baggage handling companies at Copenhagen Airport, SAS Ground Service (SAS) and Novia, and CPH-Company which owns Copenhagen Airport. For SAS and Novia, we included workers in departments working with baggage handling and doing unskilled work in other departments (see Table 1).

Novia established electronic registers on employees in 1990, and SAS in 1995; using these registers, we identified the relevant workers and their employment period. CPH-Company has registered its workers electronically since 1990, and from this company we included security

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9 service personnel and other workers in unskilled jobs with a variety of different tasks (e.g. area  
10 maintenance, certain cleaning tasks, firefighting and marshals).

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14 The workers included in the cohort are organised in three local unions of the National Union of  
15 Unskilled Workers (Danish, 3F) and the National Union of Guards and Security Personnel  
16 (NUGSP). One of the 3F local unions (3F-Kastrup) organises workers in unskilled jobs at  
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18 Copenhagen Airport and in neighbouring areas of Copenhagen. The two other 3F local unions  
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20 organises workers in unskilled jobs in other areas of Copenhagen.  
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25 The member files are centrally organised, and are electronically for periods of membership  
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27 (entry and exit dates) back to 1983 with registration by the member's personal identification  
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29 number. The NUGSP organises guards and security personnel and records periods of  
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31 membership in local unions back to 1979. Few persons had entry dates before the member  
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33 files and company registers became electronic. These data were transferred when the system  
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35 was organised electronically.  
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39 We compared data from the employee registers and the union registers and found good  
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41 agreement between the data sources. The positive predictive value (PPV) for concordance  
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43 between company registration and union member registration as a baggage handler was 87%,  
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45 and the PPV for company/union registration and survey self-reporting of being a baggage  
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47 handler (presented below) was 92%.  
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9 In cases of overlapping information, we prioritised data in the company register, because it  
10 was mandatory for any salary payment, and we included union information if this  
11 supplemented the period before the first entry date of company records.  
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16 The company registers comprised information on 5773 men and the union member registers  
17 74 736 men. Figure 1 shows the degree of overlapping information. We excluded men using  
18 the following criteria: invalid personal identification number, missing information on  
19 occupation, same entry and exit dates, administrative/management/academic tasks, absence  
20 leave, employed at an age lower than 15 years, no permanent residence in Denmark any year  
21 in the study period, only employed after end of follow-up (December 2012), death before  
22 employment, and death before 1990. After these exclusions, the final study cohort comprised  
23 69 175 men in unskilled jobs (Figure 1).  
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34 **(Figure 1 here)**  
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### 36 **Data collection**

#### 37 **Exposure to UFP**

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39 UFP exposure in the airport was estimated based on direct GPS measurements in combination  
40 with individual measurements of UFP number concentration (4), expert assessment and  
41 comprehensive information on job function/task for each calendar year of employment  
42 between 1990 and 2012.  
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9 Using GPS, we estimated the length of time spent outdoors on the apron during a normal  
10 working day among each of the five largest occupational groups in Copenhagen Airport (4). By  
11 this study, we found that occupational groups spending the largest proportion of work hours  
12 on the apron also were exposed to the highest mean levels of UFP (4). Time spent on apron in  
13 percent was therefore used as a proxy for exposure to UFP. Three airport personnel with  
14 comprehensive knowledge of work in the airport assessed time spent on the apron  
15 (percentage of a normal working day) for other occupational groups, using data on time spent  
16 on the apron obtained from the GPS measurement as benchmarks, and including information  
17 on the individual job functions and tasks of each occupational group. Groups with similar time  
18 spent on the apron were pooled (Table 1). For each calendar year we calculated the duration  
19 of UFP exposure as the group weighted proportion of time spent on the apron (apron-years).  
20 E.g. baggage handling for 150 days, and cargo work for 90 days in a calendar year gives  
21  $(150 \times 0.76 + 90 \times 0.25) / 365 = 0.37$  apron-years of UFP exposure for that year. Apron-years were  
22 cumulated during follow-up resulting in time-dependent apron-years.  
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#### 40 **Exposure to manual baggage handling**

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42 The level of exposure to manual baggage handling was estimated by direct observations,  
43 production statistics from the two handling companies SAS and Novia, and including previous  
44 assessments made by the company occupational health service in 1991, 1998 and 2001. In  
45 addition, we obtained information about the introduction of technical lifting accessories.  
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9 Since 2002 and 2009, SAS and Novia have recorded electronic data on loaded baggage in  
10 kilograms (kg) for every single flight. Based on these detailed information we estimate, that  
11 the average of total baggage lifted per day is approximately five tonnes per baggage handler,  
12 slightly less in the baggage sorting area than on the apron, and the average weight of a  
13 baggage piece is approximately 15 kg. Since the beginning of the 1990s, the daily manual  
14 baggage-handling load for each baggage handler has been rather constant over years.  
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22 In addition, we performed biomechanical measurements on a sample of 23 baggage handlers  
23 at the airport by monitoring the muscle activity using electromyography (EMG) over typical  
24 working days, including determination of the muscle activity level during specific work tasks.  
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29 The handling tasks were also analysed experimentally in a laboratory with video recordings of  
30 a baggage handler equipped with a full-body marker set-up performing different handling  
31 tasks (e.g. standing or kneeling) on force platforms. On the basis of these recordings, inverse  
32 dynamics-based musculoskeletal models of the tasks were built in the AnyBody Modeling  
33 system v. 5.3 (AnyBody Technology A/S, Aalborg, Denmark) (19).  
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#### 41 **Data sources for outcome variables**

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44 In Denmark, a person's individual identification number is used in the registration of data to  
45 the various nationwide registers, and likewise, this individual number identifies the study  
46 population of the Airport Cohort.  
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9 In the present follow-up study, we linked data in the Cohort to the National Patient Register,  
10 the Cancer Registry, the National Prescription Registry and the Register of Causes of Death  
11 (20)-(21). The National Patient Register contains data on all in-patients and since 1995 also on  
12 all out-patient contacts (20). Among the study and the reference group, we retrieved data on  
13 hospital contacts due to cardiovascular disease, respiratory diseases and musculoskeletal  
14 disorders. Further, data on incident cancer cases was obtained from the Danish Cancer  
15 Registry, established in 1943 (22). Data on drugs prescribed for respiratory diseases were  
16 retrieved from the Danish National Prescription Registry, available from 1995 (23). Data on  
17 death and causes of death were retrieved from the Danish Register of Causes of Death, which  
18 contains computerised data on all deaths in Denmark of Danish citizens since 1970 (21).  
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### 31 **Potential confounders**

#### 32 **Socio-economic and demographic data**

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34 We linked cohort data to Denmark Statistics various population based registers. Information  
35 on education level attained the year before entering the cohort was obtained from the  
36 Population Education Register (24). Information on country of birth and marital status was  
37 obtained from the Civil Registration System (25). Information on sickness absence from  
38 Coherent Social Statistics (26) was included, as well as information on any pensioning  
39 (disability pensioning, early retirement pension and retirement pension) from the Central  
40 Pension Register and Persons who are not in Ordinary Employment (27). Information on  
41 migration was obtained from the Civil Registration System (25).  
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These data sources, the Danish nationwide registers, are updated annually. In the data analyses, the various socio-demographic data were included as time-dependent variables.

#### **Lifestyle data**

Self-reported data on health and lifestyle (Table 2) were collected by questionnaire. The questionnaires were delivered to all baggage handlers and security service personal employed in Copenhagen Airport the 1th of April 2012 and a stratified random sample of the remaining groups meeting the following criteria: being alive by April 2012, having permanent residence in Denmark, aged 25–75 years and not registered as unwilling to participate in research projects (an option by Danish law). The currently employed baggage handlers completed the questionnaire in the airport during their work time; the others by post. Respondents who did not answer the questionnaire within three weeks received a telephone call and were asked to answer the questionnaire by telephone. A total of 3749 men out of 5474 responded to the questionnaire, making a response rate of 68.5%.

In analysis of respondent vs. non-respondents a larger proportions of respondents were Danish of origin, had a higher education and were married cf. Table 2.

#### **Air pollution at residence**

To obtain information on pollution at the residence all members in the cohort alive in April 2012, were geo-coded. We excluded persons with invalid postcodes, individuals who were dead or had emigrated, leaving 57 235 addresses. The exact geo-codes were identified for

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9 44 713 persons. We found invalid geocodes for 299 (0.5%) persons and for 12 223 persons we  
10 only obtained information about residential address by road, and we therefore imputed the air  
11 pollution exposure as the mean exposure for the road. Based on the Danish road network and  
12 modelled road traffic values, we calculated the distance from residence to the nearest road  
13 with annual daily traffic (ADT) of 10 000 vehicles or more, and retrieved the ADT value for the  
14 identified road segment. In addition, the heavy-duty share of the ADT value was also retrieved.  
15 Furthermore, the traffic density measure (TDM) within a buffer of 100 metres and 300 metres  
16 was assigned to every residence. To calculate the TDM, we applied the following equation:  
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$$26 \quad TDM = \sum(ADT_{road\ segment} * Length_{road\ segment})$$

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29 where  $ADT_{road\ segment}$  is the modelled number of cars on a road segment (e.g. between two  
30 intersections), and  $Length_{road\ segment}$  is the length of the same road segment in metres.  
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### 36 **Characteristics of participants**

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38 Table 2 presents baseline characteristics of men exposed to UFP and their reference group and  
39 for baggage handlers and their reference group, respectively. At baseline, larger proportions of  
40 the reference groups had a higher education and larger proportions of the exposed groups  
41 were younger and unmarried. Furthermore, slightly more persons in the reference groups  
42 were current smokers. Country of origin, average pollution at residence, alcohol, BMI and  
43 leisure-time physical activity were similar among the exposed groups and their reference  
44 groups.  
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### 10 11 Findings to date

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16 At present, three research papers have been published (3, 4, 28). In the study by Møller et al,  
17 we found that occupational groups who spent the largest amount of time on the apron during  
18 a work day also were exposed to the highest mean levels of UFP (3, 4, 28). Among baggage  
19 handlers, we reported that the incidence of sub-acromial shoulder disorders increased with  
20 cumulative years of employment (3, 4, 28) and in the study by Bern et al, based on self-  
21 reported employment history and musculoskeletal pain, the risk of musculoskeletal symptoms  
22 in six anatomical regions increased with increasing seniority as a baggage handler (3, 4, 28).  
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### 33 Strengths and limitations

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35 The main strengths of the Copenhagen Airport Cohort are the comprehensive data sources  
36 used in the construction of the cohort. First, the cohort was constructed on administrative  
37 data from company registers and union member registers, which provided detailed  
38 information on employment for each year why recall bias was avoided. Furthermore, it  
39 comprises the availability of detailed objective information on exposure, collected  
40 independently, and comprehensive register data that assess outcomes related to health. A  
41 strength is also the size of the cohort. These factors qualify analyses based on the cohort. The  
42 register-based follow-up by linkage to the various Danish, nationwide, health and population  
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8 registers enhance the follow-up, and ensure an almost complete follow-up that may be  
9 continued in the future, contrary to a questionnaire-based follow-up.  
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13 The main limitation is the impossibility to control for potential confounders, including the  
14 impact of changing lifestyle over the studied period. Self-reported descriptive data on lifestyle  
15 factors were collected among a sample, which might facilitate sensitivity analyses of the  
16 potential influence of lifestyle confounding. But, these data were cross-sectional and only  
17 available for 2012, and e.g. smoking habits might have changed over time.  
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20 Furthermore, a potential bias of an employed cohort is the healthy worker effect. To overcome  
21 this potential bias, we established a reference cohort consisting of men in unskilled jobs other  
22 than in airports (29, 30), and, thus, we may diminish this bias.  
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### 25 **Future plans**

26 We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases,  
27 stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and  
28 occupational exposures at airports, and the association between heavy lifting and  
29 musculoskeletal disorders.  
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32 We plan to update the cohort by 10 more years in 2022 including continuously information on  
33 health care contacts by linkage to the national health registers.  
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## Collaboration

The researchers would welcome collaboration on future projects. For more information, please contact Charlotte Brauer. E-mail: [Charlotte.Brauer@regionh.dk](mailto:Charlotte.Brauer@regionh.dk).

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## Footnotes

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## Ethical statement

The study was approved by the Danish Data Protection Agency (Journal no: 2012-41-0199). Under Danish law, this project did not require approval by the Danish National Committee on Health Research Ethics (Journal no: H-4-2011-125 and H-3-2012-027).

