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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.

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 enhance 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 Danish, nationwide, health and population registers ensure an almost complete follow-up
- Self-reported descriptive data on lifestyle factors were collected among a sample
- The main limitation is the impossibility to control for confounders variables such as smoking and other lifestyle factors

Introduction

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

In 2010 the Danish Centre for Environment and Energy at Aarhus University measured high number concentrations of particles in open air at Copenhagen Airport. These results showed an average number of 38 600 particles (6–700 nm in diameter)/cm^3, and about 90% of the measured particles were UFP(2)). Employees working on the apron at Copenhagen Airport were exposed to a number concentration of UFP between 12 000 and 37 000 particles/cm^3 (4). The number concentration was two–three times higher than measured at the kerbside in a traffic loaded street in Copenhagen City Centre during the same period (2).

Particulate air pollution has been associated with increased risk of ischemic heart diseases and various cancerous diseases (5-7). Previous studies have shown that particulate air pollution increases the risk of hospital admissions due to chronic obstructive respiratory disease (8, 9). Diesel exhaust, which is one of the most prevalent sources of particulate air pollution in urban environments, has also been found to have convincing evidence for carcinogenicity (9), mainly based on occupational exposures in miners (10, 11). There is, however, uncertainty regarding occupational exposures to particulate air pollution and risks of health problems (12), and to our knowledge only two studies have investigated UFP exposure among employees at civil airports and adverse health effects, and only based on self-reported data (13, 14).

It is well documented that the majority of baggage handlers are exposed to a high workload with daily heavy lifting in often awkward positions, and report a high prevalence of musculoskeletal disorders (15), especially lower back, neck and knee disorders (16-18).

However, these studies rely on self-reported data about musculoskeletal disorders in small samples, without the inclusion of a reference group, and the estimation of exposure was only based on seniority in the occupation and hours per week loading and unloading aircraft (16, 17).

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

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 (4).

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

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

The workers included in the cohort are organised in three local unions of the National Union of Unskilled Workers (Danish, 3F) and the National Union of Guards and Security Personnel (NUGSP). One of the 3F local unions (3F-Kastrup) organises workers in unskilled jobs at Copenhagen Airport and in neighbouring areas of Copenhagen. The two other 3F local unions organises workers in unskilled jobs in other areas of Copenhagen.

The member files are centrally organised, and are electronically for periods of membership (entry and exit dates) back to 1983 with registration by the member's personal identification number. The NUGSP organises guards and security personnel and records periods of membership in local unions back to 1979. Few persons had entry dates before the member files and company registers became electronic. These data were transferred when the system was organised electronically.

We compared data from the employee registers and the union registers and found good agreement between the data sources. The positive predictive value (PPV) for concordance between company registration and union member registration as a baggage handler was 87%, and the PPV for company/union registration and survey self-reporting of being a baggage handler (presented below) was 92%.

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

The company registers comprised information on 5773 men and the union member registers 74 736 men. Figure 1 shows the degree of overlapping information. We excluded men using the following criteria: invalid personal identification number, missing information on occupation, same entry and exit dates, administrative/management/academic tasks, absence leave, employed at an age lower than 15 years, no permanent residence in Denmark any year in the study period, only employed after end of follow-up (December 2012), death before employment, and death before 1990. After these exclusions, the final study cohort comprised 69 175 men in unskilled jobs (Figure 1).

(Figure 1 here)

Data collection

Exposure to UFP

UFP exposure in the airport was estimated based on direct GPS measurements in combination with individual measurements of UFP number concentration (4), expert assessment and comprehensive information on job function/task for each calendar year of employment between 1990 and 2012.

Using GPS, we estimated the length of time spent outdoors on the apron during a normal working day among each of the five largest occupational groups in Copenhagen Airport (4). By this study, we found that occupational groups spending the largest proportion of work hours on the apron also were exposed to the highest mean levels of UFP (4). Time spent on apron in percent was therefore used as a proxy for exposure to UFP. Three airport personnel with comprehensive knowledge of work in the airport assessed time spent on the apron (percentage of a normal working day) for other occupational groups, using data on time spent on the apron obtained from the GPS measurement as benchmarks, and including information on the individual job functions and tasks of each occupational group. Groups with similar time spent on the apron were pooled (Table 1). For each calendar year we calculated the duration of UFP exposure as the group weighted proportion of time spent on the apron (apron-years). E.g. baggage handling for 150 days, and cargo work for 90 days in a calendar year gives (150*0.76 + 90*0.25)/365 = 0.37 apron-years of UFP exposure for that year. Apron-years were cumulated during follow-up resulting in time-dependent apron-years.

(Table 1 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 including 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 five tonnes 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.

The handling tasks were also analysed experimentally in a laboratory with video recordings of a baggage handler equipped with a full-body marker set-up performing different handling tasks (e.g. standing or kneeling) on force platforms. On the basis of these recordings, inverse dynamics-based musculoskeletal models of the tasks were built in the AnyBody Modeling system v. 5.3 (AnyBody Technology A/S, Aalborg, Denmark) (19).

Data sources for outcome variables

In Denmark, a person's individual identification number is used in the registration of data to the various nationwide registers, and likewise, this individual number identifies the study population of the Airport Cohort.

In the present follow-up study, we linked data in the Cohort to the National Patient Register, the Cancer Registry, the National Prescription Registry and the Register of Causes of Death (20)-(21). The National Patient Register contains data on all in-patients and since 1995 also on all out-patient contacts (20). Among the study and the reference group, we retrieved data on hospital contacts due to cardiovascular disease, respiratory diseases and musculoskeletal disorders. Further, data on incident cancer cases was obtained from the Danish Cancer Registry, established in 1943 (22). Data on drugs prescribed for respiratory diseases were retrieved from the Danish National Prescription Registry, available from 1995 (23). Data on death and causes of death were retrieved from the Danish Register of Causes of Death, which contains computerised data on all deaths in Denmark of Danish citizens since 1970 (21).

Potential confounders

Socio-economic and demographic data

We linked cohort data to Denmark Statistics various population based registers. Information on education level attained the year before entering the cohort was obtained from the Population Education Register (24). Information on country of birth and marital status was obtained from the Civil Registration System (25). Information on sickness absence from Coherent Social Statistics (26) 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 (27). Information on migration was obtained from the Civil Registration System (25).

