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FLYING PERSONNEL – CANCER, ACUTE MYOCARDIAL INFARCTION AND MORTALITY

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Flying personnel –
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Aviation is proof that given, the will, we have the capacity to achieve the impossible.

Edward Vernon Rickenbacker (1890-1973)

In memory of Harald Eliasch

CONTENTS

ABSTRACT

Aim: Flying personnel are exposed to several factors in the work environment that can potentially increase their cancer incidence, mortality and acute myocardial infarction (AMI) incidence. The aim of this licentiate thesis is to study cancer incidence among Swedish cabin crew in relation to exposures in the work environment and to study mortality and AMI incidence in Swedish airline and military flying personnel.

Methods: Cancer incidence among cabin crew at the Swedish Scandinavian Airlines (SAS) was determined from the Swedish National Cancer Register. Their cancer incidence was compared with that of the general Swedish population by comparing observed and expected number of cases. To study exposure of total flight hours and exposure to "high altitude, long distance" flights a nested case-control study was performed, including cancer cases diagnosed after 1979 and four controls per case.

A cohort of flying personnel employed at the Swedish part of SAS or the Swedish Air Force was followed regarding mortality and AMI incidence using national registers of hospital discharges and deaths. The observed mortality and AMI incidence was compared with the expected rate in the Swedish population.

Results: Swedish cabin crew had an overall cancer incidence similar to that of the general population. An increased incidence of malignant skin melanoma in both male and females and non-melanoma skin cancer among men may be associated with exposure to UV radiation, either at work or outside work. An increased risk of breast cancer in female cabin crew is consistent with our results and may in part be due to differences in reproductive history. No clear associations were found between length of employment or cumulative block hours and cancer incidence.

Swedish flying personnel, except male cabin crew, had lower-than-expected all-cause mortality mostly due to a reduced cardiovascular mortality reflecting a low AMI incidence during the working life as well as after retirement.

Conclusions: Flying personnel in Sweden have a low mortality and acute myocardial infarction incidence through the life course. Swedish cabin crew have a similar cancer incidence as the population, despite the potential risk factors in the work environment. However, the increased incidences of malignant skin melanoma and non-melanoma skin cancer and the tendency to an increased incidence of breast cancer need to be addressed further regarding possibilities to prevent new cases.

SAMMANFATTNING (SWEDISH SUMMARY)

Syfte: Flygande personal är exponerade för ett flertal faktorer i arbetsmiljön som potentiellt skulle kunna öka deras cancerincidens, mortalitet och akut hjärtinfarkt-incidens. Syftet med den här licentiatavhandlingen är att studera cancerincidens hos svensk kabinpersonal i relation till exponeringar i arbetsmiljön samt att beskriva mortalitet och akut hjärtinfarkt-incidens hos svensk civil och militär flygande personal.

Metod: Cancerfall hos kabinpersonal vid den svenska delen av Scandinavian Airlines (SAS) identifierades via det nationella cancerregistret. Cancerincidensen hos kabinpersonalen jämfördes med motsvarande hos den svenska befolkningen genom att jämföra observerade och förväntade antal fall. För att studera exponeringen för totalt antal flygtimmar och exponering för höghöjds-/långdistansflygning så utfördes en nested fall-kontroll studie där cancerfall efter 1979 och fyra kontroller per fall inkluderades.

En kohort av flygande personal anställda vid den svenska delen av SAS eller vid Flygvapnet följdes avseende mortalitet och insjuknande i akut hjärtinfarkt med hjälp av slutenvårds- och dödsorsaksregistret. Den observerade mortaliteten och hjärtinfarkt-incidensen jämfördes med den förväntade i den svenska befolkningen.

Resultat: Svensk kabinpersonal hade lika stor total cancerincidens som den svenska befolkningen. En förhöjd incidens av malignt melanom hos både män och kvinnor och annan hudcancer hos män kan bero på exponering för UV-strålning, antingen på eller utanför jobbet. En förhöjd risk för bröstcancer hos kvinnlig kabinpersonal är i linje med våra resultat och kan delvis bero på färre antal födda barn och högre ålder vid första graviditet hos kabinpersonalen. Inga tydliga samband kunde ses mellan anställningstid eller kumulativa blocktimmar och cancerincidens.

Svensk flygande personal, förutom manlig kabinpersonal, hade en lägre än förväntad total mortalitet främst på grund av en reducerad hjärt- kärlmortalitet som återspeglar en låg hjärtinfarktincidens som varade även efter pensionering.

Slutsats: Flygande personal i Sverige har en låg mortalitet och akut hjärtinfarkt-incidens även efter pensionering. Cancerincidensen hos svensk kabinpersonal är samma som hos övriga befolkningen. Förhöjda risker för malignt melanom och annan hudcancer liksom tendensen till ökad bröstcancerrisk hos kvinnlig kabinpersonal är av fortsatt intresse när det gäller möjligheter att förhindra nya fall.

LIST OF PUBLICATIONS

This thesis is based on the following publications, which are referred to in the text by their roman numerals:

I. **Linnersjö A**, Hammar N, Dammström BG, Johansson M, Eliasch H.
Cancer incidence in airline cabin crew: experience from Sweden.
Occup Environ Med. 2003;60(11):810-4.

II. **Linnersjö A**, Brodin LÅ, Andersson C, Alfredsson L, Hammar N.
Low mortality and myocardial infarction incidence among flying personnel during working career and beyond.
Scand J Work Environ Health 2011;37(3):219-26.

LIST OF RELATED PUBLICATIONS

1. Hammar N, **Linnersjö A**, Alfredsson L, Dammström BG, Johansson M, Eliasch H. *Cancer incidence in airline and military pilots in Sweden 1961-1996.* Aviat Space Environ Med. 2002;73(1):2-7.

2. Pukkala E, Aspholm R, Auvinen A, Eliasch H, Gundestrup M, Haldorsen T, Hammar N, Hrafnkelsson J, Kyyrönen P, **Linnersjö A**, Rafnsson V, Storm H, Tveten U. Incidence of cancer among Nordic airline pilots over five decades: occupational cohort study. *BMJ* 2002;325(7364):567.

3. Pukkala E, Aspholm R, Auvinen A, Eliasch H, Gundestrup M, Haldorsen T, Hammar N, Hrafnkelsson J, Kyyrönen P, **Linnersjö A**, Rafnsson V, Storm H, Tveten U. Cancer incidence among 10,211 airline pilots: a Nordic study. *Aviat Space Environ Med* 2003;74(7):699-706.

4. Hammar N, Eliasch H, **Linnersjö A**, Dammström BG, Johansson M, Pukkala E. En viss ökning av hudcancer hos piloter. *Läkartidningen* 2003;100(26-27):2297-9.