## Author contribution

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9 KLM wrote the first draft of the paper except the section of exposure to manual baggage  
10 handling which was written by CB and the section of air pollution at residence which was  
11 written by TB and OH. LCT, SM, CB, KHL, SHB and KM conceived and designed the study.  
12  
13 Furthermore, LCT, SM, CB, SHB and KM contributed to data collection and construction of the  
14 cohort. All authors contributed to the critical discussion of data and analyses and all authors  
15 revised and approved the final version of the manuscript.  
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### 22 **Conflict of interest**

23  
24 The authors have no conflict of interests.  
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### 28 **References**

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Table 1. Average time spent on the apron (% of a normal work day) by occupational group.

Occupational group	Job description	Average time on apron (%)
Baggage handlers <sup>a</sup>	Assigned to aircraft procedures on the apron such as baggage loading and unloading, both inside and outside the baggage compartment. This group is also assigned to push the aircraft to the taxi-way using a push-back tractor	76
Aircraft cleaning <sup>a</sup>	Assigned to aircraft cabin cleaning. This group goes into the aircraft from the apron with a diesel powered high loader, a lorry, or from the gate	62
Drivers <sup>b</sup> , fuel drivers <sup>b</sup> and catering drivers <sup>a</sup> , catering <sup>a</sup> , inflight service <sup>b</sup>	Drivers support the aircraft with inflight service. Fuel drivers load and service the aircraft with fuel and handle de-icing. Catering drivers are assigned to load and unload food and drinks to and from the aircraft. This group goes into the aircraft from the apron with a diesel powered high loader	62
Push-back <sup>b</sup>	Aircraft parking/towing	60
Marshals <sup>b</sup>	Direct the aircraft to the right gate	40
Cargo <sup>b</sup>	Loading and unloading <b>cargo</b> carried by aircrafts	25
Maintenance service personnel <sup>b</sup>	Maintain outdoor area (mow the grass, clear snow)	25
Traffic <sup>b</sup> , gate coordinators <sup>b</sup>	Assigned to ensure that all baggage/cargo/mail is placed correctly and to check the fuel to ensure correct weight distribution of the aircraft	20
Security airside <sup>a</sup>	Assigned to security service at the security restricted area and to patrol by vehicle on the apron, gates and along fence lines and buildings	14
Firefighters <sup>b</sup>	On the apron during fire drills	10

a) Assessed by GPS measurements

b) Assessed by expert ratings (see text)

Table 2 Copenhagen Airport Cohort: Baseline characteristics with information from registers and survey

<i>Variables</i>	<b>Air pollution</b>		<b>Manual lifting</b>		<b>Non-respondents in survey</b>	
	Reference <sup>1</sup>	Exposed <sup>1</sup>	Reference <sup>2</sup>	Exposed <sup>2</sup>	Respondents	Non-respondents
<i>Data from registers</i>						
<b>N</b>	62 546	6629	65 702	3473	3749	1725
<b>Age, mean (SD)</b>	35.0 (13.7)	29.9 (8.2)	34.8 (13.6)	28.9 (7.3)	30.9 (8.6)	29.8 (8.4)
<b>Risk time, person-years</b>	679385.0	51314.2	703235.6	27463.4	.	.
<b>Danish country of origin, n (%)</b>	51 345 (83.7)	5529 (88.0)	53 839 (83.9)	3067 (89.9)	3357 (89.8)	1386 (80.8)
<b>Educational level, n (%)</b>						
Elementary school	35 664 (57.0)	3132 (47.3)	37 221 (56.65)	1575 (45.35)	1614 (43.1)	873 (50.6)
High school	8821 (14.1)	904 (13.6)	9225 (14.0)	500 (14.4)	565 (15.1)	213 (12.4)
Vocational education	16 742 (26.8)	2487 (37.5)	17 872 (27.2)	1357 (39.1)	1494 (39.9)	610 (35.4)
Higher education	1319 (2.1)	106 (1.6)	1384 (2.11)	41 (1.18)	76 (2.0)	29 (1.7)
<b>Marital status, n (%)</b>						
Married	19 663 (31.4)	1783 (26.9)	20 603 (31.36)	843 (24.27)	1169 (31.2)	433 (25.1)
Unmarried	36 438 (58.3)	4459 (67.3)	38 428 (58.49)	2469 (71.09)	2357 (62.9)	1185 (68.7)
Divorced	5712 (9.1)	379 (5.7)	5932 (9.03)	159 (4.58)	221 (5.9)	102 (5.9)
Widow	733 (1.2)	8 (0.1)	739 (1.12)	2 (0.06)	2 (0.1)	5 (0.3)
<b>Average pollution at residence</b>						
<b>Major road within 50 meter of residence, n (%)<sup>3</sup></b>	5593 (11.3)	600 (10.3)				
<i>Data from Survey</i>	Reference	Exposed	Reference	Exposed		
<b>N</b>	1473	2276	1963	1786		
<b>Smoking, n (%)</b>						
No	485 (32.9)	887 (38.5)	680 (34.8)	682 (38.5)		
Former	507 (34.4)	773 (34.0)	674 (34.5)	606 (34.2)		
Current	473 (32.1)	609 (26.8)	598 (30.6)	484 (27.3)		

Missing	8 (0.54)	17 (0.75)	11 (0.56)	14 (0.78)
<b>Units of alcohol per week, n (%)</b>				
0	355 (24.1)	582 (25.6)	502 (25.8)	435 (24.7)
1-21	999 (67.8)	1567 (68.9)	1318 (67.8)	1248 (70.7)
>21	106 (7.2)	101 (4.4)	125 (6.4)	82 (4.7)
Missing	13 (0.88)	26 (1.14)	18 (0.92)	21 (1.18)
<b>BMI, n (%)</b>				
<18.5	8 (0.5)	2 (0.1)	9 (0.47)	1 (0.1)
18.5-25	507 (34.4)	795 (34.9)	685 (35.5)	617 (35.0)
25.1-30	664 (45.1)	1087 (47.8)	892 (46.2)	859 (48.7)
>30	267 (18.1)	366 (16.1)	345 (17.9)	288 (16.3)
Missing	27 (1.83)	26 (1.14)	32 (1.63)	21 (1.18)
<b>Leisure-time physical activity hours/week, n (%)</b>				
Sedentary	188 (12.8)	242 (10.6)	255 (13.0)	175 (9.8)
Low	535 (36.3)	786 (34.5)	697 (35.5)	624 (34.9)
Medium	540 (36.7)	878 (38.6)	707 (36.0)	711 (39.8)
High	187 (12.7)	347 (15.3)	280 (14.26)	254 (14.2)
Missing	23 (1.56)	23 (1.01)	24 (1.22)	22 (1.23)

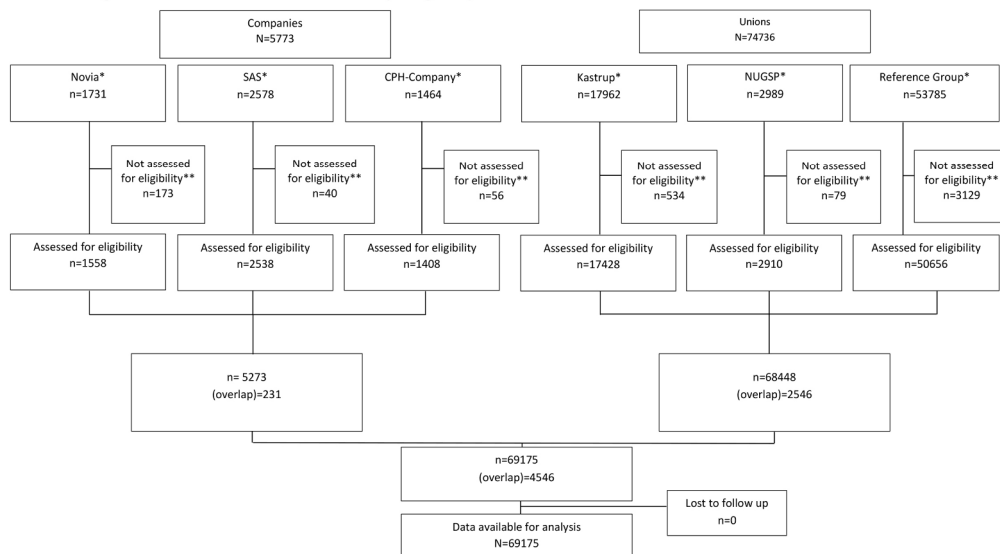
- (1) Descriptive statistics at baseline, the first year during follow-up that a person is employee in Copenhagen Airport in a job function with tasks outdoors on apron (exposed group) or first year during follow-up for workers who are never employees in Copenhagen Airport in job functions with tasks outdoors on apron (reference group).
- (2) Descriptive statistics at baseline, the first year during follow-up that a person is employed as baggage handler in Copenhagen (exposed group) or first year during follow-up for workers who are never employed as baggage handler in Copenhagen (reference group).
- (3) Major road >10 000 vehicles/day

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Figure 1. Flowchart of the construction of the Copenhagen Airport Cohort



\*Novia (Novia Denmark, handling company), SAS (SAS Ground Service, handling company), CPH (Copenhagen Airports), Kastrup (3F Kastrup-local union), NUGSP (National Union of Guards and Security Personnel), reference group includes 3F Mølleåen, 3F Kastrup and 3F Lager Post and Service Union (LPSF) all organises workers in neighbouring areas of Copenhagen  
 \*\*Not assessed for eligibility due to; invalid CPR-number, missing information on occupation, administrative/management/academic occupations, persons with leave of absence, employment before 15 years of age, men who have never stayed in Denmark under the study period (1990-2012), employment after 31th December 2012, same entry and exit date, dead before employment and dead before 1990

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# BMJ Open

## Cohort profile. Copenhagen Airport Cohort – air pollution, manual baggage handling and health

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Cohort profile. Copenhagen Airport Cohort – air pollution, manual baggage handling and health

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## Abstract

*Purpose:* Copenhagen Airport Cohort 1990-2012 presents a unique data source for studies of health effects of occupational exposure to air pollution (ultrafine particles) and manual baggage handling among airport employees. We describe the extent of information in the cohort and in the follow-up based on data linkage to the comprehensive Danish nationwide health registers. In the cohort, all information is linked to the personal identification number that also is used in Denmark Statistics demographic and socio-economic databases and in the nationwide health registers.

*Participants:* The cohort covers 69 175 men in unskilled positions. The exposed cohort includes men in unskilled jobs employed at Copenhagen Airport in the period 1990–2012 either as baggage handlers or in other outdoor work. The reference cohort includes men in unskilled jobs working in the greater Copenhagen area.

*Findings to date:* The cohort includes environmental GPS measurements in Copenhagen Airport, information on job function/task for each calendar year of employment between 1990 and 2012, exposure to air pollution at residence, average weight of baggage lifted per day and lifestyle. By linkage to registers, we retrieved socio-economic and demographic data and data on health care contacts, drug subscriptions, and incident cancer, and mortality.

*Future plans:* The size of the cohort and the completeness of the register-based follow-up enhance a more accurate assessment of the possible health risks of occupational exposure to ultrafine particles and manual baggage handling at airports than in previous studies. We plan to follow the cohort for the incidence of ischemic heart diseases, cerebrovascular disease, lung and bladder cancer, asthma and chronic obstructive pulmonary disease, and further for associations between heavy manual baggage handling and musculoskeletal disorders.

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9 *Registration:* The Danish Data Protection Agency approved the study (Journal no: 2012-41-  
10 0199).