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 questioners 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

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

$$TDM = \sum(ADT_{road\ segment} * Length_{road\ segment})$$

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

Characteristics of participants

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

(Table 2 here)

Findings to date

At present, three research papers have been published (3, 4, 28). 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 (3, 4, 28). Among baggage handlers, we reported that the incidence of sub-acromial shoulder disorders increased with cumulative years of employment (3, 4, 28) 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 (3, 4, 28).

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 year why recall bias was avoided. Furthermore, it comprises the availability of detailed objective information on exposure, collected independently, and comprehensive register data that assess outcomes related to health. A strength is also the size of the cohort. These factors qualify analyses based on the cohort. The register-based follow-up by linkage to the various Danish, nationwide, health and population

registers enhance the follow-up, and ensure an almost complete follow-up that may be continued in the future, contrary to a questionnaire-based follow-up.

The main limitation is the impossibility to control for potential confounders, including the impact of changing lifestyle over the studied period. Self-reported descriptive data on lifestyle factors were collected among a sample, which might facilitate sensitivity analyses of the potential influence of lifestyle confounding. But, these data were cross-sectional and only available for 2012, and e.g. smoking habits might have changed over time.

Furthermore, a potential bias of an employed cohort is the healthy worker effect. To overcome this potential bias, we established a reference cohort consisting of men in unskilled jobs other than in airports (29, 30), and, thus, we may diminish this bias.

Future plans

We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases, stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and occupational exposures at airports, and the association between heavy lifting and musculoskeletal disorders.

We plan to update the cohort by 10 more years in 2022 including continuously information on health care contacts by linkage to the national health registers.

Collaboration

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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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

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.

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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[a]	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[a]	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[b], fuel drivers[b] and catering drivers[a], catering[a], inflight service[b]	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[b]	Aircraft parking/towing	60
Marshals[b]	Direct the aircraft to the right gate	40
Cargo[b]	Loading and unloading ***cargo*** carried by aircrafts	25
Maintenance service personnel[b]	Maintain outdoor area (mow the grass, clear snow)	25
Traffic[b], gate coordinators[b]	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[a]	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[b]	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

	Air pollution		Manual lifting		Non-respondents in survey	
Variables						
Data from registers	Reference[1]	Exposed[1]	Reference[2]	Exposed[2]	Respondents	Non-respondents
N	62 546	6629	65 702	3473	3749	1725
Age, mean (SD)	35.0 (13.7)	29.9 (8.2)	34.8 (13.6)	28.9 (7.3)	30.9 (8.6)	29.8 (8.4)
Risk time, person-years	679385.0	51314.2	703235.6	27463.4	.	.
Danish country of origin, n (%)	51 345 (83.7)	5529 (88.0)	53 839 (83.9)	3067 (89.9)	3357 (89.8)	1386 (80.8)
Educational level, n (%)						
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)
Marital status, n (%)						
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)
Average pollution at residence						
Major road within 50 meter of residence, n (%)[3]	5593 (11.3)	600 (10.3)				
Data from Survey	Reference	Exposed	Reference	Exposed		
N	1473	2276	1963	1786		
Smoking, n (%)						
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)		

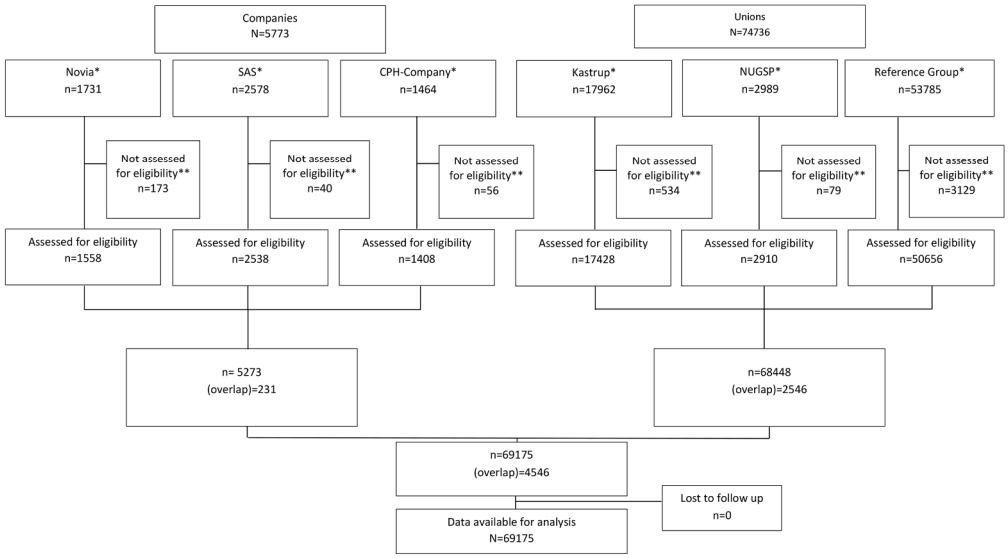
Missing	8 (0.54)	17 (0.75)	11 (0.56)	14 (0.78)
Units of alcohol per week, n (%)				
0	355 (24.1)	582 (25.6)	502 (25.8)	435 (24.7)
1-21	999 (67.8)	1567 (68.9)	1318 (67.8)	1248 (70.7)
>21	106 (7.2)	101 (4.4)	125 (6.4)	82 (4.7)
Missing	13 (0.88)	26 (1.14)	18 (0.92)	21 (1.18)
BMI, n (%)				
<18.5	8 (0.5)	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)
Leisure-time physical activity hours/week, n (%)				
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

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 Personal), 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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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.

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 enhance 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 Danish, nationwide, health and population registers ensure an almost complete follow-up
- Self-reported descriptive data on lifestyle factors were collected among a sample
- The main limitation is the impossibility to control for confounders 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 ≤ 100 nm) (3). Furthermore, the tasks of baggage handlers include daily heavy lifting of, on average, up to 4–5 tonnes of luggage (4).