5. Zeeb H, Blettner M, Langner I, Hammer GP, Ballard TJ, Santaquilani M, Gundestrup M, Storm H, Haldorsen T, Tveten U, Hammar N, **Linnersjö A**, Velonakis E, Tzonou A, Auvinen A, Pukkala E, Rafnsson V, Hrafnkelsson J. Mortality from cancer and other causes among airline cabin attendants in Europe: a collaborative cohort study in eight countries. *Am J Epidemiol* 2003;158(1):35-46.

6. Whelan EA. Cancer incidence in airline cabin crew. Editorial. *Occup Environ Med* 2003;60(11):805-6. (**Comment on**: Breast cancer risk in airline cabin attendants: a nested case-control study in Iceland; Risk factors for cutaneous malignant melanoma among aircrews and a random sample of the population; **Cancer incidence in airline cabin crew: experience from Sweden (Study I)**)

7. Langner I, Blettner M, Gundestrup M, Storm H, Aspholm R, Auvinen A, Pukkala E, Hammer GP, Zeeb H, Hrafnkelsson J, Rafnsson V, Tulinius H, De Angelis G, Verdecchia A, Haldorsen T, Tveten U, Eliasch H, Hammar N, **Linnersjö A**. Cosmic radiation and cancer mortality among airline pilots: results from a European cohort study (ESCAPE). *Radiat Environ Biophys* 2004;42(4):247-56.

8. Pukkala E, Helminen M, Haldorsen T, Hammar N, Kojo K, **Linnersjö A**, Rafnsson V, Tulinius H, Tveten U, Auvinen A. Cancer incidence among Nordic airline cabin crew. *Int J Cancer* 2012;131(12):2886-97.

9. Hammer GP, Auvinen A, De Stavola BL, Grajewski B, Gundestrup M, Haldorsen T, Hammar N, Lagorio S, **Linnersjö A,** Pinkerton L, Pukkala E, Rafnsson V, Dos-Santos-Silva I, Storm HH, Strand TE, Tzonou A, Zeeb H, Blettner M. Mortality from cancer and other causes in commercial airline crews: a joint analysis of cohorts from 10 countries. *Occup Environ Med* 2014;71:313-322.

LIST OF ABBREVIATIONS

AIDS	Acquired immunodeficiency syndrome
AMI	Acute myocardial infarction
CI	Confidence interval
CVD	Cardiovascular disease
IARC	International Agency for Research on Cancer
ICD	International classification of diseases
IHD	Ischemic heart disease
mG	milliGauss
mSv	milliSieverts
SAS	Scandinavian Airlines
SIR	Standardized incidence ratio
SMR	Standardized mortality ratio

PREFACE

In 1994 my main supervisor Niklas Hammar was contacted by the aeromedical doctor Harald Eliasch. Harald had taken the initiative to a database with all military flying personnel and Scandinavian airlines (SAS) pilots in Sweden and wanted Niklas to help him with epidemiologic studies of cardiovascular disease in these cohorts. However, in 1995 a study that reported an increased breast cancer risk in Finnish cabin crew was published. The first author of that article, Eero Pukkala, took initiative to a Nordic study of cancer incidence among pilots and cabin crew to further explore this new finding. Since Niklas and Harald was working on the Swedish cohorts they were invited to represent Sweden in the Nordic study. A data collection process for the Swedish cabin crew was started to be able to join the Nordic collaboration. Since cancer incidence is not available outside the Nordic countries an European collaboration on mortality among flying personnel was initiated from Germany mainly focusing on cancer mortality and exposure to cosmic ionizing radiation.

In 1998 I joined the project and did the analyses of cancer incidence for the Swedish airline and military pilots. This brought me into the research on the Swedish cohorts and to the Nordic and European collaborations. Study I and II of this licentiate thesis were carried out according to a similar study protocol as the international collaborative work. Niklas and I have since then also taken part in an updated follow-up of the European mortality study; now an International collaboration since USA and Great Britain also had joined. I have also started to analyze cardiovascular risk factors among military pilots, navigators and flying mechanics based on data from compulsory aeromedical examinations.

1 INTRODUCTION

1.1 AVIATION HISTORY

Working as flying personnel is a rather new experience since these occupations have only existed during the approximately last 100 years. Below is a short historical background.

1.1.1 Air ships lighter than air

In the year 1783 the Montgolfier brothers constructed the hot air balloon. This was the start of the possibilities for humans to fly. Because evolution has not given mankind the ability to adjust to life in the sky or in space a new medical discipline evolved. The Aeromedical field is dealing with the effects of flying on the human physiology, as well as how we can prevent problems with health due to flying. Already Aristotle had noticed that you can develop altitude sickness if you are going up on high mountains due to thinner air at higher altitudes. The problem with altitude sickness had to be dealt with in the early era of hot air balloons.

1.1.2 Airplanes heavier than air

When the internal combustion engine was invented the possibilities to construct an airship heavier than air was a reality. In the end of 1903 the Wright brothers did the first flight in the world history with this kind of airplane. The development accelerated and in the beginning of the First World War 1914 the speed record was 200 kilometres per hour and the height record was 6000 meters. With increasing flight speeds there were new effects on the human body through earlier unknown acceleration forces. This was a new challenge and a maiden field for Aeromedical research. A fast development within the flight technology took place during the period between the World War I and II. The flight physiologic environment became more and more trying and dangerous. Flight crashes became tragically routine experiences due to acceleration effects, lack of oxygen, illusions in the sense of balance (i.e. not knowing what is up and down during flight), barotrauma and severe coldness [Frykholm].

1.1.3 Civil and military aircraft

The Swedish Air Force was established in 1926. It expanded during the Second World War and kept doing so until the Soviet Union was dissolved. The civilian air traffic became popular after World War II. At the same time the regulations for civil air traffic was coordinated in many countries. Flight medical issues became even more important in the 1950s after the evolution of flight technology had introduced jet planes with flying altitudes of 10 000 meters and a flying speed of 900 kilometres per hour. The civilian air traffic expanded substantially until the terror attack in USA 2001. Nowadays there are approximately 440 000 cabin attendants working in the civil flight around the world [Zeeb 2003].

1.2 OCCUPATIONAL HEALTH RISKS IN FLYING PERSONNEL

Civil air traffic has been given research attention due to long working hours, sleeping disturbances and circadian disruptions in passage of several time zones in intercontinental air travel [Frykholm]. Occupational exposure to cosmic ionizing radiation and low frequency electromagnetic fields is also potential risk factors for flying personnel [Blettner 1998].

1.2.1 Cosmic ionizing radiation

Ionizing radiation consists of high-energy waves that are able to penetrate cells and make a positive charge in a molecule that is normally neutral. These ionized molecules are unstable and undergo chemical changes, which can lead to formation of free radicals that can damage the molecule or other molecules around it [American cancer society].

High altitude flights involve an increased exposure to cosmic ionizing radiation where the level of exposure is dependent on altitude, geomagnetic latitude, flight duration, and solar activity. Protection is provided by magnetic fields of the sun and earth, and the earths' atmosphere. Radiation doses can be measured during flight or may be calculated using a computer-modelling program. Unfortunately individual dosimetry is not feasible since no detector covers the whole range of different components of the cosmic ionizing radiation. Therefore the computer modelling programs have been the most common approach [Hammer 2000; Kojo 2013].