### 11 12 **Strengths and limitations of this study**

- 14 • The size of the cohort and the completeness of the register-based follow-up enhance a  
15 more accurate assessment of the possible health risks of occupational exposure to  
16 ultrafine particles and manual handling at airports than in previous studies
- 17 • The cohort included detailed information on employment for each year
- 18 • The register-based follow-up by linkage to the various Danish, nationwide, health and  
19 population registers ensure an almost complete follow-up
- 20 • Self-reported descriptive data on lifestyle factors were collected among a sample
- 21 • The main limitation is the impossibility to control for confounders variables such as  
22 smoking and other lifestyle factors

### 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 **Introduction**

38 Globally, more than 2 million civilian and military personnel are occupationally exposed to jet  
39 propulsion fuel (1). In Copenhagen Airport the ground personnel perform tasks such as aircraft  
40 fuel tanking, security, aircraft parking and towing and baggage handling (2). These tasks are  
41 often performed in a working environment with high exposure to air pollution, including high  
42 levels of ultrafine particles (UFP) (diameter  $\leq 100$  nm) (3). Furthermore, the tasks of baggage  
43 handlers include daily heavy lifting of, on average, up to 4–5 tonnes of luggage (4).  
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11 In 2010 the Danish Centre for Environment and Energy at Aarhus University measured high  
12 number concentrations of particles in open air at Copenhagen Airport. These results showed  
13 an average number of 38 600 particles (6–700 nm in diameter)/cm<sup>3</sup>, and about 90% of the  
14 measured particles were UFP(3)). Employees working on the apron at Copenhagen Airport  
15 were exposed to a number concentration of UFP between 12 000 and 37 000 particles/cm<sup>3</sup> (5).  
16  
17 The number concentration was two–three times higher than measured at the kerbside in a  
18 traffic loaded street in Copenhagen City Centre during the same period (3). As a part of a large  
19 project to improve the air quality of the working environment, the Danish Centre for  
20 Environment and Energy in 2010 estimated air pollution on the apron at Copenhagen Airport.  
21 They found that the particle number concentration was two–three times higher on the apron  
22 than in a traffic loaded street in the centre of Copenhagen, with 90% of the measured particles  
23 in the size frame of <100nm (ultrafine particles (UFP))(3). For other pollutants (NO, NO<sub>2</sub>, PM<sub>2.5</sub>,  
24 SO<sub>2</sub>, particle mass, concentration of elemental carbon (EC) in the particulate matter,  
25 concentration of polycyclic aromatic hydrocarbons (PAH) in the particulate matter and  
26 concentration of volatile organic compounds (VOC)) where EU limit values exist all levels  
27 measured at Copenhagen Airport were below, but no air quality limit values for particle  
28 number exists (6).  
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48 We therefore assume that if this study found any health effects among airport employees  
49 working outdoors, this would be a consequence of exposure to UFP. However, one can only  
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8 speculate about the degree to which other pollutant may influence any health related effects  
9 among airport employees. We therefore assume that if this study found any health effects  
10 among airport employees working outdoors, this would be a consequence of exposure to UFP.  
11 However, one can only speculate about the degree to which other pollutants may influence  
12 any health related effects among airport employees.  
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21 Over the past 10 years, the scientific interest has moved from mass concentration ( $PM_{2.5}$  and  
22  $PM_{10}$ ) to the number concentration of UFP (7). UFP differs from larger particles due to the  
23 large surface area with adhered toxins and high alveolar deposition (8). Several experimental  
24 studies in animals have shown that UFP can translocate into the blood vessels due to the small  
25 size (8-12), and this is likely to occur in humans although translocation from the lungs has not  
26 been firmly established (13).  
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35 Ground personnel working on the apron near and around the aircraft are exposed to exhaust  
36 from jet fuel and diesel exhaust from handling equipment (3). Previous studies have shown  
37 that the major sources of UFP are emissions from motor vehicles and other combustion  
38 machines (8, 14).  
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45 Particulate air pollution has been associated with increased risk of ischemic heart diseases and  
46 various cancerous diseases (15-17). Previous studies have shown that particulate air pollution  
47 increases the risk of hospital admissions due to chronic obstructive respiratory disease (18,  
48 19). Diesel exhaust, which is one of the most prevalent sources of particulate air pollution in  
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9 urban environments, has also been found to have convincing evidence for carcinogenicity (9),  
10 mainly based on occupational exposures in miners (20, 21). There is, however, uncertainty  
11 regarding occupational exposures to particulate air pollution and risks of health problems (22),  
12 and to our knowledge only two studies have investigated UFP exposure among employees at  
13 civil airports and adverse health effects, and only based on self-reported data (23, 24).  
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21 It is well documented that the majority of baggage handlers are exposed to a high workload  
22 with daily heavy lifting in often awkward positions, and report a high prevalence of  
23 musculoskeletal disorders (25), especially lower back, neck and knee disorders (26-28).  
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25 However, these studies rely on self-reported data about musculoskeletal disorders in small  
26 samples, without the inclusion of a reference group, and the estimation of exposure was only  
27 based on seniority in the occupation and hours per week loading and unloading aircraft (26,  
28 27).  
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39 At present, no previous study has analysed the health effects of occupational exposure to UFP  
40 and/or to manual lifting among airport employees utilising data in a large cohort with  
41 complete and long follow-up. The Copenhagen Airport Cohort includes a unique source of  
42 information for occupational epidemiological studies of health effects of high exposure to air  
43 pollution and manual baggage handling with follow-up information based upon linkage to the  
44 Danish nationwide registers. Hence, we present the information included in the cohort study  
45 and some preliminary data.  
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## Cohort description

### Location

Copenhagen Airport is located 8 km from the city centre of Copenhagen and is the largest airport in Denmark, with approximately 22 000 employees working in different companies. In 2015, the total number of international and domestic flights was slightly above 254 000. The apron is the area at the airport where aircrafts are parked, unloaded and loaded, refueled or boarded (5).

Figure 1 here.

### Population and sample size

The cohort comprises men in unskilled jobs employed at Copenhagen Airport in the period 1990–2012 either as baggage handlers or in other outdoor work on the apron. We created a reference cohort of men in unskilled jobs working indoors at Copenhagen Airport and of men in unskilled jobs working in the greater Copenhagen area without any previous employment at Copenhagen Airport.

We only included men, as there were few women working as baggage handlers or employed in outdoor work at Copenhagen Airport.

From company employment registers and the union membership registers, we obtained a complete occupational history for each person concerning both present and former employment (Figure 2).

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9 Company registers included the two baggage handling companies at Copenhagen Airport, SAS  
10 Ground Service (SAS) and Novia, and CPH-Company which owns Copenhagen Airport. For SAS  
11 and Novia, we included workers in departments working with baggage handling and doing  
12 unskilled work in other departments (see Table 2).  
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18 Novia established electronic registers on employees in 1990, and SAS in 1995; using these  
19 registers, we identified the relevant workers and their employment period. CPH-Company has  
20 registered its workers electronically since 1990, and from this company we included security  
21 service personnel and other workers in unskilled jobs with a variety of different tasks (e.g. area  
22 maintenance, certain cleaning tasks, firefighting and marshals).  
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30 The workers included in the cohort are organised in three local unions of the National Union of  
31 Unskilled Workers (Danish, 3F) and the National Union of Guards and Security Personnel  
32 (NUGSP). One of the 3F local unions (3F-Kastrup) organises workers in unskilled jobs at  
33 Copenhagen Airport and in neighbouring areas of Copenhagen. The two other 3F local unions  
34 organises workers in unskilled jobs in other areas of Copenhagen.  
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41 The member files are centrally organised, and are electronic for periods of membership  
42 (entry and exit dates) back to 1983 with registration by the member's personal identification  
43 number. The NUGSP organises guards and security personnel and records periods of  
44 membership in local unions back to 1979. Few persons had entry dates before the member  
45 files and company registers became electronic. These data were transferred when the system  
46 was organised electronically.  
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11 In case of overlapping information, we prioritized data in the company register, because it was  
12 mandatory for any salary payment, and we included union information if this supplemented  
13 the period before the first entry date of company records.  
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19 The validity of union information on job function was assessed by calculating the percentage  
20 with the same job function recorded in the company registers. We assessed the validity of  
21 questionnaire information on job function the same way. We found good agreement between  
22 the data sources. E.g., 87% of persons recorded as baggage handlers by the union were also  
23 recorded as baggage handlers in company records, and 92% of persons who in the  
24 questionnaire declared that they had worked as security personnel were recorded as such in  
25 the company records.  
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35 The company registers comprised information on 5773 men and the union member registers  
36 74 736 men. Figure 2 shows the degree of overlapping information. We excluded men using  
37 the following criteria: invalid personal identification number, missing information on  
38 occupation, same entry and exit dates, administrative/management/academic tasks, absence  
39 leave, employed at an age lower than 15 years, no permanent residence in Denmark any year  
40 in the study period, only employed after end of follow-up (December 2012), death before  
41 employment, and death before 1990. After these exclusions, the final study cohort comprised  
42 69 175 men in unskilled jobs (Figure 2).  
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9 At baseline the majority of the reference group was employed in occupations unexposed to  
10 high levels of UFP (e.g. municipal workers, drivers, postal workers, garbage collectors, factory  
11 workers)(29). Only few were employed in the construction or welding industry (4%). These  
12 groups may have been exposed to high levels of UFP and vehicle exhausts. However, studies of  
13 ischemic heart disease in welders indicate that if there is an increased risk, it is small and will  
14 hardly contribute to any substantial increased risk in the reference population (30).  
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22 (Figure 2 here)

#### 23 24 25 **Data collection**

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28 (Table 1 here)

#### 29 30 31 **Exposure to UFP**

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33 UFP exposure in the airport was estimated based on direct GPS measurements in combination  
34 with individual measurements of UFP number concentrations (5), expert assessment and  
35 comprehensive information on job function/task for each calendar year of employment  
36 between 1990 and 2012.  
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42 Among 30 employees from the five largest occupational groups at the airport (baggage  
43 handlers, catering drivers, cleaning staff, airside security and landside security staff) we  
44 measured time spent on the apron from GPS measurements in combination with personal  
45 monitoring of UFP number concentration ( $n/cm^3$ ) during a normal working day (5). We found  
46 that baggage handlers were exposed to daily average concentrations (geometric mean, GM:  
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9 37x10<sup>3</sup>UFP/cm<sup>3</sup>) significantly larger than employees mainly working indoors (GM:  
10 5x10<sup>3</sup>UFP/cm<sup>3</sup>) (5). Cleaning staff, catering drivers and airside security were exposed to  
11 concentrations in the same range (GM: 12 to 20x10<sup>3</sup>UFP/cm<sup>3</sup>). Much higher concentrations  
12 were measured on the apron compared to other locations at the airport, whether indoors or  
13 outdoors (5). Therefore the proportion of daily working hours spent on the apron may serve as  
14 a proxy for UFP-exposure for occupational groups without UFP and GPS measurements. Five of  
15 the occupational groups with measured apron times were used as benchmarks, to assess the  
16 average apron times for the remaining occupational groups. This was assessed by three airport  
17 worker representatives with a comprehensive knowledge of the working procedures for  
18 different occupational groups at the airport. In this assessment, the apron times of all drivers,  
19 that is, drivers with inflight service, fuel drivers, catering drivers and other inflight and catering  
20 personnel were considered to be similar to that of cleaning staff(measured as 62% of the time)  
21 and differed from the actually measured apron time for catering drivers (measured as 34% of  
22 the time). However, the number concentrations of UFP measured for catering drivers working  
23 on the apron was 43x10<sup>3</sup> UFP/cm<sup>3</sup> and for cleaning staff working on the apron 23x10<sup>3</sup> UFP/cm<sup>3</sup>  
24 (5) . The apron time was considered as a proxy for UFP-exposure and therefore we assigned  
25 the same apron time to this mixed group of drivers, including catering drivers, as that of  
26 cleaning staff (62%), assuming that these groups had similar exposure to UFP. All other  
27 occupational groups were assigned an exposure estimate based on expert assessment of their  
28 working time on the apron, expressed as a percentage of daily working time. We pooled  
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9 groups with similar apron time, resulting in 10 occupational exposure groups with different  
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11 average apron times.