In 2010 the Danish Centre for Environment and Energy at Aarhus University measured high number concentrations of particles in open air at Copenhagen Airport. These results showed an average number of 38 600 particles (6–700 nm in diameter)/cm^3, and about 90% of the measured particles were UFP(3)). Employees working on the apron at Copenhagen Airport were exposed to a number concentration of UFP between 12 000 and 37 000 particles/cm^3 (5). The number concentration was two–three times higher than measured at the kerbside in a traffic loaded street in Copenhagen City Centre during the same period (3). As a part of a large project to improve the air quality of the working environment, the Danish Centre for Environment and Energy in 2010 estimated air pollution on the apron at Copenhagen Airport. They found that the particle number concentration was two–three times higher on the apron than in a traffic loaded street in the centre of Copenhagen, with 90% of the measured particles in the size frame of <100nm (ultrafine particles (UFP))(3). For other pollutants (NO, NO_2, $PM_{2.5}$, SO_2, particle mass, concentration of elemental carbon (EC) in the particulate matter, concentration of polycyclic aromatic hydrocarbons (PAH) in the particulate matter and concentration of volatile organic compounds (VOC)) where EU limit values exist all levels measured at Copenhagen Airport were below, but no air quality limit values for particle number exists (6).

We therefore assume that if this study found any health effects among airport employees working outdoors, this would be a consequence of exposure to UFP. However, one can only

speculate about the degree to which other pollutant may influence any health related effects among airport employees. We therefore assume that if this study found any health effects among airport employees working outdoors, this would be a consequence of exposure to UFP. However, one can only speculate about the degree to which other pollutants may influence any health related effects among airport employees.

Over the past 10 years, the scientific interest has moved from mass concentration ($PM_{2.5}$ and PM_{10}) to the number concentration of UFP (7). UFP differs from larger particles due to the large surface area with adhered toxins and high alveolar deposition (8). Several experimental studies in animals have shown that UFP can translocate into the blood vessels due to the small size (8-12), and this is likely to occur in humans although translocation from the lungs has not been firmly established (13).

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

Particulate air pollution has been associated with increased risk of ischemic heart diseases and various cancerous diseases (15-17). Previous studies have shown that particulate air pollution increases the risk of hospital admissions due to chronic obstructive respiratory disease (18, 19). Diesel exhaust, which is one of the most prevalent sources of particulate air pollution in

urban environments, has also been found to have convincing evidence for carcinogenicity (9), mainly based on occupational exposures in miners (20, 21). There is, however, uncertainty regarding occupational exposures to particulate air pollution and risks of health problems (22), and to our knowledge only two studies have investigated UFP exposure among employees at civil airports and adverse health effects, and only based on self-reported data (23, 24).

It is well documented that the majority of baggage handlers are exposed to a high workload with daily heavy lifting in often awkward positions, and report a high prevalence of musculoskeletal disorders (25), especially lower back, neck and knee disorders (26-28). However, these studies rely on self-reported data about musculoskeletal disorders in small samples, without the inclusion of a reference group, and the estimation of exposure was only based on seniority in the occupation and hours per week loading and unloading aircraft (26, 27).

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

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).

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

The workers included in the cohort are organised in three local unions of the National Union of Unskilled Workers (Danish, 3F) and the National Union of Guards and Security Personnel (NUGSP). One of the 3F local unions (3F-Kastrup) organises workers in unskilled jobs at Copenhagen Airport and in neighbouring areas of Copenhagen. The two other 3F local unions organises workers in unskilled jobs in other areas of Copenhagen.

The member files are centrally organised, and are electronical for periods of membership (entry and exit dates) back to 1983 with registration by the member's personal identification number. The NUGSP organises guards and security personnel and records periods of membership in local unions back to 1979. Few persons had entry dates before the member files and company registers became electronic. These data were transferred when the system was organised electronically.

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

The validity of union information on job function was assessed by calculating the percentage with the same job function recorded in the company registers. We assessed the validity of questionnaire information on job function the same way. We found good agreement between the data sources. E.g., 87% of persons recorded as baggage handlers by the union were also recorded as baggage handlers in company records, and 92% of persons who in the questionnaire declared that they had worked as security personnel were recorded as such in the company records.

The company registers comprised information on 5773 men and the union member registers 74 736 men. Figure 2 shows the degree of overlapping information. We excluded men using the following criteria: invalid personal identification number, missing information on occupation, same entry and exit dates, administrative/management/academic tasks, absence leave, employed at an age lower than 15 years, no permanent residence in Denmark any year in the study period, only employed after end of follow-up (December 2012), death before employment, and death before 1990. After these exclusions, the final study cohort comprised 69 175 men in unskilled jobs (Figure 2).

At baseline the majority of the reference group was employed in occupations unexposed to high levels of UFP (e.g. municipal workers, drivers, postal workers, garbage collectors, factory workers)(29). Only few were employed in the construction or welding industry (4%). These groups may have been exposed to high levels of UFP and vehicle exhausts. However, studies of ischemic heart disease in welders indicate that if there is an increased risk, it is small and will hardly contribute to any substantial increased risk in the reference population (30).

(Figure 2 here)

Data collection

(Table 1 here)

Exposure to UFP

UFP exposure in the airport was estimated based on direct GPS measurements in combination with individual measurements of UFP number concentrations (5), expert assessment and comprehensive information on job function/task for each calendar year of employment between 1990 and 2012.

Among 30 employees from the five largest occupational groups at the airport (baggage handlers, catering drivers, cleaning staff, airside security and landside security staff) we measured time spent on the apron from GPS measurements in combination with personal monitoring of UFP number concentration (n/cm3) during a normal working day (5). We found that baggage handlers were exposed to daily average concentrations (geometric mean, GM:

37x10^{3}UFP/cm^3) significantly larger than employees mainly working indoors (GM: 5x10^{3}UFP/cm^3) (5). Cleaning staff, catering drivers and airside security were exposed to concentrations in the same range (GM: 12 to 20x10^{3}UFP/cm^3). Much higher concentrations were measured on the apron compared to other locations at the airport, whether indoors or outdoors (5). Therefore the proportion of daily working hours spent on the apron may serve as a proxy for UFP-exposure for occupational groups without UFP and GPS measurements. Five of the occupational groups with measured apron times were used as benchmarks, to assess the average apron times for the remaining occupational groups. This was assessed by three airport worker representatives with a comprehensive knowledge of the working procedures for different occupational groups at the airport. In this assessment, the apron times of all drivers, that is, drivers with inflight service, fuel drivers, catering drivers and other inflight and catering personnel were considered to be similar to that of cleaning staff(measured as 62% of the time) and differed from the actually measured apron time for catering drivers (measured as 34% of the time). However, the number concentrations of UFP measured for catering drivers working on the apron was 43x10^3 UFP/cm^3 and for cleaning staff working on the apron 23x10^3 UFP/cm^3 (5) . The apron time was considered as a proxy for UFP-exposure and therefore we assigned the same apron time to this mixed group of drivers, including catering drivers, as that of cleaning staff (62%), assuming that these groups had similar exposure to UFP. All other occupational groups were assigned an exposure estimate based on expert assessment of their working time on the apron, expressed as a percentage of daily working time. We pooled

groups with similar apron time, resulting in 10 occupational exposure groups with different average apron times.