It has been suggested that commercial aircraft personnel may be receiving yearly doses of cosmic ionizing radiation in the order of 3–6 milliSieverts (mSv) through occupational exposure [Nicholas 1998]. This is comparable to the exposure received by workers at nuclear plants, but only slightly higher than the commonly occurring background level of radiation [Blettner 1998; Swedish Radiation Protection Authority]. Separate calculations for different altitudes gave an annual mean exposure of 2–3 mSv for long-haul and 1–2 mSv for short-haul flights among European crew members [Bagshaw 2008]. Epidemiological studies of flight crew have so far not shown conclusive evidence for any increase in cancer mortality or cancer incidence directly attributable to ionizing radiation exposure. However, cosmic ionizing radiation is still a potential risk factor for cancer in the working environment of flying personnel [Sigurdson 2004; Yong LC 2009].

1.2.2 Electromagnetic fields

Non-ionizing radiation is low-frequency radiation that does not have enough energy to cause ionization in tissues, but may cause adverse health consequences in other ways. Electromagnetic fields is a type of non-ionizing radiation that is produced by moving electric charges and may be of natural origin (the sun) or human origin (electronic devices) [American cancer society].

Flying personnel are exposed to eletromagnetic fields generated by the electrical system in the aircraft. Measurements of electromagnetic fields in the aircraft during flight have indicated exposure levels in the order of 2–3 milliGauss (mG) in economy class and 5–10 mG in first class [Nicholas 1998]. The magnetic field levels in the frontal areas of the air plane are elevated compared to normal office levels [Kojo 2013]. Therefore exposure to electromagnetic fields is one of the potential health hazards for flying personnel. International Agency for Research on Cancer (IARC) has classified extremely low-frequency magnetic fields as possibly carcinogenic factors [IARC monograph vol.80].

1.2.3 Circadian disruptions and shift work

There is rather strong evidence in favour of association between shift work and coronary heart disease and that has been repeatedly demonstrated during over 20 years of research [Szosland 2010]. Working shift work and during nights is also risk factors for cancer incidence [Yong M 2012; Stevens 2011]. In 2010, IARC concluded that shift work that involves circadian disruption is probably carcinogenic to humans (Group 2A) [IARC monograph vol.98]. Circadian rhythm disorders are disruptions in a person's circadian rhythm, a name given to the "internal body clock" that regulates the (approximately) 24-hour cycle of biological processes in animals and plants. The industrialisation has increased the use of electricity to light the night. This exposure can disrupt human circadian rhythm (melatonin production, sleep and the circadian clock) [Stevens 2013]. Melatonin is a hormone produced naturally by the pineal gland, located just beneath the center of the brain, in response to darkness. Melatonin made by the body plays a large role in the daily rhythms of sleeping and waking [American cancer society]. Disruption of the circadian rhythm in association with long distance flights over several time zones may influence melatonin levels, and thereby, increase the risk of certain cancer types [Mawson 1998]. Studies on blind people have shown a decreased cancer incidence in this group possibly due to higher levels of melatonin since light has very low effect on the melatonin levels among the blind [Feychting 1998].

1.3 PREVIOUS RESEARCH

1.3.1 Aeromedical research in Sweden

In Sweden studies of flying personnel have mainly focused on cabin air quality, hearing status, sleeping problems, musculosceletal symptoms, psychosocial work environment and digestive functional symptoms in airline crew studied by Torsten Lindgren and co-authors. Neck pain in military pilots has been studied by Björn Äng and co-authors and experimental studies of for example physiologic reactions to acceleration forces in the human body have been performed by Ola Eiken and co-authors. However, as far as we know, we are the first to study both groups of flying personnel (airline and military) jointly in Sweden as well as the first to study cancer, myocardial infarction and mortality in these occupations in Sweden.

1.3.2 Epidemiologic studies of cancer in flying personnel

Several studies from other countries have reported an excess risk of breast cancer for female cabin attendants. The first report came from Finland, showing a standardized incidence ratio (SIR) of 1.9 for breast cancer incidence [Pukkala 1995]. Similar findings have been reported from Denmark [Lynge 1996], USA [Wartenberg 1998; Reynolds 2002] and Iceland [Rafnsson 2001]. In a study from Norway no excess breast cancer risk was observed [Haldorsen 2001]. Several meta-analyses have been published during recent years [Buja 2005 & 2006]. Recently the Nordic collaboration on cancer incidence in cabin crew (where the Swedish cabin crew cohort is included) showed a SIR of 1.50 (95% CI 1.32-1.69) for breast cancer incidence.
Several hypotheses have been discussed regarding the causes of an excess of breast cancer for female cabin attendants. These hypotheses include occupational exposures but also lifestyle factors such as alcohol [Singletary 2001] and reproductive factors, including the number of pregnancies and age at birth of first child [Ewertz 1990]. Most widely discussed in recent years is the issue of disruption of day–night rhythm, similar to what happens during shift work in other occupations [Yong M 2012]. It is difficult to disentangle the effects of cosmic ionizing radiation and disruption of circadian rhythm, but this discussion is ongoing [Zeeb 2012].

An increased incidence of malignant skin melanoma and overall cancer in female flight attendants was found in an Icelandic study [Rafnsson 2001]. The increased incidence of overall cancer was even greater in cabin crew starting to work in 1971 or later, when the jet era started. They had also an increased incidence of breast cancer in this subgroup. An increased incidence of malignant skin melanoma, as well as non-melanoma skin cancer, has also been reported for Norwegian cabin attendants of both genders [Haldorsen 2001]. Among men there were also an increased incidence of cancer in the upper respiratory and gastric tract, and cancer of the liver. A study from the United States reported an increased incidence of malignant skin melanoma in male as well as in female cabin crew [Reynolds 2002].

Recently the Nordic collaboration on cancer incidence in cabin crew (where the Swedish cabin crew cohort is included) showed increased incidences of malignant skin melanoma and leukaemia among female cabin crew. In male cabin crew there were increased incidences of malignant skin melanoma, non-melanoma skin cancer, Kaposi sarcoma and alcohol related cancers.

However, a nested case-control analysis within the Nordic collaboration concluded that the excesses appeared not to be related to cosmic ionizing radiation or circadian disruptions from crossing multiple time zones [Pukkala 2012].

Studies of cancer incidence in pilots do not give a completely consistent pattern, but indicate that pilots have increased risks of malignant skin melanoma and non-melanoma skin cancer [Band 1990 & 1996; Grayson 1996 & 1996; Gundestrup 1999; Haldorsen 2000; Rafnsson 2000; Hammar 2002; Milanov 1999; Yamane 2003].