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14 The apron time was calculated for each calendar year as the proportion of time worked on the  
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16 apron that year according to entry and exit dates for work in specific occupational groups. E.g.  
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18 baggage handling for 150 days, and cargo work for 90 days in a calendar year gives  $(150 \times 0.76 +$   
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20  $90 \times 0.25) / 365 = 0.37$  apron-years of UFP exposure for that year. During follow-up, apron-years  
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22 were cumulated resulting in time-dependent apron-years.  
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25 **(Table 2 here)**  
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#### 27 28 **Exposure to manual baggage handling**

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30 The level of exposure to manual baggage handling was estimated by direct observations,  
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32 production statistics from the two handling companies SAS and Novia, and including previous  
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34 assessments made by the company occupational health service in 1991, 1998 and 2001. In  
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36 addition, we obtained information about the introduction of technical lifting accessories.  
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39 Since 2002 and 2009, SAS and Novia have recorded electronic data on loaded baggage in  
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41 kilograms (kg) for every single flight. Based on these detailed information we estimate, that  
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43 the average of total baggage lifted per day is approximately five tonnes per baggage handler,  
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45 slightly less in the baggage sorting area than on the apron, and the average weight of a  
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47 baggage piece is approximately 15 kg. Since the beginning of the 1990s, the daily manual  
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49 baggage-handling load for each baggage handler has been rather constant over years.  
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9 In addition, we performed biomechanical measurements on a sample of 23 baggage handlers  
10 at the airport by monitoring the muscle activity using electromyography (EMG) over typical  
11 working days, including determination of the muscle activity level during specific work tasks.  
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15 The handling tasks were also analysed experimentally in a laboratory with video recordings of  
16 a baggage handler equipped with a full-body marker set-up performing different handling  
17 tasks (e.g. standing or kneeling) on force platforms. On the basis of these recordings, inverse  
18 dynamics-based musculoskeletal models of the tasks were built in the AnyBody Modeling  
19 system v. 5.3 (AnyBody Technology A/S, Aalborg, Denmark) (31). Output from the models was  
20 muscle and joint forces. These forces were subsequently used as weights in the register-part of  
21 the study.  
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### 32 **Data sources for outcome variables**

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35 In Denmark, a person's individual identification number is used in the registration of data to  
36 the various nationwide registers, and likewise, this individual number identifies the study  
37 population of the Airport Cohort.  
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42 In the present follow-up study, we linked data in the Cohort to the National Patient Register,  
43 the Cancer Registry, the National Prescription Registry and the Register of Causes of Death  
44 (32)-(33). The National Patient Register contains data on all in-patients and since 1995 also on  
45 all out-patient contacts (32). Among the study and the reference group, we retrieved data on  
46 hospital contacts due to cardiovascular disease, respiratory diseases and musculoskeletal  
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8 disorders. Further, data on incident cancer cases was obtained from the Danish Cancer  
9 Registry, established in 1943 (34). Data on drugs prescribed for respiratory diseases were  
10 retrieved from the Danish National Prescription Registry, available from 1995 (35). Data on  
11 death and causes of death were retrieved from the Danish Register of Causes of Death, which  
12 contains computerised data on all deaths in Denmark of Danish citizens since 1970 (33).  
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## 20 **Potential confounders**

### 21 **Socio-economic and demographic data**

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23 We linked cohort data to Denmark Statistics various population based registers. Information  
24 on education level attained the year before entering the cohort was obtained from the  
25 Population Education Register (36). Information on country of birth and marital status was  
26 obtained from the Civil Registration System (37). Information on sickness absence from  
27 Coherent Social Statistics (38) was included, as well as information on any pensioning  
28 (disability pensioning, early retirement pension and retirement pension) from the Central  
29 Pension Register and Persons who are not in Ordinary Employment (39). Information on  
30 migration was obtained from the Civil Registration System (37).  
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43 These data sources, the Danish nationwide registers, are updated annually. In the data  
44 analyses, the various socio-demographic data were included as time-dependent variables.  
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### 48 **Lifestyle data**



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9 Self-reported data on health and lifestyle (Table 3) were collected by questionnaire. The  
10 questioners were delivered to all baggage handlers and security service personal employed in  
11 Copenhagen Airport the 1th of April 2012 and a stratified random sample of the remaining  
12 groups (CPH-company, NUGSP, 3F Kastrup with other jobs at the airport, 3F Kastrup without  
13 work at the airport, and the two other 3F unions (LPSF and 3F Mølleåen) and for previously  
14 employed security service personnel) meeting the following criteria: being alive by April 2012,  
15 having permanent residence in Denmark, aged 25–75 years and not registered as unwilling to  
16 participate in research projects (an option by Danish law). The currently employed baggage  
17 handlers completed the questionnaire in the airport during their work time; the others by  
18 post. Respondents who did not answer the questionnaire within three weeks received a  
19 telephone call and were asked to answer the questionnaire by telephone. A total of 3749 men  
20 out of 5474 responded to the questionnaire (433 were obtained from telephone interview),  
21 making a response rate of 68.5%.  
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39 In analysis of respondent vs. non-respondents a larger proportions of respondents were  
40 Danish of origin, had a higher education and were married cf. Table 3.  
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#### 43 **Air pollution at residence**

44 To obtain information on pollution at the residence all members in the cohort alive in April  
45 2012, were geo-coded. We excluded persons with invalid postcodes, individuals who were  
46 dead or had emigrated, leaving 57 235 addresses. The exact geo-codes were identified for  
47 44 713 persons. We found invalid geocodes for 299 (0.5%) persons and for 12 223 persons we  
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9 only obtained information about residential address by road, and we therefore imputed the air  
10 pollution exposure as the mean exposure for the road. Based on the Danish road network and  
11 modelled road traffic values, we calculated the distance from residence to the nearest road  
12 with annual daily traffic (ADT) of 10 000 vehicles or more, and retrieved the ADT value for the  
13 identified road segment. In addition, the heavy-duty share of the ADT value was also retrieved.  
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15 Furthermore, the traffic density measure (TDM) within a buffer of 100 metres and 300 metres  
16 was assigned to every residence. To calculate the TDM, we applied the following equation:  
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$$24 \quad TDM = \sum(ADT_{road\ segment} * Length_{road\ segment})$$

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27 where  $ADT_{road\ segment}$  is the modelled number of cars on a road segment (e.g. between two  
28 intersections), and  $Length_{road\ segment}$  is the length of the same road segment in metres.  
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### 33 **Characteristics of participants**

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36 Table 3 presents baseline characteristics of men exposed to UFP and their reference group and  
37 for baggage handlers and their reference group, respectively. At baseline, larger proportions of  
38 the reference groups had a higher education and larger proportions of the exposed groups  
39 were younger and unmarried. Furthermore, slightly more persons in the reference groups  
40 were current smokers. Country of origin, average pollution at residence, alcohol, BMI and  
41 leisure-time physical activity were similar among the exposed groups and their reference  
42 groups.  
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51 **(Table 3 here)**  
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### Analysis methods

The cohort will be followed from start of employment, 1<sup>st</sup> January 1990 or immigration after employment, whichever came last, and until first diagnosis of outcome under study, emigration, death or end of follow-up (31 December 2012), whichever came first. This means that cohort members also will be followed after possible end of employment. We will exclude persons with a diagnosis of outcome under study before 1990 and persons who only had employment after a diagnosis of outcome under study.

For association between air pollution data and health outcomes, we will use survival regression models and include the exposure variable in three different models: 1. the exposed group compared to the reference group. 2. apron-years as a categorical variable (non-exposed, 0.1-2.9 years, 3.0-6.9 years and  $\geq 7$  years), based on the quantile distribution (Q1=0.8, median=2.7 and Q3=6.7). 3. apron-years as a continuous linear variable adjusted for the binary variable (exposed/reference group) to evaluate the influence of cumulative apron-years among the exposed group.

For the influence of manual lifting, we will include a proxy variable of manual lifting as cumulative years of employment as a baggage handler: 1) baggage handlers compared to the reference group. 2. baggage handler cumulative years categorical (reference group, 0.1–2.9 years, 3.0–9.9, 10.0–19.9 and 3. cumulative years as a continuous variable.

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9 For both analyses we will also investigate the non-linear influence of the exposure variables  
10 using restricted cubic spline regression.  
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### 12 13 **Findings to date**

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18 At present, three research papers have been published (4, 5, 40). In the study by Møller et al,  
19 we found that occupational groups who spent the largest amount of time on the apron during  
20 a work day also were exposed to the highest mean levels of UFP (4, 5, 40). Among baggage  
21 handlers, we reported that the incidence of sub-acromial shoulder disorders and meniscal  
22 lesions increased with cumulative years of employment (4, 5, 29, 40) and in the study by Bern  
23 et al, based on self-reported employment history and musculoskeletal pain, the risk of  
24 musculoskeletal symptoms in six anatomical regions increased with increasing seniority as a  
25 baggage handler (4, 5, 40).  
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### 37 **Strengths and limitations**

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39 The main strengths of the Copenhagen Airport Cohort are the comprehensive data sources  
40 used in the construction of the cohort. First, the cohort was constructed on administrative  
41 data from company registers and union member registers, which provided detailed  
42 information on employment for each year why recall bias was avoided. Furthermore, it  
43 comprises the availability of detailed objective information on exposure, collected  
44 independently, and comprehensive register data that assess outcomes related to health. A  
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9 strength is also the size of the cohort. These factors qualify analyses based on the cohort. The  
10 register-based follow-up by linkage to the various Danish, nationwide, health and population  
11 registers enhance the follow-up, and ensure an almost complete follow-up that may be  
12 continued in the future, contrary to a questionnaire-based follow-up. Finally, this cohort will  
13 contribute with long-term follow-up information on health and airport work, which is lacking  
14 at present.  
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22 The main limitation is the impossibility to control for potential confounders, including the  
23 impact of changing lifestyle over the studied period. Self-reported descriptive data on lifestyle  
24 factors were collected among a sample, which might facilitate sensitivity analyses of the  
25 potential influence of lifestyle confounding. But, these data were cross-sectional and only  
26 available for 2012, and e.g. smoking habits might have changed over time.  
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34 The number concentration of UFP measured on the apron will probably have changed over  
35 time due to a wide range of initiatives from Copenhagen Airport, where diesel powered  
36 equipment have been changed with electric equipment. Measurements of UFP was first  
37 introduced in 2010, thus the UFP levels of today cannot be compared with levels measured  
38 back in time. Working time on the apron near the aircraft could have changed during time, as  
39 new and faster equipment are available today. However, with the increasing movements it is  
40 not very likely that the actual working time on the apron is different from the past.  
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9 Information from all registers overlap with the cohort except the prescription register, where  
10 data are available since 1995. For this specific register, we may therefore have missed  
11 information on drug use dated before 1995, which could lead to truncation bias.  
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15 We have information on the full employment history of SAS employees from 1995 and  
16 onwards. The lack of electronic data from SAS from 1990-1995 means that we have not  
17 included employees who stopped their employment before 1995, however, we don't think this  
18 may have introduced bias since we have the whole employment history for those included.  
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24 Finally, a potential bias of an employed cohort is the healthy worker effect. To diminish this  
25 potential bias, we established a reference cohort consisting of men in unskilled jobs other than  
26 in airports (41, 42).  
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### 32 **Future plans**

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34 We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases,  
35 cerebrovascular disease, lung and bladder cancer, asthma and chronic obstructive pulmonary  
36 disease and occupational exposures at airports, and the association between heavy lifting and  
37 musculoskeletal disorders.  
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45 We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases,  
46 stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and  
47 occupational exposures at airports. In addition we plan to assess dose-response relationships  
48 between heavy lifting, stooped postures and kneeling and musculoskeletal disorders in the low  
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9 back, shoulders and knees by combining data from the biomechanical measurements with  
10 data on handled baggage per day and employment history. Furthermore we will have focus on  
11 studies on work status and prognostic studies in relation to the musculoskeletal disorders.  
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16 We plan to update the cohort by 10 more years in 2022 including continuously information on  
17 health care contacts by linkage to the national health registers.  
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### 20 21 22 **Collaboration**

23  
24 The researchers would welcome collaboration on future projects. For more information,  
25 please contact Charlotte Brauer. E-mail: [Charlotte.Brauer@regionh.dk](mailto:Charlotte.Brauer@regionh.dk).  
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### 29 30 31 **Acknowledgements**

32  
33 We want to thank Copenhagen Airport, the baggage handling companies, unions and  
34 employees in the airport for their invaluable help and support of the study.  
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### 38 39 40 **Footnotes**

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44  
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**Ethical statement**

The study was approved by the Danish Data Protection Agency (Journal no: 2012-41-0199).

Under Danish law, this project did not require approval by the Danish National Committee on Health Research Ethics (Journal no: H-4-2011-125 and H-3-2012-027).

**Author contribution**

KLM wrote the first draft of the paper except the section of exposure to manual baggage handling which was written by CB and the section of air pollution at residence which was written by TB and OH. LCT, SM, CB, KHL, SHB and KM conceived and designed the study. Furthermore, LCT, SM, CB, SHB and KM contributed to data collection and construction of the cohort. All authors contributed to the critical discussion of data and analyses and all authors revised and approved the final version of the manuscript.

**Conflict of interest**

The authors have no conflict of interests.

**Data sharing statement**

The researchers would welcome collaboration on future projects. For more information, please contact Charlotte Brauer. E-mail: Charlotte.Brauer@regionh.dk.