The apron time was calculated for each calendar year as the proportion of time worked on the apron that year according to entry and exit dates for work in specific occupational groups. E.g. baggage handling for 150 days, and cargo work for 90 days in a calendar year gives (150*0.76 + 90*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 including 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 five tonnes 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.

The handling tasks were also analysed experimentally in a laboratory with video recordings of a baggage handler equipped with a full-body marker set-up performing different handling tasks (e.g. standing or kneeling) on force platforms. On the basis of these recordings, inverse dynamics-based musculoskeletal models of the tasks were built in the AnyBody Modeling system v. 5.3 (AnyBody Technology A/S, Aalborg, Denmark) (31). Output from the models was muscle and joint forces. These forces were subsequently used as weights in the register-part of the study.

Data sources for outcome variables

In Denmark, a person's individual identification number is used in the registration of data to the various nationwide registers, and likewise, this individual number identifies the study population of the Airport Cohort.

In the present follow-up study, we linked data in the Cohort to the National Patient Register, the Cancer Registry, the National Prescription Registry and the Register of Causes of Death (32)-(33). The National Patient Register contains data on all in-patients and since 1995 also on all out-patient contacts (32). Among the study and the reference group, we retrieved data on hospital contacts due to cardiovascular disease, respiratory diseases and musculoskeletal

disorders. Further, data on incident cancer cases was obtained from the Danish Cancer Registry, established in 1943 (34). Data on drugs prescribed for respiratory diseases were retrieved from the Danish National Prescription Registry, available from 1995 (35). Data on death and causes of death were retrieved from the Danish Register of Causes of Death, which contains computerised data on all deaths in Denmark of Danish citizens since 1970 (33).

Potential confounders

Socio-economic and demographic data

We linked cohort data to Denmark Statistics various population based registers. Information on education level attained the year before entering the cohort was obtained from the Population Education Register (36). Information on country of birth and marital status was obtained from the Civil Registration System (37). Information on sickness absence from Coherent Social Statistics (38) 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 (39). Information on migration was obtained from the Civil Registration System (37).

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 questioners 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 (CPH-company, NUGSP, 3F Kastrup with other jobs at the airport, 3F Kastrup without work at the airport, and the two other 3F unions (LPSF and 3F Mølleåen) and for previously employed security service personnel) 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 (433 were obtained from telephone interview), 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 3.

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 44 713 persons. We found invalid geocodes for 299 (0.5%) persons and for 12 223 persons we

only obtained information about residential address by road, and we therefore imputed the air pollution exposure as the mean exposure for the road. Based on the Danish road network and modelled road traffic values, we calculated the distance from residence to the nearest road with annual daily traffic (ADT) of 10 000 vehicles or more, and retrieved the ADT value for the identified road segment. In addition, the heavy-duty share of the ADT value was also retrieved. Furthermore, the traffic density measure (TDM) within a buffer of 100 metres and 300 metres was assigned to every residence. To calculate the TDM, we applied the following equation:

$$TDM = \sum(ADT_{road\ segment} * Length_{road\ segment})$$

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

Characteristics of participants

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

(Table 3 here)

Analysis methods

The cohort will be followed from start of employment, 1st 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 ≥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.

For both analyses we will also investigate the non-linear influence of the exposure variables using restricted cubic spline regression.

Findings to date

At present, three research papers have been published (4, 5, 40). 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 (4, 5, 40). Among baggage handlers, we reported that the incidence of sub-acromial shoulder disorders and meniscal lesions increased with cumulative years of employment (4, 5, 29, 40) 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, 5, 40).

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 year why recall bias was avoided. Furthermore, it comprises the availability of detailed objective information on exposure, collected independently, and comprehensive register data that assess outcomes related to health. A

strength is also the size of the cohort. These factors qualify analyses based on the cohort. The register-based follow-up by linkage to the various Danish, nationwide, health and population registers enhance the follow-up, and ensure an almost complete follow-up that may be continued in the future, contrary to a questionnaire-based follow-up. Finally, this cohort will contribute with long-term follow-up information on health and airport work, which is lacking at present.

The main limitation is the impossibility to control for potential confounders, including the impact of changing lifestyle over the studied period. Self-reported descriptive data on lifestyle factors were collected among a sample, which might facilitate sensitivity analyses of the potential influence of lifestyle confounding. But, these data were cross-sectional and only available for 2012, and e.g. smoking habits might have changed over time.

The number concentration of UFP measured on the apron will probably have changed over time due to a wide range of initiatives from Copenhagen Airport, where diesel powered equipment have been changed with electric equipment. Measurements of UFP was first introduced in 2010, thus the UFP levels of today cannot be compared with levels measured back in time. Working time on the apron near the aircraft could have changed during time, as new and faster equipment are available today. However, with the increasing movements it is not very likely that the actual working time on the apron is different from the past.

Information from all registers overlap with the cohort except the prescription register, where data are available since 1995. For this specific register, we may therefore have missed information on drug use dated before 1995, which could lead to truncation bias.

We have information on the full employment history of SAS employees from 1995 and onwards. The lack of electronic data from SAS from 1990-1995 means that we have not included employees who stopped their employment before 1995, however, we don't think this may have introduced bias since we have the whole employment history for those included.

Finally, a potential bias of an employed cohort is the healthy worker effect. To diminish this potential bias, we established a reference cohort consisting of men in unskilled jobs other than in airports (41, 42).

Future plans

We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases, cerebrovascular disease, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and occupational exposures at airports, and the association between heavy lifting and musculoskeletal disorders.

We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases, stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and occupational exposures at airports. In addition we plan to assess dose-response relationships between heavy lifting, stooped postures and kneeling and musculoskeletal disorders in the low

back, shoulders and knees by combining data from the biomechanical measurements with data on handled baggage per day and employment history. Furthermore we will have focus on studies on work status and prognostic studies in relation to the musculoskeletal disorders.