No obvious occupational related risk factors for the increased incidence of malignant skin melanoma have been reported. The most common risk factor for skin cancer are exposure for ultraviolet radiation [IARC monograph vol.55; American cancer society]. Measurements of ultraviolet (UV) radiation in the aircraft during flight have shown very low levels of exposure, and that the windshield of the aircraft gives a good protection against this type of radiation [Diffey 1990]. Thus, work as a cabin attendant during flight does not seem to give an increase in exposure to UV radiation. However, during recent years hypotheses have been posted that cosmic ionizing radiation could be a risk factor for malignant skin melanoma [Fink 2005].

1.3.3 Epidemiologic studies of mortality and cardiovascular disease in flying personnel

Several studies have reported a lower-than-expected cardiovascular mortality among flying personnel compared to the general population [Band 1996; Blettner 2003; Haldorsen 2002; Irvine 1999; Kaji 1993; MacIntyre 1978; Qiang 2003; Zeeb 2003 & 2003; Yong LC 2014; Zeeb 2010; Hammer 2012 & 2014]. This has many possible explanations including person-related as well as occupation-related factors. When entering the profession, flying personnel in general need to be in good health. This is true for military and airline pilots, navigators, and flying mechanics and also, to some extent, cabin crew.

In Sweden, military flying personnel need to stay in good physical shape throughout their careers to manage the yearly compulsory physical tests [Forsvarsmakten.se; Fhs.se]. Commercial airline flying personnel also undergo regular medical examinations [Aleris.se; SAShms.com].

There are several factors in the work environment of flying personnel that may influence the risk of cardiovascular disease. These factors include exposure to exhaust fumes and irregular working hours [Boice 2000]. In particular, airline personnel may also be exposed to job strain (high psychological demands and low work control) [Wahlstedt 2010] and – for those working on long distance flights – disruptions of the circadian rhythm. Historically, airline personnel were also exposed to environmental tobacco smoke. Before 1997, smoking was allowed in the cabin of SAS aircrafts exposing especially cabin crew, but also pilots to some extent, to environmental tobacco smoke [Lindgren 2003]. These factors would tend to at least to some extent balance a healthy selection effect into the occupation with regard to cardiovascular risk.

In Sweden, airline as well as military flying personnel are categorized as high-level non-manual employees [SCB.se]. This socioeconomic group has been associated with a reduced risk of cardiovascular disease [Rosengren 1988]. A low mortality from cardiovascular diseases could, at least theoretically, be due to a better survival after acute myocardial infarction (AMI). An increased awareness of symptoms and signs and a greater propensity to seek care leading to an earlier treatment could be related to a better survival. From an air safety perspective, it is important to know whether the low cardiovascular mortality reflects a correspondingly low myocardial infarction incidence; from a public health perspective, it is also of interest to see if it lasts after retirement [Pocock 1988; Tunstall-Pedoe 1984].

1.4 WHAT THIS THESIS ADDS

The possible excess of breast cancer among female cabin crew and the lack of a consistent pattern in previous epidemiological studies makes it important to provide additional data on the cancer incidence in this group [Lynge 2001; Whelan 2003].
In view of different hypotheses of possible agents that may cause an increased risk of cancer, it is also of interest to compare cabin attendants with or without experience of “high altitude, long distance” flight duty to see if different exposure levels for cosmic ionizing radiation and disruptions of circadian rhythms would effect the cancer incidence based on objective flight hour data at individual level.

Although several studies have shown a lower cardiovascular mortality among flying personnel as compared to the general population, there are few studies on cardiovascular disease incidence during working life [Hoiberg 1983 & 1985; Qiang 2005] and essentially no studies including cardiovascular disease incidence after retirement. Very few studies include both airline and military flying personnel [Boice 2000]. These groups have in some respects a common background in the recruitment into the occupation but, as noted above, differ in several respects with regard to occupational exposures of possible relevance for cardiovascular risk.

2 AIMS

The general aim of this thesis was to study chronic diseases in flying personnel. The specific aims were:

- To describe cancer incidence in Swedish cabin crew taking total flight hours and exposure to "high altitude, long distance" flights into account.

- To analyze the mortality pattern among airline and military flying personnel and investigate the acute myocardial infarction incidence (AMI) among these groups in Sweden using national registers of causes of death and AMI.

3 MATERIAL AND METHODS

3.1 COHORTS AND DATA COLLECTION

3.1.1 Pilots, navigators and mechanics

The airline pilot cohort consisted of male airline pilots working at the Swedish part of Scandinavian Airlines (SAS), resident in Sweden, and employed anytime between 1957–1994 (N=1478). The military cohort consisted of military pilots (N=2166) as well as navigators and mechanics (N=991), resident in Sweden and recorded in the medical records 1957–1994 in the Aero Medical Centre at Swedish Armed Forces. As there were very few female pilots, navigators, and mechanics, the cohorts were restricted to males in these occupations.

Airline pilots at SAS were identified using administrative company registers of employees, seniority lists and archive documents at the Swedish part of SAS. Dates of employment for the airline pilots were collected from archives at the Swedish SAS and at the Swedish Aviation Inspection Board. For the identification of the military cohort registers from compulsory periodic health examinations were used.

Since 1957 all aeromedical examinations for the military cohort have been kept at the former Aero Medical Centre belonging to the Swedish Armed Forces in Stockholm. The examinations are performed regularly every fifth year until 40 year, thereafter every second year until 50 year and then annually until retirement. Date of first compulsory examination was used as a proxy for date of employment in the military cohort.

The Swedish personal identification number was retrieved for all members of the study groups.

3.1.2 Cabin crew

The cabin crew cohort consisted of cabin crew employed at the Swedish part of SAS, resident in Sweden and employed some time during the period 1957–1994. The cabin attendants at SAS were identified using administrative company registers of employees and archive documents at the Swedish part of SAS. In all, the study population included 3202 subjects. The Swedish personal identification number and date of employment were retrieved for 2956 of the study population (92%), of whom 2324 were women and 632 men. Analyses of the completeness of the cohort indicated only a small number of cabin crew missing when compared with information about annual numbers of cabin attendants employed at SAS during the study period.

3.1.2.1 Nested case-control study

In order to be able to study the association between exposures during flight and cancer risk we did a nested case-control study. Earlier studies of cabin crew have only collected information about flight hours flown from interviews with cabin crew members or on group level based on time tables [Kojo 2005]. This procedure can introduce so called “recall bias” if cancer cases are remembering their flight hours differently compared to the rest of the cabin crew.

From 1979 and onwards, cumulative block hours by aircraft type during employment in Swedish SAS were recorded by the company on a routine basis, yielding monthly summary reports. Block hours include the time from departure of a flight until arrival, in the air as well as on the ground. Possibilities to use information from these routinely collected reports gave us the chance to be the first country to gather objective information of flight hours for cabin crew on an individual level. Due to time and cost limits we did a nested case-control study within the cabin crew cohort. This means that exposure information is not needed for the entire cohort. Instead a subsample can represent the whole cohort making the collection of exposure data more efficient.