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Table 1. Overview of variables and data collection

Variable	Data Collection
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CPR number	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> <li>- The Danish Civil Registration System</li> <li>- Registers at Statistics Denmark</li> <li>- National Patient Registry</li> <li>- Register of Causes of Death</li> <li>- The Danish National Prescription Registry</li> <li>- Data from Department of Environmental Science, Aarhus University</li> </ul>
Occupational group <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> </ul>
Date for start of employment <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> </ul>
Job function <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> </ul>
Physical loads <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company statistics</li> <li>- Observations and measurements</li> <li>- Questionnaire</li> </ul>
Date of first hospital contact <sup>2</sup>	<ul style="list-style-type: none"> <li>- National Patient Registry</li> </ul>
Diagnosis <sup>2</sup>	<ul style="list-style-type: none"> <li>- National Patient Registry</li> <li>- <i>The Danish Cancer Registry</i></li> </ul>
Surgical codes <sup>2</sup>	<ul style="list-style-type: none"> <li>- National Patient Registry</li> </ul>
Date of death <sup>2</sup>	<ul style="list-style-type: none"> <li>- Register of Causes of Death</li> </ul>
Cause of death <sup>2</sup>	<ul style="list-style-type: none"> <li>- Register of Causes of Death</li> </ul>
Weight, height, leisure time physical activity, smoking status, alcohol <sup>3</sup>	<ul style="list-style-type: none"> <li>- Questionnaire</li> </ul>
Educational level <sup>3</sup>	<ul style="list-style-type: none"> <li>- Registers at Statistics Denmark</li> </ul>
Marital status <sup>3</sup>	<ul style="list-style-type: none"> <li>- Registers at Statistics Denmark</li> </ul>
Country of origin <sup>3</sup>	<ul style="list-style-type: none"> <li>- Registers at Statistics Denmark</li> </ul>

Average pollution at residence <sup>3</sup>	Data from Department of Environmental Science, Aarhus University
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<sup>1</sup>Exposure variables

<sup>2</sup>Outcome variables

<sup>3</sup>Potential confounders

Table 2. Average time spent on the apron (% of a normal work day) by occupational group.

Occupational group	Job description	Average time on apron (%)
Baggage handlers <sup>a</sup>	Assigned to aircraft procedures on the apron such as baggage loading and unloading, both inside and outside the baggage compartment. This group is also assigned to push the aircraft to the taxi-way using a push-back tractor	76
Cleaning staff (aircraft cleaners) <sup>a</sup>	Assigned to aircraft cabin cleaning. This group goes into the aircraft from the apron with a diesel powered high loader, a lorry, or from the gate	62
Catering drivers <sup>c</sup> , fuel drivers <sup>b</sup> , inflight service drivers <sup>b</sup> and other catering and inflight service personnel <sup>b</sup>	Catering drivers are assigned to load and unload food and drinks to and from the aircraft. This group goes into the aircraft from the apron with a diesel powered high loader Fuel drivers load and service the aircraft with fuel and handle de-icing. Inflight service drivers support the aircraft with inflight service.	62
Push-back <sup>b</sup>	Aircraft parking/towing	60
Marshals <sup>b</sup>	Direct the aircraft to the right gate	40
Cargo <sup>b</sup>	Loading and unloading cargo carried by aircrafts	25
Maintenance service personnel <sup>b</sup>	Maintain outdoor area (mow the grass, clear snow)	25
Traffic <sup>b</sup> , gate coordinators <sup>b</sup>	Assigned to ensure that all baggage/cargo/mail is placed correctly and to check the fuel to ensure correct weight distribution of the aircraft	20
Airside security (Security guards on	Assigned to security service at the security restricted area and to patrol by vehicle on the apron, gates and along fence lines and	14

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the airfield) <sup>a</sup>	buildings	
Firefighters <sup>b</sup>	On the apron during fire drills	10

- a) Assessed by GPS measurements
- b) Assessed by expert ratings (see text)
- c) A combination of expert ratings, GPS measurements and average air pollution

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Table 3 Copenhagen Airport Cohort: Baseline characteristics with information from registers and survey

<i>Variables</i>	<b>Air pollution</b>		<b>Manual lifting</b>		<b>Non-respondents in survey</b>	
	Reference <sup>1</sup>	Exposed <sup>1</sup>	Reference <sup>2</sup>	Exposed <sup>2</sup>	Respondents	Non-respondents
<i>Data from registers</i>						
<b>N</b>	62 546	6629	65 702	3473	3749	1725
<b>Age, mean (SD)</b>	35.0 (13.7)	29.9 (8.2)	34.8 (13.6)	28.9 (7.3)	30.9 (8.6)	29.8 (8.4)
<b>Risk time, person-years</b>	679385.0	51314.2	703235.6	27463.4	.	.
<b>Danish country of origin, n (%)</b>	51 345 (83.7)	5529 (88.0)	53 839 (83.9)	3067 (89.9)	3357 (89.8)	1386 (80.8)
<b>Educational level, n (%)</b>						
Elementary school	35 664 (57.0)	3132 (47.3)	37 221 (56.65)	1575 (45.35)	1614 (43.1)	873 (50.6)
High school	8821 (14.1)	904 (13.6)	9225 (14.0)	500 (14.4)	565 (15.1)	213 (12.4)
Vocational education	16 742 (26.8)	2487 (37.5)	17 872 (27.2)	1357 (39.1)	1494 (39.9)	610 (35.4)
Higher education	1319 (2.1)	106(1.6)	1384 (2.11)	41 (1.18)	76 (2.0)	29 (1.7)
<b>Marital status, n (%)</b>						
Married	19 663 (31.4)	1783 (26.9)	20 603 (31.36)	843 (24.27)	1169 (31.2)	433 (25.1)
Unmarried	36 438 (58.3)	4459 (67.3)	38 428 (58.49)	2469 (71.09)	2357 (62.9)	1185 (68.7)
Divorced	5712 (9.1)	379 (5.7)	5932 (9.03)	159 (4.58)	221 (5.9)	102 (5.9)
Widow	733 (1.2)	8 (0.1)	739 (1.12)	2 (0.06)	2 (0.1)	5 (0.3)
<b>Average pollution at residence</b>						
<b>Major road within 50 meter of residence, n (%)<sup>3</sup></b>	5593 (11.3)	600 (10.3)				
<i>Data from Survey</i>	Reference	Exposed	Reference	Exposed		
<b>N</b>	1473	2276	1963	1786		
<b>Smoking, n (%)</b>						
No	485 (32.9)	887 (38.5)	680 (34.8)	682 (38.5)		
Former	507 (34.4)	773 (34.0)	674 (34.5)	606 (34.2)		
Current	473 (32.1)	609 (26.8)	598 (30.6)	484 /27.3)		
<b>Units of alcohol per week, n (%)</b>						



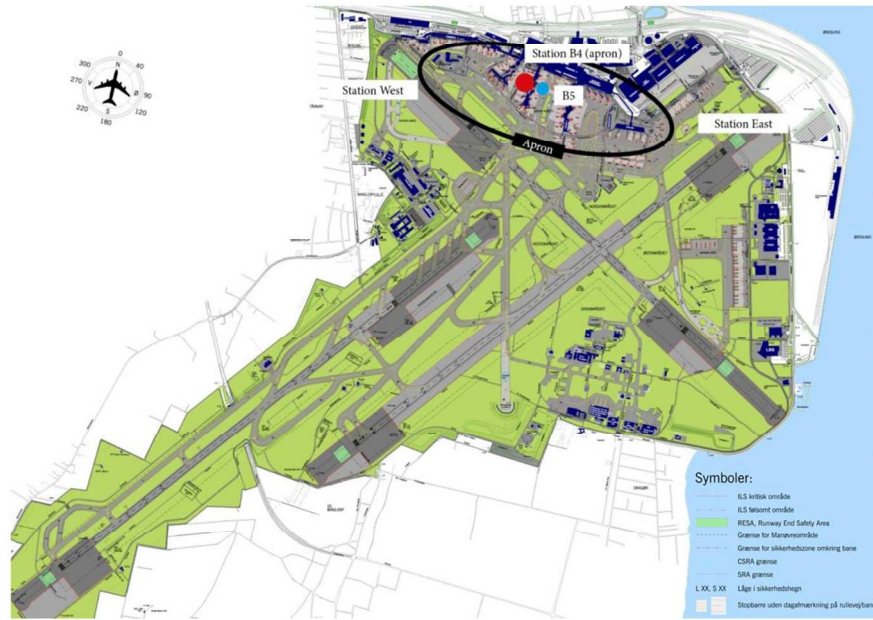
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0	355 (24.1)	582 (25.6)	502 (25.8)	435 (24.7)
1-21	999 (67.8)	1567 (68.9)	1318 (67.8)	1248 (70.7)
>21	106 (7.2)	101 (4.4)	125 (6.4)	82 (4.7)
<b>BMI, n (%)</b>				
<18.5	8 (0.5)	2 (0.1)	9 (0.47)	1 (0.1)
18.5-25	507 (34.4)	795 (34.9)	685 (35.5)	617 (35.0)
25.1-30	664 (45.1)	1087 (47.8)	892 (46.2)	859 (48.7)
>30	267 (18.1)	366 (16.1)	345 (17.9)	288 (16.3)
<b>Leisure-time physical activity hours/week, n (%)</b>				
Sedentary	188 (12.8)	242 (10.6)	255 (13.0)	175 (9.8)
Low	535 (36.3)	786 (34.5)	697 (35.5)	624 (34.9)
Medium	540 (36.7)	878 (38.6)	707 (36.0)	711 (39.8)
High	187 (12.7)	347 (15.3)	280 (14.26)	254 (14.2)

- (1) Descriptive statistics at baseline, the first year during follow-up that a person is employee in Copenhagen Airport in a job function with tasks outdoors on apron (exposed group) or first year during follow-up for workers who are never employees in Copenhagen Airport in job functions with tasks outdoors on apron (reference group).
- (2) Descriptive statistics at baseline, the first year during follow-up that a person is employed as baggage handler in Copenhagen (exposed group) or first year during follow-up for workers who are never employed as baggage handler in Copenhagen (reference group).
- (3) Major road >10 000 vehicles/day

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Figure 1. Map of Copenhagen Airport



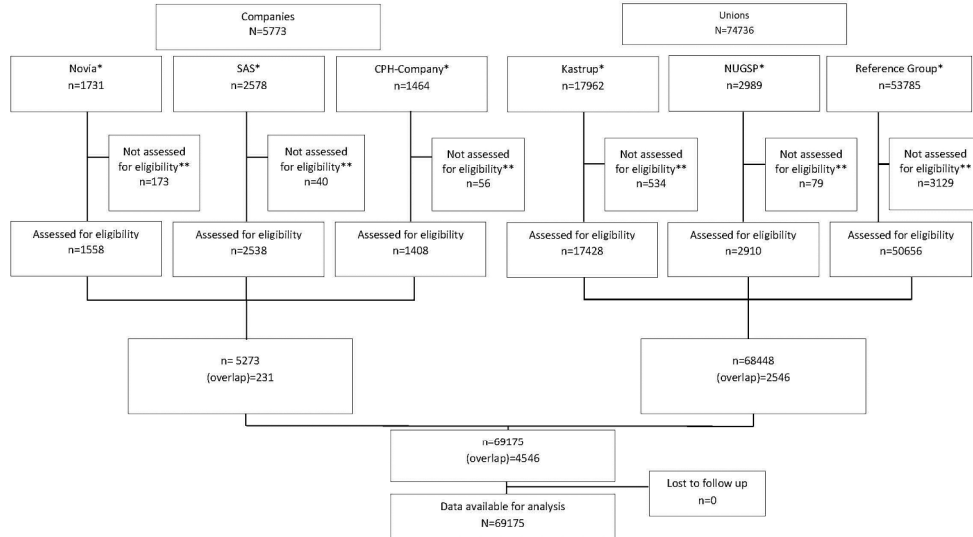
Reference: Copenhagen Airports A/S

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Figure 2. Flowchart of the construction of the Copenhagen Airport Cohort



\*Novia (Novia Denmark, handling company), SAS (SAS Ground Service, handling company), CPH (Copenhagen Airports), Kastrup (3F Kastrup-local union), NUGSP (National Union of Guards and Security Personnel), reference group includes 3F Mølleåen, 3F Kastrup and 3F Lager Post and Service Union (LPSU) all organises workers in neighbouring areas of Copenhagen  
 \*\*Not assessed for eligibility due to: invalid CPR-number, missing information on occupation, administrative/management/academic occupations, persons with leave of absence, employment before 15 years of age, men who have never stayed in Denmark under the study period (1990-2012), employment after 31th December 2012, same entry and exit date, dead before employment and dead before 1990

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# BMJ Open

## Cohort profile. Copenhagen Airport Cohort – air pollution, manual baggage handling and health

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Manuscript ID	bmjopen-2016-012651.R2
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<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Research methods, Occupational and environmental medicine
Keywords:	cohort profile, ultrafine particles, baggage handling, air pollution, airport, occupational exposure

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## Cohort profile. Copenhagen Airport Cohort – air pollution, manual baggage handling and health

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Data sharing statement

The researchers would welcome collaboration on future projects. For more information, please contact Charlotte Brauer. E-mail: Charlotte.Brauer@regionh.dk.