We plan to update the cohort by 10 more years in 2022 including continuously information on health care contacts by linkage to the national health registers.

Collaboration

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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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

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.

No financial disclosures were reported by the authors of this paper

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Table 1. Overview of variables and data collection

Variable	Data Collection

CPR number	- Company and Union registers - Questionnaire - The Danish Civil Registration System - Registers at Statistics Denmark - National Patient Registry - Register of Causes of Death - The Danish National Prescription Registry - Data from Department of Environmental Science, Aarhus University
Occupational group[1]	- Company and Union registers - Questionnaire
Date for start of employment[1]	- Company and Union registers - Questionnaire
Job function[1]	- Company and Union registers - Questionnaire
Physical loads[1]	- Company statistics - Observations and measurements - Questionnaire
Date of first hospital contact[2]	- National Patient Registry
Diagnosis[2]	- National Patient Registry - *The Danish Cancer Registry*
Surgical codes[2]	- National Patient Registry
Date of death[2]	- Register of Causes of Death
Cause of death[2]	- Register of Causes of Death
Weight, height, leisure time physical activity, smoking status, alcohol[3]	- Questionnaire
Educational level[3]	- Registers at Statistics Denmark
Marital status[3]	- Registers at Statistics Denmark
Country of origin[3]	- Registers at Statistics Denmark

Average pollution at residence[3]	Data from Department of Environmental Science, Aarhus University

[1]Exposure variables

[2] Outcome variables

[3]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[a]	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)[a]	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[c], fuel drivers[b], inflight service drivers[b] and other catering and inflight service personnel[b]	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[b]	Aircraft parking/towing	60
Marshals[b]	Direct the aircraft to the right gate	40
Cargo[b]	Loading and unloading cargo carried by aircrafts	25
Maintenance service personnel[b]	Maintain outdoor area (mow the grass, clear snow)	25
Traffic[b], gate coordinators[b]	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

the airfield)[a]	buildings	
Firefighters[b]	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

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

	Air pollution		Manual lifting		Non-respondents in survey	
Variables						
Data from registers	Reference[1]	Exposed[1]	Reference[2]	Exposed[2]	Respondents	Non-respondents
N	62 546	6629	65 702	3473	3749	1725
Age, mean (SD)	35.0 (13.7)	29.9 (8.2)	34.8 (13.6)	28.9 (7.3)	30.9 (8.6)	29.8 (8.4)
Risk time, person-years	679385.0	51314.2	703235.6	27463.4	.	.
Danish country of origin, n (%)	51 345 (83.7)	5529 (88.0)	53 839 (83.9)	3067 (89.9)	3357 (89.8)	1386 (80.8)
Educational level, n (%)						
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)
Marital status, n (%)						
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)
Average pollution at residence						
Major road within 50 meter of residence, n (%)[3]	5593 (11.3)	600 (10.3)				
Data from Survey	Reference	Exposed	Reference	Exposed		
N	1473	2276	1963	1786		
Smoking, n (%)						
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)		
Units of alcohol per week, n (%)						

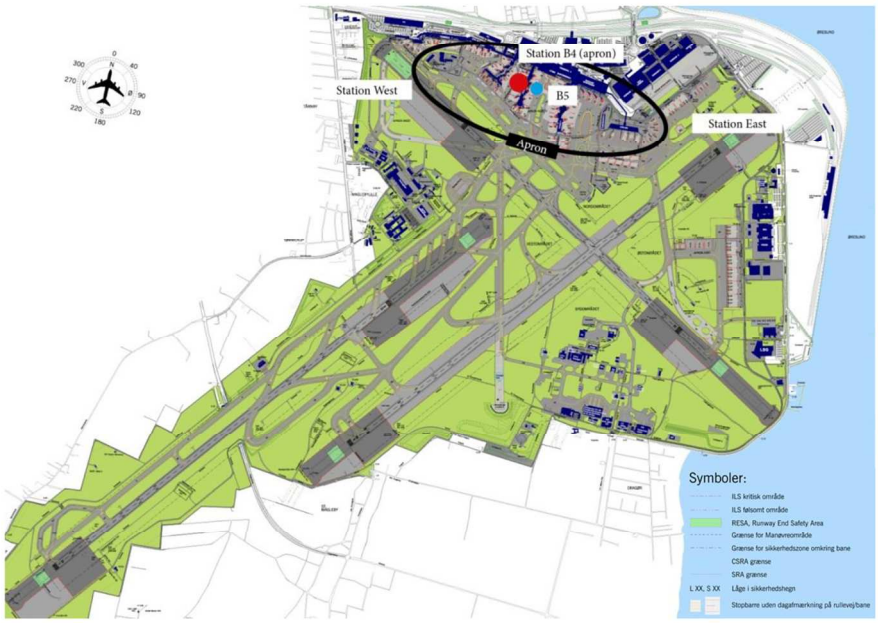
0	355 (24.1)	582 (25.6)	502 (25.8)	435 (24.7)
1-21	999 (67.8)	1567 (68.9)	1318 (67.8)	1248 (70.7)
>21	106 (7.2)	101 (4.4)	125 (6.4)	82 (4.7)
BMI, n (%)				
<18.5	8 (0.5)	2 (0.1)	9 (0.47)	1 (0.1)
18.5-25	507 (34.4)	795 (34.9)	685 (35.5)	617 (35.0)
25.1-30	664 (45.1)	1087 (47.8)	892 (46.2)	859 (48.7)
>30	267 (18.1)	366 (16.1)	345 (17.9)	288 (16.3)
Leisure-time physical activity hours/week, n (%)				
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