From SAS monthly reports cumulative block hours by aircraft type were extracted annually by 31 December during the period 1979–1995 for the cancer cases registered from 1980 to 1996 and for four controls per case. The controls were randomly selected from each case's "risk set", which was composed of all individuals in the cohort who matched the case by gender and age group (5 years), and who were employed in SAS and not diagnosed with cancer at the time the case was diagnosed. In 1993 a Swedish domestic airline company (Linjeflyg) was merged with Swedish SAS. Cabin crew formerly employed in Linjeflyg could not be included in the case-control study because of a lack of information on block hours before joining Swedish SAS.

Information about annual cumulative block hours for the remaining cabin crew was obtained for 48 cases and 174 controls (92%). For some cabin attendants, however, block hours were missing for one or more years during the observation period, and for these years cumulative block hours were imputed using information from adjacent years. Since exposure is increasing by altitude and flight duration we wanted to create a group with the most exposed individuals having flown "High altitude, long distance" flights determined on the basis of the aircraft type. All block hours attributed to DC 8, DC 10, Boeing 747, and Boeing 767 were considered to concern "high altitude, long distance" flights.

3.1.2.2 Reproductive factors

Information on reproductive factors among the female cabin attendants and among the total Swedish female population in 1980 was used to evaluate to what extent reproductive factors may have influenced the breast cancer incidence of female cabin attendants. The method used has been recommended when evaluating confounding due to cigarette smoking in occupational studies [Axelson 1988]. In this evaluation estimates from a meta-analysis of the relative risk of breast cancer for the Swedish female population according to reproductive factors were used [Ewertz 1990].

3.2 INFORMATION FROM SWEDISH NATIONAL REGISTERS

3.2.1 Study I

Incident cases of cancer in the study population during the period 1961–1996 were identified by record linkage to the Swedish National Cancer Register using the personal identification number. Reference data of cancer incidence in the Swedish population was also retrieved from this register. Similarly, all deaths in the study population during this period were obtained from the National Cause of Death Register. From a register of migration at Statistics Sweden, all migrations into or out of Sweden by members of the study population during the years 1968–1996 were recorded. Reproductive history for the female cabin attendants was obtained using the Multi-Generation Register at Statistics Sweden and the National Medical Birth Register. The Multi-Generation Register was also used for information about parity and age at birth of first child among women in Sweden in 1980, eventually used as reference data in the parity calculations.

3.2.2 Study II

Cause-specific deaths for all the cohorts were retrieved from the Swedish national cause of death register, as well as reference data from the Swedish population. Results for major causes of deaths including total, cardiovascular disease, cancer, aircraft accidents, and external causes without aircraft accidents are presented separately. In addition, results are presented for alcohol-related deaths and deaths due to acquired immunodeficiency syndrome (AIDS) since these causes have been highlighted in earlier research [Zeeb 2003; Haldorsen 2001]. During the study period several different versions of the International Classification of Diseases (ICD) have been used in Sweden (ICD-7--ICD-10). We tried to create the mortality categories as similar as possible across ICD-versions. We used the same categories in the international collaboration projects of mortality in airline pilots and cabin crew [Blettner 2003; Zeeb 2003; Hammer 2014].

The presented causes of deaths were defined as:

Cancer [International Classification of Diseases, 9th revision (ICD-9): 140–208)],
Cardiovascular disease (ICD-9: 390–416, 420–441, 444, 453),
Aircraft accidents (ICD-9: E840–E844),
External causes except aircraft accidents (ICD-9: E800–E999 except E840– E844),
AIDS (ICD-9: 279.5–279.6), and
Alcohol-related deaths (ICD-9: 291, 303, 305.0, 357.5, 535.3, 571).

Incident cases of AMI were identified through the national hospital discharge register and the national cause of death register. AMI incidence was defined as ICD-9 code 410. All hospital discharges with AMI and all deaths due to AMI for the cohort members were extracted from the registers and regarded as the same AMI episode if they occurred within 28 days. The Swedish National Board of Health and Welfare uses this method, which has been evaluated in earlier studies [Hammar 2001]. We also obtained information about the mortality and AMI incidence in the general population from these registers to be used as reference rates when calculating expected number of cases.

From a register of migration at Statistics Sweden, all migrations into or out of Sweden by members of the study population during the years 1968–1999 was recorded.

3.3 FOLLOW-UP

3.3.1 Study I

The observation period started on 1 January 1961, at the time of employment or at the time of immigration to Sweden, whichever came last. It ended on 31 December 1996, at the time of death, at the time of cancer diagnosis or at the time of emigration out of Sweden, whichever came first. For a subject moving out of the country, the observation period was terminated at the time of emigration, irrespective of eventual later re-migration to Sweden.

3.3.2 Study II

In the analysis of mortality, the observation period began 1 January 1961, at the time of employment (SAS personnel), date of first medical examination (military personnel), or immigration to Sweden, whichever came last. It ended 31 December 1999, at the time of death, or emigration out of Sweden, whichever came first.
The Swedish hospital discharge register began national coverage of hospitalizations in 1987, therefore in the analysis of AMI incidence the observation period started on 1 January 1987, at the time of employment (SAS personnel), date of first medical examination (military personnel), or immigration to Sweden, whichever came last.
It ended 31 December 1999, at the time of AMI, at time of death, or emigration out of Sweden, whichever came first. For a subject moving out of the country, the observation period was terminated at the time of emigration, irrespective of eventual later re-migration to Sweden.

3.4 STATISTICAL ANALYSES

3.4.1 Study I

3.4.1.1 Cohort

Cancer incidence overall and for specific cancer sites for cabin crew were compared with the corresponding incidence in the general Swedish population by calculation of standardized incidence ratios (SIR), based on the ratio of the observed number of cases and the expected number of cases. The expected number of cases was computed using five-year age groups and eight different calendar periods (1961–1962, 1963–1967, 1968–1972, 1973–1977, 1978–1982, 1983–1987, 1988–1992, 1993–1996). Together with the SIR, 95% confidence intervals (95% CI) were computed, assuming that the observed number of cancer cases followed a Poisson distribution. Analyses were carried out using Epicure release 2.10 [Hirosoft International Corp, Seattle, WA, USA].

3.4.1.2 Nested case-control

The case-control study nested within the cohort was analysed by calculating odds ratios (OR) for cancer incidence overall, malignant skin melanoma, and for breast cancer among women by comparing cabin crew with at least 10 000 cumulated block hours, any "high altitude, long distance" flight duty, and cabin crew with at least 5000 "high altitude, long distance" flight hours with cabin attendants without this experience. Odds ratios were calculated, together with 95% confidence intervals, using conditional logistic regression. Analyses were carried out using SAS for Windows, version 8 [SAS Institute, Cary, NC, USA].