Keywords: Occupational exposure, air pollution, ultrafine particles, airport, baggage handling, cohort profile

**Abstract**

*Purpose:* Copenhagen Airport Cohort 1990-2012 presents a unique data source for studies of health effects of occupational exposure to air pollution (ultrafine particles) and manual baggage handling among airport employees. We describe the extent of information in the cohort and in the follow-up based on data linkage to the comprehensive Danish nationwide health registers. In the cohort, all information is linked to the personal identification number that also is used in Denmark Statistics demographic and socio-economic databases and in the nationwide health registers.

*Participants:* The cohort covers 69 175 men in unskilled positions. The exposed cohort includes men in unskilled jobs employed at Copenhagen Airport in the period 1990–2012 either as baggage handlers or in other outdoor work. The reference cohort includes men in unskilled jobs working in the greater Copenhagen area.

*Findings to date:* The cohort includes environmental GPS measurements in Copenhagen Airport, information on job function/task for each calendar year of employment between 1990 and 2012, exposure to air pollution at residence, average weight of baggage lifted per day and lifestyle. By linkage to registers, we retrieved socio-economic and demographic data and data on health care contacts, drug subscriptions, incident cancer, and mortality.

*Future plans:* The size of the cohort and the completeness of the register-based follow-up allow a more accurate assessment of the possible health risks of occupational exposure to ultrafine particles and manual baggage handling at airports than in previous studies. We plan to follow the cohort for the incidence of ischemic heart diseases, cerebrovascular disease, lung and bladder cancer, asthma and chronic obstructive pulmonary disease, and further for associations between heavy manual baggage handling and musculoskeletal disorders.

*Registration:* The Danish Data Protection Agency approved the study (Journal no: 2012-41-0199).

### Strengths and limitations of this study

- The size of the cohort and the completeness of the register-based follow-up allows a more accurate assessment of the possible health risks of occupational exposure to ultrafine particles and manual handling at airports than in previous studies
- The cohort included detailed information on employment for each year
- The register-based follow-up by linkage to the various nationwide Danish health and population registers ensures an almost complete follow-up
- Self-reported descriptive data on lifestyle factors were collected among a sample of the study population
- The main limitation is the impossibility to control for confounder variables such as smoking and other lifestyle factors

### Introduction

Globally, more than 2 million civilian and military personnel are occupationally exposed to jet propulsion fuel (1). In Copenhagen Airport the ground personnel perform tasks such as aircraft fuel tanking, security, aircraft parking and towing and baggage handling (2). These tasks are often performed in a working environment with high exposure to air pollution, including high levels of ultrafine particles (UFP) (diameter  $\leq 100$  nm) (3). Furthermore, the tasks of baggage handlers include daily heavy lifting of, on average, up to 4–5 tonnes of luggage (4).

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9 As a part of a large project to improve the air quality of the working environment, the Danish  
10 Centre for Environment and Energy at Aarhus University in 2010 measured high number  
11 concentrations of particles in open air at Copenhagen Airport. The results showed an average  
12 number of 38 600 particles (6–700 nm in diameter)/cm<sup>3</sup>, and about 90% of the measured  
13 particles were smaller than 100nm (ultrafine particles (UFP))(3). Employees working on the  
14 apron at Copenhagen Airport were exposed to a number concentration of UFP between  
15 12 000 and 37 000 particles/cm<sup>3</sup> (5). The number concentration of UFP was two–three times  
16 higher than measured at the kerbside in a traffic loaded street in Copenhagen City Centre  
17 during the same period (3).  
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28 For other pollutants (NO, NO<sub>2</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, particle mass, concentration of elemental carbon (EC)  
29 in the particulate matter, concentration of polycyclic aromatic hydrocarbons (PAH) in the  
30 particulate matter and concentration of volatile organic compounds (VOC)) with established  
31 EU limit values, all levels measured at Copenhagen Airport were below these limits. Air quality  
32 limit values for particle number have not been established (6).  
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43 Over the past 10 years, the scientific interest has moved from mass concentration (PM<sub>2.5</sub> and  
44 PM<sub>10</sub>) to the number concentration of UFP (7). UFP differs from larger particles due to the  
45 large surface area with adhered toxins and high alveolar deposition (8). Several experimental  
46 studies in animals have shown that UFP can translocate into the blood vessels due to the small  
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9 size (8-12), and this is likely to occur in humans although translocation from the lungs has not  
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11 been firmly established (13).

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14 Ground personnel working on the apron near and around the aircraft is exposed to exhaust  
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16 from jet fuel and diesel exhaust from handling equipment (3). Previous studies have shown  
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18 that the major sources of UFP are emissions from motor vehicles and other combustion  
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20 machines (8, 14).

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23 Particulate air pollution has been associated with increased risk of ischemic heart diseases and  
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25 various cancers (15-17). Previous studies have shown that particulate air pollution increases  
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27 the risk of hospital admissions due to chronic obstructive respiratory disease (18, 19). Diesel  
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29 exhaust, which is one of the most prevalent sources of particulate air pollution in urban  
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31 environments, is an established carcinogen, (9), mainly based on evidence from occupational  
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33 exposures among miners (20, 21). There is, however, uncertainty regarding the relation  
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35 between occupational exposures to particulate air pollution and health problems (22). To our  
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37 knowledge, only two studies have investigated the relation between UFP exposure among  
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39 employees at civil airports and adverse health effects, and these studies were only based on  
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41 self-reported data (23, 24).

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47 It is well documented that the majority of baggage handlers are exposed to a high workload  
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49 with daily heavy lifting, often in awkward positions, and they report a high prevalence of  
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51 musculoskeletal disorders (25), especially lower back, neck and knee disorders (26-28).

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9 However, these studies relied on self-reported data about musculoskeletal disorders in small  
10 samples and did not include a reference group, and the estimation of exposure were only  
11 based on seniority in the occupation and hours per week loading and unloading aircraft (26,  
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19 At present, no previous study has analysed the health effects of occupational exposure to UFP  
20 or to manual lifting among airport employees utilising data in a large cohort with complete and  
21 long follow-up. The Copenhagen Airport Cohort includes a unique source of information for  
22 occupational epidemiological studies of health effects of high exposure to air pollution and  
23 manual baggage handling with follow-up information based upon linkage to the Danish  
24 nationwide registers. We present the information included in the cohort study and some  
25 preliminary data.  
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### 36 **Cohort description**

#### 37 **Location**

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39 Copenhagen Airport is located 8 km from the city centre of Copenhagen and is the largest  
40 airport in Denmark, with approximately 22 000 employees working in different companies. In  
41 2015, the total number of international and domestic flights was slightly above 254 000. The  
42 apron is the area at the airport where aircrafts are parked, unloaded and loaded, refueled or  
43 boarded (5).  
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52 Figure 1 here.  
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### Population and sample size

The cohort comprises men in unskilled jobs employed at Copenhagen Airport in the period 1990–2012 either as baggage handlers or in other outdoor work on the apron. We created a reference cohort of men in unskilled jobs working indoors at Copenhagen Airport and of men in unskilled jobs working in the greater Copenhagen area without any employment at Copenhagen Airport.

We only included men, as there were few women working as baggage handlers or employed in outdoor work at Copenhagen Airport.

From company employment registers and the union membership registers, we obtained complete occupational history for each person concerning both present and former employment (Figure 2).

Company registers included the two baggage handling companies at Copenhagen Airport, SAS Ground Service (SAS) and Novia, and CPH-Company which owns Copenhagen Airport. For SAS and Novia, we included workers in departments working with baggage handling and doing unskilled work in other departments (see Table 2).

Novia established electronic registers on employees in 1990, and SAS in 1995; using these registers, we identified the relevant workers and their employment period. CPH-Company has registered its workers electronically since 1990, and from this company we included security

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9 service personnel and other workers in unskilled jobs with a variety of different tasks (e.g. area  
10 maintenance, certain cleaning tasks, firefighting and marshals).

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14 The workers included in the cohort are organised in three local unions of the National Union of  
15 Unskilled Workers (Danish, 3F) and the National Union of Guards and Security Personnel  
16 (NUGSP). One of the 3F local unions (3F Kastrup) organises workers in unskilled jobs at  
17 Copenhagen Airport and in neighbouring areas of Copenhagen. The two other 3F local unions  
18 organise workers in unskilled jobs in other areas of greater Copenhagen. The 3F member files  
19 are centrally organised, and are electronic for periods of membership (entry and exit dates)  
20 back to 1983. The NUGSP organises guards and security personnel and records periods of  
21 membership in local unions back to 1979.

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32 Few persons had entry dates before the member files and company registers became  
33 electronic.

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37 In case of overlapping information, we prioritized data in the company register, because it was  
38 mandatory for any salary payment, and we included union information if this supplemented  
39 the period before the first entry date of company records.

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44 The validity of union information on job function was assessed by calculating the percentage  
45 with the same job function recorded in the company registers. We assessed the validity of  
46 questionnaire information on job function the same way. We found good agreement between  
47 the data sources. E.g., 87% of persons recorded as baggage handlers by the union were also  
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9 recorded as baggage handlers in company records, and 92% of persons who in the  
10 questionnaire declared that they had worked as security personnel were recorded as such in  
11 the company records.  
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15 The company registers comprised information on 5773 men and the union member registers  
16 74 736 men. Figure 2 shows the degree of overlapping information. We excluded men using  
17 the following criteria: invalid personal identification number, missing information on  
18 occupation, same entry and exit dates, administrative/management/academic tasks, absence  
19 leave, employed at an age below 15 years, no permanent residence in Denmark any year in the  
20 study period, only employed after end of follow-up (December 2012), death before  
21 employment, and death before 1990. After these exclusions, the final study cohort comprised  
22 69 175 men in unskilled jobs (Figure 2).  
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34 At baseline the reference group worked in a variety of different occupations (e.g. municipal  
35 workers, drivers, postal workers, garbage collectors, factory workers etc) (29). We do not have  
36 representative measures of UFP and vehicle exhaustion for the various occupations. However,  
37 we are convinced that only few occupations and few persons in the reference group were  
38 continuously exposed to UFP or vehicle exhaust at a similar level as on the apron at  
39 Copenhagen Airport. Temporarily high exposure levels may occur among drivers, garbage  
40 collectors, and in the welding and construction industries. However, in the absence of specific  
41 exposure information and considering that such groups with potentially high exposures were  
42 relatively few, we decided to not to exclude any specific occupations from the reference  
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9 group. The effect may be a slightly diluted difference in exposure related effects between the  
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11 reference group and the exposed group.  
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14 **(Figure 2 here)**

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17 **Data collection**

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20 **(Table 1 here)**

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23 **Exposure to UFP**

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25 UFP exposure in the airport was estimated based on direct GPS measurements in combination  
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27 with individual measurements of UFP number concentrations (5), expert assessment and  
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29 comprehensive information on job function and task for each calendar year of employment  
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31 between 1990 and 2012.  
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34 Among 30 employees from the five largest occupational groups at the airport (baggage  
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36 handlers, catering drivers, cleaning staff, airside security and landside security staff), we  
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38 measured time spent on the apron from GPS measurements in combination with personal  
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40 monitoring of UFP number concentration ( $n/cm^3$ ) during a normal working day (5). We found  
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42 that baggage handlers were exposed to daily average concentrations (geometric mean, GM:  
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44  $37 \times 10^3 UFP/cm^3$ ), which was significantly larger than employees mainly working indoors (GM:  
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46  $5 \times 10^3 UFP/cm^3$ ) (5). Cleaning staff, catering drivers and airside security were exposed to  
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48 concentrations at the same intermediate level (GM: 12 to  $20 \times 10^3 UFP/cm^3$ ). Higher  
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50 concentrations were measured on the apron compared to other locations at the airport,  
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8 whether indoors or outdoors (5). Therefore the proportion of daily working hours spent on the  
9 apron may serve as a proxy for UFP-exposure for occupational groups without UFP and GPS  
10 measurements. Five of the occupational groups with measured apron times were used as  
11 benchmarks, to assess the average apron times for the remaining occupational groups. This  
12 was assessed by three airport worker representatives with a comprehensive knowledge of the  
13 working procedures for different occupational groups at the airport. In this assessment, the  
14 apron times of all drivers, that is, drivers with inflight service, fuel drivers, catering drivers and  
15 other inflight and catering personnel, were considered to be similar to that of cleaning staff  
16 (measured as 62% of the time) and differed from the actually measured apron time for  
17 catering drivers (measured as 34% of the time). However, the number concentrations of UFP  
18 measured for catering drivers working on the apron was  $43 \times 10^3$  UFP/cm<sup>3</sup> and for cleaning staff  
19 working on the apron  $23 \times 10^3$  UFP/cm<sup>3</sup> (5). The apron time was considered as a proxy for UFP-  
20 exposure and therefore we assigned the same apron time to this mixed group of drivers,  
21 including catering drivers, as that of cleaning staff (62%), assuming that these groups had  
22 similar exposure to UFP. All other occupational groups were assigned an exposure estimate  
23 based on expert assessment of their working time on the apron, expressed as a percentage of  
24 daily working time. We pooled groups with similar apron time, resulting in 10 occupational  
25 exposure groups with different apron times.  
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48 The apron time was calculated for each calendar year as the proportion of time worked on the  
49 apron that year according to entry and exit dates for work in specific occupational groups. E.g.  
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baggage handling for 150 days, and cargo work for 90 days in a calendar year gives  $(150 \times 0.76 + 90 \times 0.25) / 365 = 0.37$  apron-years of UFP exposure for that year. During follow-up, apron-years were cumulated resulting in time-dependent apron-years.