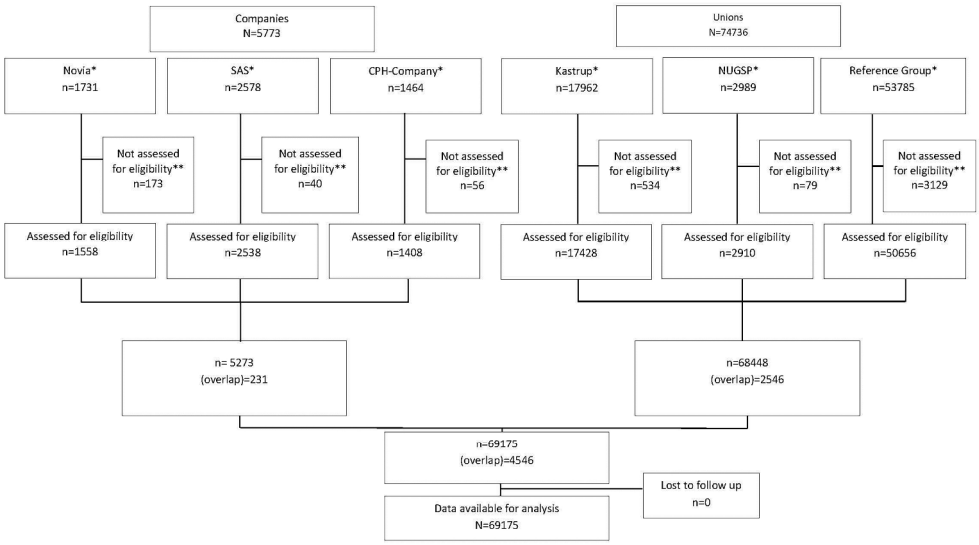
Figure 1. Map of Copenhagen Airport



Reference: Copenhagen Airports A/S

165x129mm (300 x 300 DPI)

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 Personal), reference group includes 3F Møleåen, 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

297x210mm (300 x 300 DPI)

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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, 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 ≤ 100 nm) (3). Furthermore, the tasks of baggage handlers include daily heavy lifting of, on average, up to 4–5 tonnes of luggage (4).

As a part of a large project to improve the air quality of the working environment, the Danish Centre for Environment and Energy at Aarhus University in 2010 measured high number concentrations of particles in open air at Copenhagen Airport. The results showed an average number of 38 600 particles (6–700 nm in diameter)/cm^3, and about 90% of the measured particles were smaller than 100nm (ultrafine particles (UFP))(3). Employees working on the apron at Copenhagen Airport were exposed to a number concentration of UFP between 12 000 and 37 000 particles/cm^3 (5). The number concentration of UFP was two–three times higher than measured at the kerbside in a traffic loaded street in Copenhagen City Centre during the same period (3).

For other pollutants (NO, NO_2, $PM_{2.5}$, SO_2, particle mass, concentration of elemental carbon (EC) in the particulate matter, concentration of polycyclic aromatic hydrocarbons (PAH) in the particulate matter and concentration of volatile organic compounds (VOC)) with established EU limit values, all levels measured at Copenhagen Airport were below these limits. Air quality limit values for particle number have not been established (6).

Over the past 10 years, the scientific interest has moved from mass concentration ($PM_{2.5}$ and PM_{10}) to the number concentration of UFP (7). UFP differs from larger particles due to the large surface area with adhered toxins and high alveolar deposition (8). Several experimental studies in animals have shown that UFP can translocate into the blood vessels due to the small

size (8-12), and this is likely to occur in humans although translocation from the lungs has not been firmly established (13).

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

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

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

However, these studies relied on self-reported data about musculoskeletal disorders in small samples and did not include a reference group, and the estimation of exposure were only based on seniority in the occupation and hours per week loading and unloading aircraft (26, 27).

At present, no previous study has analysed the health effects of occupational exposure to UFP or to manual lifting among airport employees utilising data in a large cohort with complete and long follow-up. The Copenhagen Airport Cohort includes a unique source of information for occupational epidemiological studies of health effects of high exposure to air pollution and manual baggage handling with follow-up information based upon linkage to the Danish nationwide registers. We present the information included in the cohort study and some preliminary data.

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 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

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

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

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

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

The validity of union information on job function was assessed by calculating the percentage with the same job function recorded in the company registers. We assessed the validity of questionnaire information on job function the same way. We found good agreement between the data sources. E.g., 87% of persons recorded as baggage handlers by the union were also

recorded as baggage handlers in company records, and 92% of persons who in the questionnaire declared that they had worked as security personnel were recorded as such in the company records.

The company registers comprised information on 5773 men and the union member registers 74 736 men. Figure 2 shows the degree of overlapping information. We excluded men using the following criteria: invalid personal identification number, missing information on occupation, same entry and exit dates, administrative/management/academic tasks, absence leave, employed at an age below 15 years, no permanent residence in Denmark any year in the study period, only employed after end of follow-up (December 2012), death before employment, and death before 1990. After these exclusions, the final study cohort comprised 69 175 men in unskilled jobs (Figure 2).

At baseline the reference group worked in a variety of different occupations (e.g. municipal workers, drivers, postal workers, garbage collectors, factory workers etc) (29). We do not have representative measures of UFP and vehicle exhaustion for the various occupations. However, we are convinced that only few occupations and few persons in the reference group were continuously exposed to UFP or vehicle exhaust at a similar level as on the apron at Copenhagen Airport. Temporarily high exposure levels may occur among drivers, garbage collectors, and in the welding and construction industries. However, in the absence of specific exposure information and considering that such groups with potentially high exposures were relatively few, we decided to not to exclude any specific occupations from the reference

group. The effect may be a slightly diluted difference in exposure related effects between the reference group and the exposed group.

(Figure 2 here)

Data collection

(Table 1 here)

Exposure to UFP

UFP exposure in the airport was estimated based on direct GPS measurements in combination with individual measurements of UFP number concentrations (5), expert assessment and comprehensive information on job function and task for each calendar year of employment between 1990 and 2012.