3.4.2 Study II

Person years at risk were calculated in 5-year age and calendar intervals using the software package Epicure release 2.10 [Hirosoft International Corp, Seattle, WA, USA]. Expected numbers of deaths and incident AMI were calculated using age, gender, and calendar-year-specific mortality and AMI incidence rates in the Swedish population. Standardized mortality ratios (SMR) were calculated dividing observed numbers of deaths by expected numbers using SAS for Windows version 9.1 [SAS Institute, Cary, NC, USA]. Standardized incidence ratios (SIR) for AMI were calculated correspondingly. Both SMR and SIR were accompanied by 95% confidence intervals (95% CI) assuming that the observed number of cases followed a Poisson distribution. For a direct comparison of AMI incidence between airline and military pilots, a standardized relative risk (SRR) was calculated by gender using 5-year age groups.

3.5 ETHICS

The studies in this licentiate thesis complies with the Declaration of Helsinki and has been evaluated and approved by the ethical committee of Karolinska Institutet [diary number 99-391 and 2010/230--32]. The study participants were not contacted in person. The benefits for the group of flying personnel from these studies are bigger than the eventual harm the register matches would do.

4 RESULTS

4.1 STUDY I

4.1.1 Cohort

The total number of person-years was 39 135 in women, and 12 774 in men. At the start of follow up, members of the cabin crew were in general below 30 years of age; a dominant part of the person-years generated in this study were below 50 years of age. Only about 5% of the person-years were above 60 years of age, which is the regular age of retirement among cabin crew in Sweden. Emigration and immigration was quite common in the cohort; 21.1% (n = 490) of the women emigrated during the study period and 5.3% (n = 124) immigrated. The corresponding figures for men were 19% (n = 120) emigrants and 8.5% (n = 54) immigrants. At the end of follow up 29 women and 48 men were dead.

A total of 109 cancer cases were observed, of which 76 were among women and 33 among men. The observed number of cases was close to that expected on the basis of the cancer incidence of the general Swedish population, taking age and calendar period into consideration. The SIR was 1.01 (95% CI 0.78 to 1.24) for women and 1.16 (95% CI 0.76 to 1.55) for men. In both genders there was an increased incidence of malignant skin melanoma (SIR 2.18 (95% CI 1.09 to 3.90) for women and 3.66 (95% CI 1.34 to 7.97) for men). Men also had an increased incidence of non-melanoma skin cancer (SIR 4.42; 95% CI 1.20 to 11.32). Of the four cases of non-melanoma skin cancer in men, one was a Kaposi's sarcoma, which, because of the very low incidence in the general population, gave a high SIR. In women, a tendency to an increased incidence was found for breast cancer (SIR 1.30; 95% CI 0.85 to 1.74) and for leukaemia (SIR 3.14; 95% CI 0.86 to 8.04).

No clear associations were found between years of employment and cancer incidence overall or malignant skin melanoma, nor for breast cancer among women. For malignant skin melanoma the total number of observed cases for men and women combined was 17 compared to 6.53 expected (SIR 2.61; 95% CI 1.52 to 4.17). Based on these 17 cases no association with length of employment was seen.

The SIR for malignant skin melanoma was in the order of 2.2–3.0 throughout the study period with no substantial changes. An increased incidence of leukaemia was seen among subjects with 20 or more years of employment in SAS, but this was based on only two cases.

4.1.2 Nested case-control

Information about total flight hours and flight hours in “high altitude, long distance” flights was obtained for 48 cancer cases diagnosed 1980–1996 and for 174 controls. Of these cases 16 had breast cancer and 10 had melanoma or non-melanoma skin cancer. The numbers of total and “high altitude, long distance” block hours, respectively, were similar between cases and controls. There were substantial differences in block hours between men and women. The average number of total cumulative block hours in 1995 was 6440 hours for female and 13 370 hours for male cabin crew.

In general, no statistically significant associations between block hours and/or experience of “high altitude, long distance” flights and cancer incidence could be determined. In most analyses, the number of cases was small. Female cabin crew with at least 5000 “high altitude, long distance” block hours showed a non-significant increased incidence for breast cancer (SIR 3.27; 95% CI 0.54 to 19.70) compared to female cabin crew with less or no experience of “high altitude, long distance” flights.

4.1.3 Reproductive factors

The proportion of the female cabin attendants who had given birth to a child was 72.5%, which was very close to the corresponding proportion among all Swedish women in 1980. Female cabin attendants tended to have fewer pregnancies, which were later in life. The proportion of cabin attendants who gave birth before 25 years of age was only 7% compared to 51% among all Swedish women. Given these differences in reproductive history and with the relative risks for breast cancer, estimated from a Nordic meta-analysis [Ewertz 1990], one could expect an excess incidence of breast cancer among female cabin crew in the order of 10% (SIR 1.10) compared to the Swedish female population. This is lower than, but considering random variation, consistent with, the observed SIR for breast cancer in this study.

4.2 STUDY II

4.2.1 Mortality

The military personnel had a higher inclusion age in the beginning of the study period because, prior to 1968, the health examinations began when the individual reached 40 years of age. All groups of flying personnel, except male cabin crew, had a reduced all-cause mortality (figure 1A). Airline pilots and female cabin crew had about 40% reduced mortality, and military flying personnel had a 25% reduction. If we exclude the aircraft accidents from the all-cause mortality, the SMR decreased by an additional 4–15% in the different flying personnel groups.

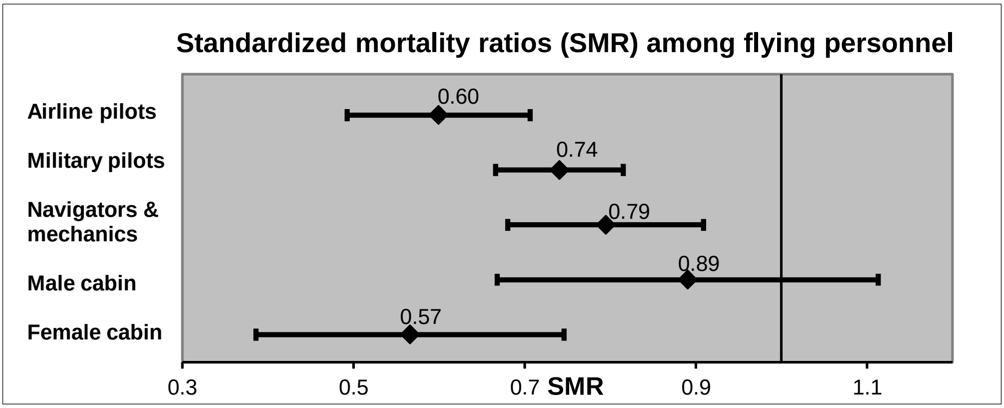

Figure 1 A – All causes

Military pilots and female cabin crew had a reduced risk of cancer mortality while the other groups had about the same risk as the population (figure 1B).