**(Table 2 here)**

### **Exposure to manual baggage handling**

The level of exposure to manual baggage handling was estimated by direct observations, production statistics from the two handling companies (SAS and Novia), and previous assessments made by the company occupational health service in 1991, 1998 and 2001. In addition, we obtained information about the introduction of technical lifting accessories.

Since 2002 and 2009, SAS and Novia have recorded electronic data on loaded baggage in kilograms (kg) for every single flight. Based on these detailed information we estimate that the average of total baggage lifted per day is approximately 5000 kg per baggage handler, slightly less in the baggage sorting area than on the apron, and the average weight of a baggage piece is approximately 15 kg. Since the beginning of the 1990s, the daily manual baggage-handling load for each baggage handler has been rather constant over years.

In addition, we performed biomechanical measurements on a sample of 23 baggage handlers at the airport by monitoring the muscle activity using electromyography (EMG) over typical working days, including determination of the muscle activity level during specific work tasks.



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9 The handling tasks were also analysed experimentally in a laboratory with video recordings of  
10 a baggage handler equipped with a full-body marker set-up performing different handling  
11 tasks (e.g. standing or kneeling) on force platforms. On the basis of these recordings, inverse  
12 dynamics-based musculoskeletal models of the tasks were built in the AnyBody Modeling  
13 system v. 5.3 (AnyBody Technology A/S, Aalborg, Denmark) (30). Output from the models was  
14 muscle and joint forces. These forces were subsequently used as weights in the register-part of  
15 the study.  
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#### 24 **Data sources for outcome variables**

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27 In Denmark, a person's individual identification number is used in the registration of data to  
28 the various nationwide registers, and likewise, this individual number identifies all persons in  
29 the study population of the Airport Cohort.  
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35 We linked the cohort with the National Patient Register, the Cancer Registry, the National  
36 Prescription Registry and the Register of Causes of Death (31)-(32-34). The National Patient  
37 Register contains data on all in-patients contacts since 1977 and all out-patient and emergency  
38 room contacts since 1995 (31). We retrieved data on hospital contacts due to cardiovascular  
39 disease, respiratory diseases and musculoskeletal disorders. Further, data on incident cancer  
40 cases was obtained from the Danish Cancer Registry, established in 1943 (33). Data on drugs  
41 prescribed for respiratory diseases were retrieved from the Danish National Prescription  
42 Registry, available from 1995 (34). Data on death and causes of death were retrieved from the  
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Danish Register of Causes of Death, which contains computerised data on all deaths in Denmark of Danish citizens since 1970 (32).

### **Potential confounders**

#### **Socio-economic and demographic data**

We linked cohort data to Denmark Statistics various population-based registers. Information on educational level attained the year before entering the cohort was obtained from the Population Education Register (35). Information on country of birth and marital status was obtained from the Civil Registration System (36). Information on sickness absence from Coherent Social Statistics (37) was included, as well as information on any pensioning (disability pensioning, early retirement pension and retirement pension) from the Central Pension Register and Persons who are not in Ordinary Employment (38). Information on migration was obtained from the Civil Registration System (36).

These data sources, the Danish nationwide registers, are updated annually. In the data analyses, the various socio-demographic data were included as time-dependent variables.

#### **Lifestyle data**

Self-reported data on health and lifestyle (Table 3) were collected by questionnaire. The questionnaires were delivered to all baggage handlers and security service personal employed in Copenhagen Airport by 1 April 2012. Furthermore, a stratified random sample of the remaining groups (CPH-company, NUGSP, 3F Kastrup with other jobs at the airport, 3F Kastrup

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9 without work at the airport, and the two other 3F unions (LPSF and 3F Mølleåen) and for  
10 previously employed security service personnel). All meet the following criteria: being alive by  
11 1 April 2012, having permanent residence in Denmark, aged 25–75 years and not registered as  
12 unwilling to participate in research projects (an option by Danish law). The currently employed  
13 baggage handlers completed the questionnaire in the airport during their work time; the  
14 others by post. Respondents who did not answer the questionnaire within three weeks  
15 received a telephone call and were asked to answer the questionnaire by telephone. A total of  
16 3749 men out of 5474 responded to the questionnaire (433 were obtained from telephone  
17 interview), making a response rate of 68.5%.

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30 In analysis of respondent vs. non-respondents of the questionnaire, a larger proportion of  
31 respondents were Danish of origin, had a higher education and were married cf. Table 3.

### 32 33 34 35 **Air pollution at residence**

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37 To obtain information on pollution at the residence, all members in the cohort alive 1 April  
38 2012, were geo-coded. We excluded persons with invalid postcodes, individuals who were  
39 dead or had emigrated, leaving 57 235 addresses. The exact geo-codes were identified for  
40 44 713 persons. We found invalid geocodes for 299 (0.5%) persons and for 12 223 persons we  
41 only obtained information about residential address by road, and we therefore imputed the air  
42 pollution exposure as the mean exposure for that road. Based on the Danish road network and  
43 modelled road traffic values, we calculated the distance from residence to the nearest road  
44 with annual daily traffic (ADT) of 10 000 vehicles or more, and retrieved the ADT value for the  
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8 identified road segment. In addition, the heavy-duty share of the ADT value was also retrieved.  
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10 Furthermore, the traffic density measure (TDM) within a buffer of 100 metres and 300 metres  
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12 was assigned to every residence. To calculate the TDM, we applied the following equation:  
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$$15 \quad TDM = \sum(ADT_{road\ segment} * Length_{road\ segment})$$

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18 where  $ADT_{road\ segment}$  is the modelled number of cars on a road segment (e.g. between two  
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20 intersections), and  $Length_{road\ segment}$  is the length of the same road segment in metres.  
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### 24 25 **Characteristics of participants**

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27 Table 3 presents baseline characteristics of men exposed to UFP and their reference group and  
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29 for baggage handlers and their reference group, respectively. At baseline, larger proportions of  
30  
31 the reference groups had a higher education and larger proportions of the exposed groups  
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33 were younger and unmarried. Furthermore, slightly more persons in the reference groups  
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35 were current smokers. Country of origin, average pollution at residence, alcohol, BMI and  
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37 leisure-time physical activity were similar among the exposed groups and their reference  
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39 groups.  
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43 **(Table 3 here)**

### 44 45 **Analysis methods**

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47 The cohort will be followed from start of employment, 1 January 1990 or immigration after  
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49 employment, whichever came last, and until first diagnosis of outcome under study,  
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9 emigration, death or end of follow-up (31 December 2012), whichever came first. This means  
10 that cohort members also will be followed after possible end of employment. We will exclude  
11 persons with a diagnosis of outcome under study before 1990 and persons who only had  
12 employment after a diagnosis of outcome under study.  
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19 For associations between air pollution data and health outcomes, we will use survival  
20 regression models and include the exposure variable in three different models: 1. the exposed  
21 group compared to the reference group. 2. apron-years as a categorical variable (non-exposed,  
22 0.1-2.9 years, 3.0-6.9 years and  $\geq 7$  years), based on the quantile distribution (Q1=0.8,  
23 median=2.7 and Q3=6.7). 3. apron-years as a continuous linear variable adjusted for the binary  
24 variable (exposed/reference group) to evaluate the influence of cumulative apron-years  
25 among the exposed group.  
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36 For the influence of manual lifting, we will include a proxy variable of manual lifting as  
37 cumulative years of employment as a baggage handler: 1) baggage handlers compared to the  
38 reference group. 2) baggage handler cumulative years categorical (reference group, 0.1–2.9  
39 years, 3.0–9.9, 10.0–19.9 and 3) cumulative years as a continuous variable.  
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45 For both analyses we will also investigate the non-linear influence of the exposure variables  
46 using restricted cubic spline regression.  
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### Findings to date

At present, four research papers have been published (4, 5, 29, 39). In the study by Møller et al, we found that occupational groups who spent the largest amount of time on the apron during a work day also were exposed to the highest mean levels of UFP (5). Among baggage handlers, we reported that the incidence of sub-acromial shoulder disorders and meniscal lesions increased with cumulative years of employment (29, 39) and in the study by Bern et al, based on self-reported employment history and musculoskeletal pain, the risk of musculoskeletal symptoms in six anatomical regions increased with increasing seniority as a baggage handler (4).

### Strengths and limitations

The main strengths of the Copenhagen Airport Cohort are the comprehensive data sources used in the construction of the cohort. First, the cohort was constructed on administrative data from company registers and union member registers, which provided detailed information on employment for each calendar year. Thus, recall bias was avoided. Furthermore, it comprises detailed objective information on exposure, and comprehensive register data on outcomes related to health. The size of the cohort is also a strength. The register-based follow-up by linkage to the various nationwide Danish health and population registers ensures an almost complete follow-up, which may be continued in the future. Finally,

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9 the cohort will contribute with long-term follow-up information on health and airport work,  
10 which is lacking at present.  
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13 The main limitation is the lack of information about a number of important potential  
14 confounders, including changing lifestyle over the studied period. Self-reported descriptive  
15 data on lifestyle factors were collected among a sample of the cohort. However, these data  
16 were cross-sectional and only available for 2012, and e.g. smoking habits might have changed  
17 over time.  
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25 The number concentration of UFP measured on the apron will probably have changed over  
26 time due to a wide range of initiatives from Copenhagen Airport, where diesel powered  
27 equipment has been replaced by electric equipment. Measurements of UFP were first  
28 introduced in 2010 and consequently UFP levels of today cannot be compared with levels  
29 measured back in time. Working time on the apron near the aircraft could have changed  
30 during time since new and faster equipment is available today. However, with the increasing  
31 number of flights it is not very likely that the actual working time on the apron is different from  
32 the past.  
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43 Information from all registers overlap with the cohort except the prescription register, where  
44 data are only available since 1995. For this specific register, we may therefore have missed  
45 information on drug use dated before 1995, which could lead to truncation bias.  
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9 We have information on the full employment history of SAS employees from 1995 and  
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11 onwards. The lack of electronic data from SAS from 1990-1995 means that we have not  
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13 included employees who stopped their employment before 1995, however, we don't think this  
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15 may have introduced bias since we have the whole employment history for those included.  
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18 Finally, a potential bias of an employed cohort is the healthy worker effect. To diminish this  
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20 potential bias, we established a reference cohort consisting of men in unskilled jobs other than  
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22 in airports (40, 41).  
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#### 24 25 **Future plans**

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28 We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases,  
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30 stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and  
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32 occupational exposures at airports. In addition we plan to assess dose-response relationships  
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34 between heavy lifting, stooped postures and kneeling and musculoskeletal disorders in the low  
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36 back, shoulders and knees by combining data from the biomechanical measurements with  
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38 data on handled baggage per day and employment history. Furthermore, we will have focus on  
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40 prognostic studies of musculoskeletal disorders.  
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44 We plan to update the cohort by 10 more years in 2022 including information on health care  
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46 contacts by linkage to the national health registers.  
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**Collaboration**

The researchers would welcome collaboration on future projects. For more information, please contact Charlotte Brauer. E-mail: [Charlotte.Brauer@regionh.dk](mailto:Charlotte.Brauer@regionh.dk).