Among 30 employees from the five largest occupational groups at the airport (baggage handlers, catering drivers, cleaning staff, airside security and landside security staff), we measured time spent on the apron from GPS measurements in combination with personal monitoring of UFP number concentration (n/cm3) during a normal working day (5). We found that baggage handlers were exposed to daily average concentrations (geometric mean, GM: $37x10^3 UFP/cm^3$), which was significantly larger than employees mainly working indoors (GM: $5x10^3 UFP/cm^3$) (5). Cleaning staff, catering drivers and airside security were exposed to concentrations at the same intermediate level (GM: 12 to $20x10^3 UFP/cm^3$). Higher concentrations were measured on the apron compared to other locations at the airport,

whether indoors or outdoors (5). Therefore the proportion of daily working hours spent on the apron may serve as a proxy for UFP-exposure for occupational groups without UFP and GPS measurements. Five of the occupational groups with measured apron times were used as benchmarks, to assess the average apron times for the remaining occupational groups. This was assessed by three airport worker representatives with a comprehensive knowledge of the working procedures for different occupational groups at the airport. In this assessment, the apron times of all drivers, that is, drivers with inflight service, fuel drivers, catering drivers and other inflight and catering personnel, were considered to be similar to that of cleaning staff (measured as 62% of the time) and differed from the actually measured apron time for catering drivers (measured as 34% of the time). However, the number concentrations of UFP measured for catering drivers working on the apron was $43x10^3$ UFP/cm^3 and for cleaning staff working on the apron $23x10^3$ UFP/cm^3 (5) . The apron time was considered as a proxy for UFP-exposure and therefore we assigned the same apron time to this mixed group of drivers, including catering drivers, as that of cleaning staff (62%), assuming that these groups had similar exposure to UFP. All other occupational groups were assigned an exposure estimate based on expert assessment of their working time on the apron, expressed as a percentage of daily working time. We pooled groups with similar apron time, resulting in 10 occupational exposure groups with different apron times.

The apron time was calculated for each calendar year as the proportion of time worked on the apron that year according to entry and exit dates for work in specific occupational groups. E.g.

baggage handling for 150 days, and cargo work for 90 days in a calendar year gives (150*0.76 + 90*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.

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

Data sources for outcome variables

In Denmark, a person's individual identification number is used in the registration of data to the various nationwide registers, and likewise, this individual number identifies all persons in the study population of the Airport Cohort.

We linked the cohort with the National Patient Register, the Cancer Registry, the National Prescription Registry and the Register of Causes of Death (31)-(32-34). The National Patient Register contains data on all in-patients contacts since 1977 and all out-patient and emergency room contacts since 1995 (31). We retrieved data on hospital contacts due to cardiovascular disease, respiratory diseases and musculoskeletal disorders. Further, data on incident cancer cases was obtained from the Danish Cancer Registry, established in 1943 (33). Data on drugs prescribed for respiratory diseases were retrieved from the Danish National Prescription Registry, available from 1995 (34). Data on death and causes of death were retrieved from the

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

without work at the airport, and the two other 3F unions (LPSF and 3F Mølleåen) and for previously employed security service personnel). All meet the following criteria: being alive by 1 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 (433 were obtained from telephone interview), making a response rate of 68.5%.

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

Air pollution at residence

To obtain information on pollution at the residence, all members in the cohort alive 1 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 44 713 persons. We found invalid geocodes for 299 (0.5%) persons and for 12 223 persons we only obtained information about residential address by road, and we therefore imputed the air pollution exposure as the mean exposure for that road. Based on the Danish road network and modelled road traffic values, we calculated the distance from residence to the nearest road with annual daily traffic (ADT) of 10 000 vehicles or more, and retrieved the ADT value for the

identified road segment. In addition, the heavy-duty share of the ADT value was also retrieved. Furthermore, the traffic density measure (TDM) within a buffer of 100 metres and 300 metres was assigned to every residence. To calculate the TDM, we applied the following equation:

$$TDM = \sum(ADT_{road\ segment} * Length_{road\ segment})$$

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

Characteristics of participants

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

(Table 3 here)

Analysis methods

The cohort will be followed from start of employment, 1 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 associations 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 ≥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.
For both analyses we will also investigate the non-linear influence of the exposure variables using restricted cubic spline regression.

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,

the cohort will contribute with long-term follow-up information on health and airport work, which is lacking at present.

The main limitation is the lack of information about a number of important potential confounders, including changing lifestyle over the studied period. Self-reported descriptive data on lifestyle factors were collected among a sample of the cohort. However, these data were cross-sectional and only available for 2012, and e.g. smoking habits might have changed over time.

The number concentration of UFP measured on the apron will probably have changed over time due to a wide range of initiatives from Copenhagen Airport, where diesel powered equipment has been replaced by electric equipment. Measurements of UFP were first introduced in 2010 and consequently UFP levels of today cannot be compared with levels measured back in time. Working time on the apron near the aircraft could have changed during time since new and faster equipment is available today. However, with the increasing number of flights it is not very likely that the actual working time on the apron is different from the past.

Information from all registers overlap with the cohort except the prescription register, where data are only available since 1995. For this specific register, we may therefore have missed information on drug use dated before 1995, which could lead to truncation bias.

We have information on the full employment history of SAS employees from 1995 and onwards. The lack of electronic data from SAS from 1990-1995 means that we have not included employees who stopped their employment before 1995, however, we don't think this may have introduced bias since we have the whole employment history for those included.

Finally, a potential bias of an employed cohort is the healthy worker effect. To diminish this potential bias, we established a reference cohort consisting of men in unskilled jobs other than in airports (40, 41).

Future plans

We intend to explore correlations between specific morbidity by e.g. ischemic heart diseases, stroke, lung and bladder cancer, asthma and chronic obstructive pulmonary disease and occupational exposures at airports. In addition we plan to assess dose-response relationships between heavy lifting, stooped postures and kneeling and musculoskeletal disorders in the low back, shoulders and knees by combining data from the biomechanical measurements with data on handled baggage per day and employment history. Furthermore, we will have focus on prognostic studies of musculoskeletal disorders.

We plan to update the cohort by 10 more years in 2022 including information on health care contacts by linkage to the national health registers.

Collaboration

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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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

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.

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Table 1. Overview of variables and data collection

Variable	Data Collection
CPR number	- Company and Union registers - Questionnaire - The Danish Civil Registration System - Registers at Statistics Denmark - National Patient Registry - Register of Causes of Death - The Danish National Prescription Registry - Data from Department of Environmental Science, Aarhus University
Occupational group[1]	- Company and Union registers - Questionnaire
Date for start of employment[1]	- Company and Union registers - Questionnaire
Job function[1]	- Company and Union registers - Questionnaire
Physical loads[1]	- Company statistics - Observations and measurements - Questionnaire
Date of first hospital contact[2]	- National Patient Registry
Diagnosis[2]	- National Patient Registry
Surgical codes[2]	- National Patient Registry
Date of death[2]	- Register of Causes of Death
Cause of death[2]	- Register of Causes of Death
Weight, height, leisure time physical activity, smoking status, alcohol[3]	- Questionnaire
Educational level[3]	- Registers at Statistics Denmark