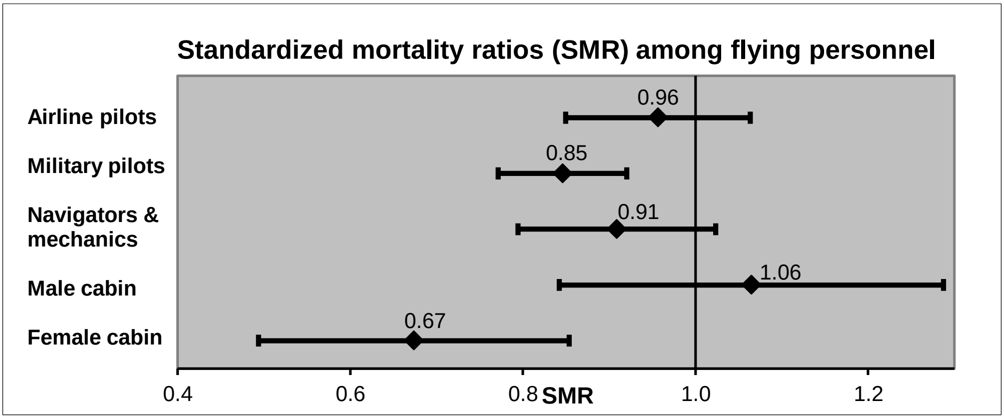

Figure 1 B - All cancer (ICD-9: 140-208)

Mortality from cardiovascular diseases was substantially reduced in all groups (figure 1C). It was a 20% reduction among navigators and mechanics and a 50% reduction among airline pilots, military pilots, and male cabin crew. Female cabin crew had a very low cardiovascular mortality (SMR 0.31, 95% CI 0.09–0.80). The reduced total as well as cardiovascular mortality was present over the whole study period with only small fluctuations. The reduction was found in all age groups except >=80 years of age for all cardiovascular mortality.

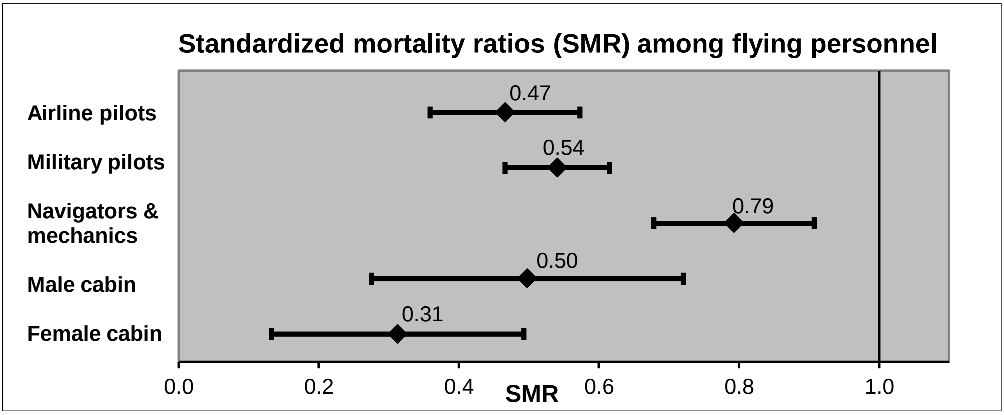

Figure 1 C - All cardiovascular (ICD-9: 390-416, 420-441, 444, 453)

An excess mortality was found for aircraft accidents in all groups, except male cabin crew with no recorded deaths due to this cause (figure 1D). Mortality due to aircraft accidents was common among military pilots (SMR 165.68, 95% CI 122.28–209.07). Airline pilots had a SMR of 23.87 (95% CI 8.76–51.94). Navigators and mechanics as well as female cabin crew had an intermediate mortality ratio in aircraft accidents in-between the pilot groups. All aircraft accidents for cabin crew as well as navigators and mechanics were classified as occupational in the national causes of death register. The corresponding figures were 83% and 75% for airline and military pilots, respectively. The high mortality due to aircraft accidents mainly existed in lower age groups. Dividing cabin crew by age group resulted in small numbers indicating the same pattern.

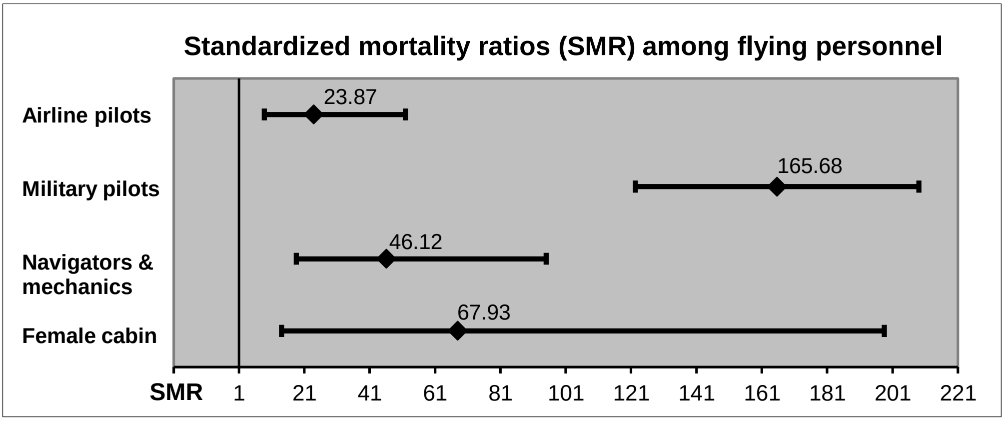

Figure 1 D - Aircraft accidents (ICD-9: E840-E844)

Mortality from external causes, except aircraft accidents, was significantly reduced in all groups except navigators and mechanics (figure 1E). Among pilots and cabin crew, it was approximately halved.

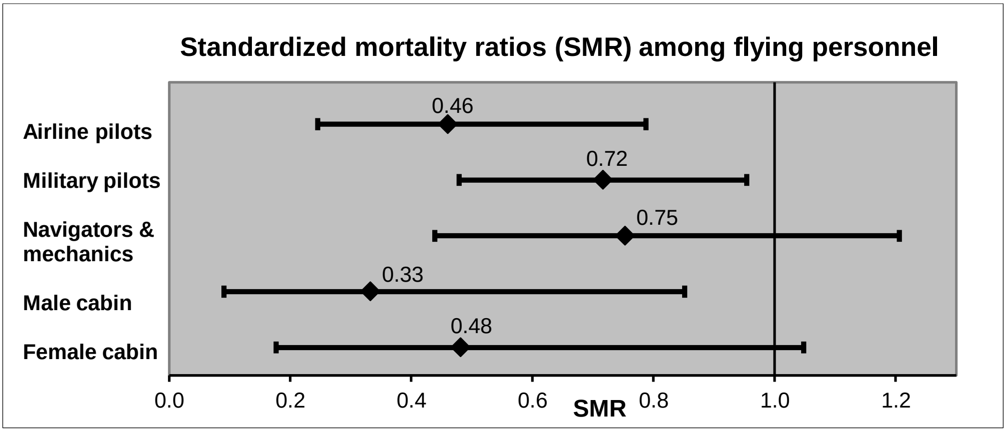

Figure 1 E - External causes except aircraft accidents (ICD-9: E800-E999, not E840-E844)

Alcohol-related mortality was reduced in all groups except male cabin crew who had a more than doubled mortality compared with the expected rate (SMR 2.66, 95% CI 1.15–5.23). Male cabin attendants had also an increased AIDS mortality (SMR 47.31, 95% CI 19.02–97.47).