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**Footnotes****Funding**

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**Ethical statement**

The study was approved by the Danish Data Protection Agency (Journal no: 2012-41-0199). Under Danish law, this project did not require approval by the Danish National Committee on Health Research Ethics (Journal no: H-4-2011-125 and H-3-2012-027).

**Author contribution**

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9 KLM wrote the first draft of the paper except the section of exposure to manual baggage  
10 handling which was written by CB and the section of air pollution at residence which was  
11 written by TB and OH. LCT, SM, CB, KHL, SHB and KM conceived and designed the study.  
12  
13 Furthermore, LCT, SM, CB, SHB and KM contributed to data collection and construction of the  
14 cohort. All authors contributed to the critical discussion of data and analyses and all authors  
15 revised and approved the final version of the manuscript.  
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### 22 **Conflict of interest**

23  
24 The authors have no conflict of interests.  
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Table 1. Overview of variables and data collection

Variable	Data Collection
CPR number	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> <li>- The Danish Civil Registration System</li> <li>- Registers at Statistics Denmark</li> <li>- National Patient Registry</li> <li>- Register of Causes of Death</li> <li>- The Danish National Prescription Registry</li> <li>- Data from Department of Environmental Science, Aarhus University</li> </ul>
Occupational group <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> </ul>
Date for start of employment <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> </ul>
Job function <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company and Union registers</li> <li>- Questionnaire</li> </ul>
Physical loads <sup>1</sup>	<ul style="list-style-type: none"> <li>- Company statistics</li> <li>- Observations and measurements</li> <li>- Questionnaire</li> </ul>
Date of first hospital contact <sup>2</sup>	<ul style="list-style-type: none"> <li>- National Patient Registry</li> </ul>
Diagnosis <sup>2</sup>	<ul style="list-style-type: none"> <li>- National Patient Registry</li> </ul>
Surgical codes <sup>2</sup>	<ul style="list-style-type: none"> <li>- National Patient Registry</li> </ul>
Date of death <sup>2</sup>	<ul style="list-style-type: none"> <li>- Register of Causes of Death</li> </ul>
Cause of death <sup>2</sup>	<ul style="list-style-type: none"> <li>- Register of Causes of Death</li> </ul>
Weight, height, leisure time physical activity, smoking status, alcohol <sup>3</sup>	<ul style="list-style-type: none"> <li>- Questionnaire</li> </ul>
Educational level <sup>3</sup>	<ul style="list-style-type: none"> <li>- Registers at Statistics Denmark</li> </ul>

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Marital status <sup>3</sup>	- Registers at Statistics Denmark
Country of origin <sup>3</sup>	- Registers at Statistics Denmark
Average pollution at residence <sup>3</sup>	Data from Department of Environmental Science, Aarhus University

<sup>1</sup>Exposure variables  
<sup>2</sup>Outcome variables  
<sup>3</sup>Potential confounders

Table 2. Average time spent on the apron (% of a normal work day) by occupational group.

Occupational group	Job description	Average time on apron (%)
Baggage handlers <sup>a</sup>	Assigned to aircraft procedures on the apron such as baggage loading and unloading, both inside and outside the baggage compartment. This group is also assigned to push the aircraft to the taxi-way using a push-back tractor	76
Cleaning staff (aircraft cleaners) <sup>a</sup>	Assigned to aircraft cabin cleaning. This group goes into the aircraft from the apron with a diesel powered high loader, a lorry, or from the gate	62
Catering drivers <sup>c</sup> , fuel drivers <sup>b</sup> , inflight service drivers <sup>b</sup> and other catering and inflight service personnel <sup>b</sup>	Catering drivers are assigned to load and unload food and drinks to and from the aircraft. This group goes into the aircraft from the apron with a diesel powered high loader Fuel drivers load and service the aircraft with fuel and handle de-icing. Inflight service drivers support the aircraft with inflight service.	62
Push-back <sup>b</sup>	Aircraft parking/towing	60
Marshals <sup>b</sup>	Direct the aircraft to the right gate	40
Cargo <sup>b</sup>	Loading and unloading <i>cargo</i> carried by aircrafts	25
Maintenance service personnel <sup>b</sup>	Maintain outdoor area (mow the grass, clear snow)	25
Traffic <sup>b</sup> , gate coordinators <sup>b</sup>	Assigned to ensure that all baggage/cargo/mail is placed correctly and to check the fuel to ensure correct weight distribution of the aircraft	20
Airside security (Security guards on the airfield) <sup>a</sup>	Assigned to security service at the security restricted area and to patrol by vehicle on the apron, gates and along fence lines and buildings	14
Firefighters <sup>b</sup>	On the apron during fire drills	10



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- a) Assessed by GPS measurements
- b) Assessed by expert ratings (see text)
- c) A combination of expert ratings, GPS measurements and average air pollution

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Table 3 Copenhagen Airport Cohort: Baseline characteristics with information from registers and survey

<i>Variables</i>	Air pollution		Manual lifting		Non-respondents in survey	
	Reference <sup>1</sup>	Exposed <sup>1</sup>	Reference <sup>2</sup>	Exposed <sup>2</sup>	Respondents	Non-respondents
<i>Data from registers</i>						
<b>N</b>	62 546	6629	65 702	3473	3749	1725
<b>Age, median (Q1-Q3)</b>	31 (24-43)	28 (24-35)	31 (24-43)	27 (23-33)	29 (24-36)	28 (24-35)
<b>Risk time, person-years</b>	679385.0	51314.2	703235.6	27463.4	.	.
<b>Danish country of origin, n (%)</b>	51 345 (83.7)	5529 (88.0)	53 839 (83.9)	3067 (89.9)	3357 (89.8)	1386 (80.8)
<b>Educational level, n (%)</b>						
Elementary school	35 664 (57.0)	3132 (47.3)	37 221 (56.65)	1575 (45.35)	1614 (43.1)	873 (50.6)
High school	8821 (14.1)	904 (13.6)	9225 (14.0)	500 (14.4)	565 (15.1)	213 (12.4)
Vocational education	16 742 (26.8)	2487 (37.5)	17 872 (27.2)	1357 (39.1)	1494 (39.9)	610 (35.4)
Higher education	1319 (2.1)	106 (1.6)	1384 (2.11)	41 (1.18)	76 (2.0)	29 (1.7)
<b>Marital status, n (%)</b>						
Married	19 663 (31.4)	1783 (26.9)	20 603 (31.36)	843 (24.27)	1169 (31.2)	433 (25.1)
Unmarried	36 438 (58.3)	4459 (67.3)	38 428 (58.49)	2469 (71.09)	2357 (62.9)	1185 (68.7)
Divorced	5712 (9.1)	379 (5.7)	5932 (9.03)	159 (4.58)	221 (5.9)	102 (5.9)
Widower	733 (1.2)	8 (0.1)	739 (1.12)	2 (0.06)	2 (0.1)	5 (0.3)
<b>Average pollution at residence Major road within 50 meter of residence, n (%)<sup>3</sup></b>						
	5593 (11.3)	600 (10.3)				
<i>Data from Survey</i>	Reference	Exposed	Reference	Exposed		
<b>N</b>	1473	2276	1963	1786		
<b>Smoking, n (%)</b>						
No	485 (32.9)	887 (38.5)	680 (34.8)	682 (38.5)		
Former	507 (34.4)	773 (34.0)	674 (34.5)	606 (34.2)		
Current	473 (32.1)	609 (26.8)	598 (30.6)	484 (27.3)		

Missing	8 (0.54)	17 (0.75)	11 (0.56)	14 (0.78)
<b>Units of alcohol per week, n (%)</b>				
0	355 (24.1)	582 (25.6)	502 (25.8)	435 (24.7)
1-21	999 (67.8)	1567 (68.9)	1318 (67.8)	1248 (70.7)
>21	106 (7.2)	101 (4.4)	125 (6.4)	82 (4.7)
Missing	13 (0.88)	26 (1.14)	18 (0.92)	21 (1.18)
<b>BMI, n (%)</b>				
<18.5	8 (0.5)	2 (0.1)	9 (0.47)	1 (0.1)
18.5-25	507 (34.4)	795 (34.9)	685 (35.5)	617 (35.0)
25.1-30	664 (45.1)	1087 (47.8)	892 (46.2)	859 (48.7)
>30	267 (18.1)	366 (16.1)	345 (17.9)	288 (16.3)
Missing	27 (1.83)	26 (1.14)	32 (1.63)	21 (1.18)
<b>Leisure-time physical activity hours/week, n (%)</b>				
Sedentary	188 (12.8)	242 (10.6)	255 (13.0)	175 (9.8)
Low	535 (36.3)	786 (34.5)	697 (35.5)	624 (34.9)
Medium	540 (36.7)	878 (38.6)	707 (36.0)	711 (39.8)
High	187 (12.7)	347 (15.3)	280 (14.26)	254 (14.2)
Missing	23 (1.56)	23 (1.01)	24 (1.22)	22 (1.23)

- (1) Descriptive statistics at baseline, the first year during follow-up that a person is employee in Copenhagen Airport in a job function with tasks outdoors on apron (exposed group) or first year during follow-up for workers who are never employees in Copenhagen Airport in job functions with tasks outdoors on apron (reference group).
- (2) Descriptive statistics at baseline, the first year during follow-up that a person is employed as baggage handler in Copenhagen (exposed group) or first year during follow-up for workers who are never employed as baggage handler in Copenhagen (reference group).
- (3) Major road >10 000 vehicles/day

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Figure 1. Map of Copenhagen Airport

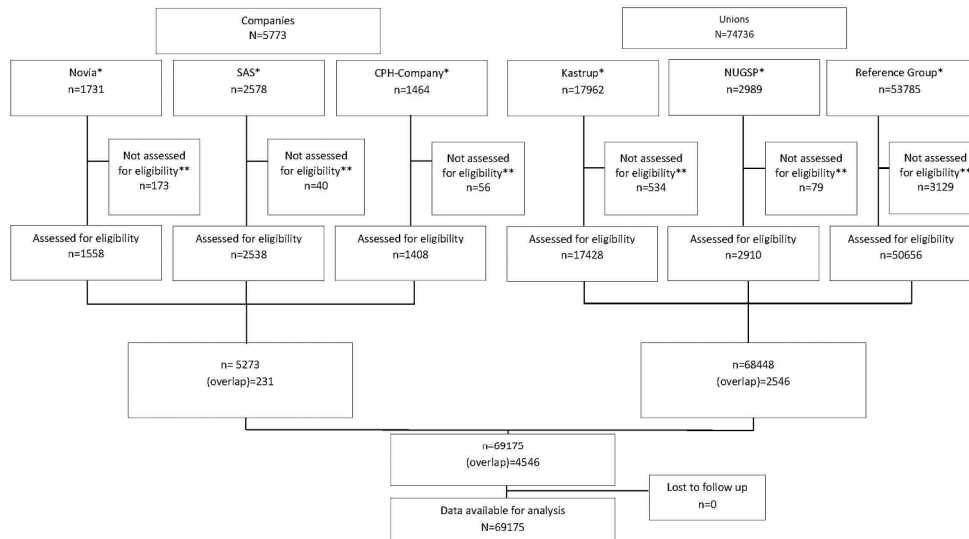


Reference: Copenhagen Airports A/S

165x129mm (300 x 300 DPI)

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Figure 2. Flowchart of the construction of the Copenhagen Airport Cohort



\*Novia (Novia Denmark, handling company), SAS (SAS Ground Service, handling company), CPH (Copenhagen Airports), Kastrup (3F Kastrup-local union), NUGSP (National Union of Guards and Security Personnel), reference group includes 3F Mølleåen, 3F Kastrup and 3F Lager Post and Service Union (LPSU) all organises workers in neighbouring areas of Copenhagen  
 \*\*Not assessed for eligibility due to: invalid CPR-number, missing information on occupation, administrative/management/academic occupations, persons with leave of absence, employment before 15 years of age, men who have never stayed in Denmark under the study period (1990-2012), employment after 31th December 2012, same entry and exit date, dead before employment and dead before 1990

297x210mm (300 x 300 DPI)

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