Marital status[3]	- Registers at Statistics Denmark
Country of origin[3]	- Registers at Statistics Denmark
Average pollution at residence[3]	Data from Department of Environmental Science, Aarhus University

[1]Exposure variables
[2] Outcome variables
[3]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[a]	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)[a]	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[c], fuel drivers[b], inflight service drivers[b] and other catering and inflight service personnel[b]	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[b]	Aircraft parking/towing	60
Marshals[b]	Direct the aircraft to the right gate	40
Cargo[b]	Loading and unloading ***cargo*** carried by aircrafts	25
Maintenance service personnel[b]	Maintain outdoor area (mow the grass, clear snow)	25
Traffic[b], gate coordinators[b]	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)[a]	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[b]	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

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

	Air pollution		Manual lifting		Non-respondents in survey	
Variables						
Data from registers	Reference[1]	Exposed[1]	Reference[2]	Exposed[2]	Respondents	Non-respondents
N	62 546	6629	65 702	3473	3749	1725
Age, median (Q1-Q3)	31 (24-43)	28 (24-35)	31 (24-43)	27 (23-33)	29 (24-36)	28 (24-35)
Risk time, person-years	679385.0	51314.2	703235.6	27463.4	.	.
Danish country of origin, n (%)	51 345 (83.7)	5529 (88.0)	53 839 (83.9)	3067 (89.9)	3357 (89.8)	1386 (80.8)
Educational level, n (%)						
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)
Marital status, n (%)						
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)
Average pollution at residence						
Major road within 50 meter of residence, n (%)[3]	5593 (11.3)	600 (10.3)				
Data from Survey	Reference	Exposed	Reference	Exposed		
N	1473	2276	1963	1786		
Smoking, n (%)						
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)		

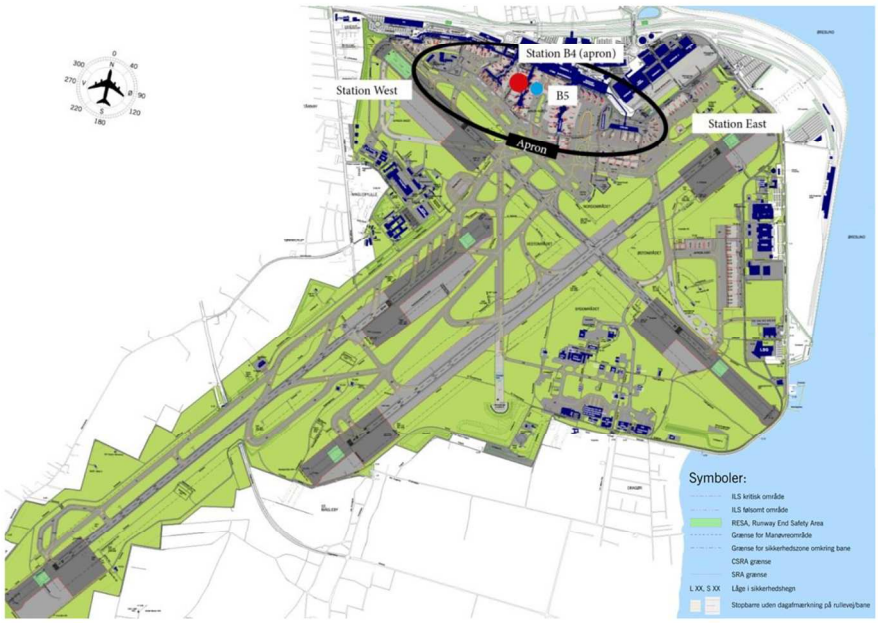
Missing	8 (0.54)	17 (0.75)	11 (0.56)	14 (0.78)
Units of alcohol per week, n (%)				
0	355 (24.1)	582 (25.6)	502 (25.8)	435 (24.7)
1-21	999 (67.8)	1567 (68.9)	1318 (67.8)	1248 (70.7)
>21	106 (7.2)	101 (4.4)	125 (6.4)	82 (4.7)
Missing	13 (0.88)	26 (1.14)	18 (0.92)	21 (1.18)
BMI, n (%)				
<18.5	8 (0.5)	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)
Leisure-time physical activity hours/week, n (%)				
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

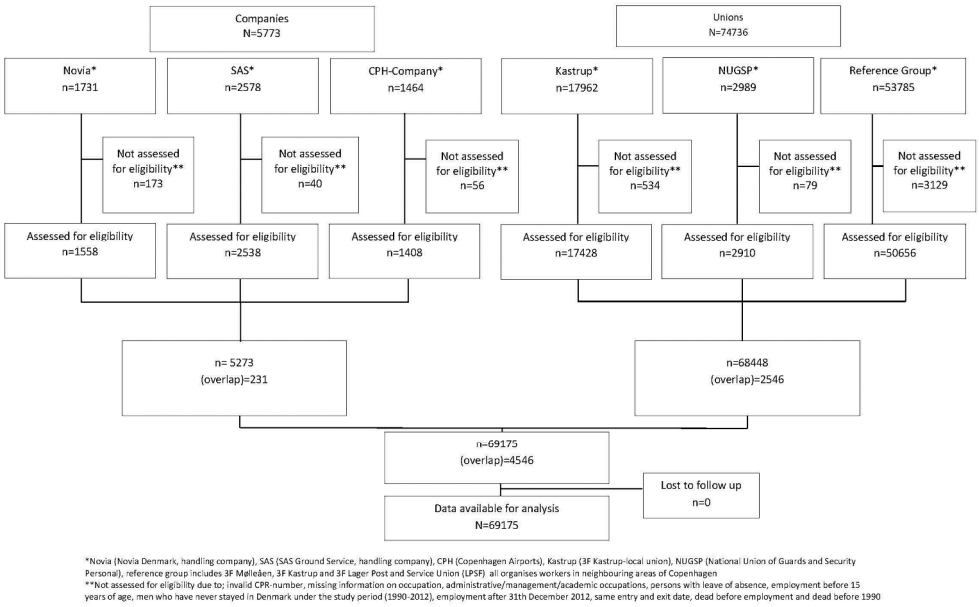
Figure 1. Map of Copenhagen Airport



Reference: Copenhagen Airports A/S

165x129mm (300 x 300 DPI)

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 Personal), 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

297x210mm (300 x 300 DPI)