4.2.2 Acute myocardial infarction incidence

In all occupational groups, the AMI incidence was lower than expected. Commercial airline flying personnel had significantly lower SIR than military personnel. The SIR for myocardial infarction ranged from 0.13 (95% CI 0.02-0.48) in female cabin attendants to 0.61 (95% CI 0.45-0.76) among military navigators and mechanics. Analyses of AMI incidence by time period showed that the incidence reduction was most pronounced in the later years. The risk reduction in AMI incidence was present in all age groups even after retirement.

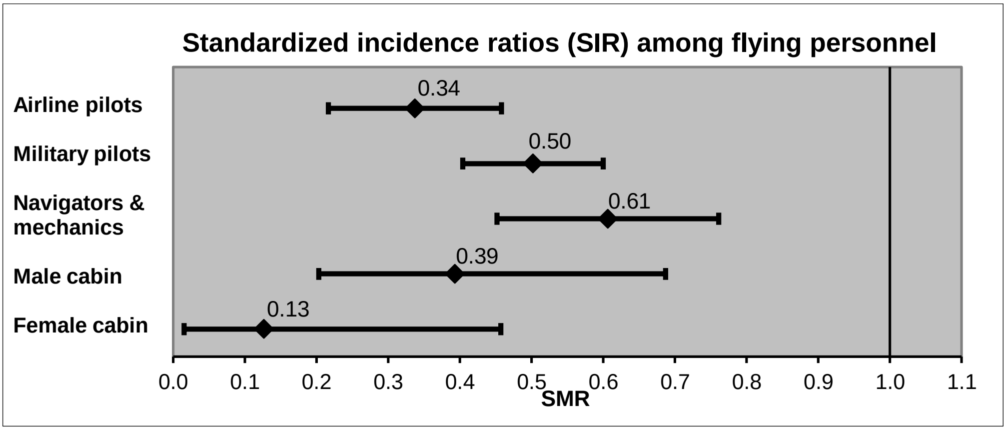

Figure 2 - Acute myocardial infarction incidence

By calculating a SRR, we made a comparison of the AMI incidence between airline and military pilots. The SRR was 1.99 (95% CI 1.11–3.55) for military versus airline pilots.

5 DISCUSSION

5.1 STUDY I

5.1.1 Malignant skin melanoma and non-melanoma skin cancer

The results showed an increased incidence of malignant skin melanoma in Swedish cabin crew among both men and women and of non-melanoma skin cancer in men. These increased incidences are in agreement with corresponding analyses previously reported from Iceland, Norway, and the United States [Rafnsson 2001; Haldorsen 2001; Reynolds 2002]. Similar findings have also been suggested from studies of Nordic pilots [Gundestrup 1999; Haldorsen 2000; Rafnsson 2000; Hammar 2002].

The increased incidence of malignant skin melanoma remained stable throughout the study period. During this period the incidence of malignant skin melanoma increased in the population [Westerdahl 1995], which with stable relative risks for cabin crew would mean a greater increase of the incidence among cabin attendants than in the general population.

It is likely that the observed increase of malignant skin melanoma in all cabin crew and of non-melanoma skin cancer in male cabin crew is real. The causes of these increased risks remain unclear, and both occupational and non-occupational causes may be involved [Kojo 2013; Rafnsson 2003; Nicholas 2009]. Both natural sunlight and artificial light sources increases the risk [American cancer society; IARC]. The melanomas often occurred on the trunk, indicating that sunburn could be of etiological importance. Measurements of ultraviolet (UV) radiation in the aircraft during flight have shown very low levels of exposure, and that the windshield of the aircraft gives a good protection against this type of radiation [Diffey 1990]. Thus, work as a cabin attendant during flight does not seem to give an increase in exposure to UV radiation. Safer habits during sun exposure could be a potential preventive action.

5.1.2 Breast cancer

The tendency to an increased incidence of breast cancer in female cabin crew is consistent with the previously reported corresponding results from Iceland, Finland, and the United States [Rafnsson 2001 & 2003; Pukkala 1995; Reynolds 2002], but not in agreement with the results from a Norwegian study [Haldorsen 2001]. In view of similar findings in the Nordic collaboration [Pukkala 2012] and in the United States it is likely that this reflects a real increased incidence in this occupational group.

The causes of this increase are not known and may involve occupational as well as other factors, including reproductive history. Reproductive history in female cabin crew could yield a 10% increase in breast cancer incidence compared to the general population according to our estimations. This could be an important contributing factor to the increased breast cancer incidence in female cabin crew, but does not seem to fully explain this excess.

It has been suggested that exposure to cosmic ionizing radiation and disturbances of the circadian rhythm at long distance flights may be causes of an increased risk of breast cancer in cabin crew [Auvinen 1999; Grajewski 2013; Mawson 1998; Megdal 2005; Jia 2013; Langner 2004]. Our findings in analyses of block hours and "high altitude, long distance" flights are consistent with these hypotheses, but the numbers were small and the results therefore uncertain. Analysis of employment years in SAS indicated that the breast cancer risk was similar regardless of the number of working years. However, some cabin crew may have been working as cabin attendants for other companies during their career. Our results, together with those of previous studies, call for further investigations of breast cancer risk in female cabin crew. A reduction of exposure to light at night could be a potential preventive action [Bonde 2012].

5.1.3 Potential misclassification of outcome

The Swedish National Cancer Register used in this study for identification of cases is based on a compulsory reporting of diagnosed cases and has a high degree of completeness. A comparison to the National Cause of Death Register in 1978 showed a loss of cases in the Cancer Register of 4.5% [Mattsson 1984]. Each case is generally reported both by the clinician first making the diagnosis and also by a pathologist or cytologist. This contributes to a comparatively low misclassification of disease in the cancer register.

It is possible that the frequent and regular health examinations of the flying personnel contributes to an earlier detection of cancer cases and thus to a higher diagnostic rate. This could result in an overestimation of the cancer incidence in cabin crew compared with the general population.

Cabin crew is an occupational group with a comparatively extensive international migration. In this study we could take immigration to and emigration from Sweden into account by using national population registers going back to 1968. In order to avoid a loss of cases due to immigration or emigration, the follow up time was started at the time of immigration and terminated at the time of first emigration. Thus, no person-time at risk was accumulated outside Sweden, where cancer cases could not be detected. The loss of person-years and cases among subjects returning to Sweden was about 10% of all potential person-years and cases in the study. By record linkage to the National Cause of Death Register, all deaths during the study period could be obtained, thereby avoiding an overestimation of the person years at risk.

5.1.4 Potential misclassification of exposure

Total block hours and block hours at “high altitude, long distance” flights were estimated from monthly reports recorded at the Swedish SAS. This does not give a complete account of all block hours of the cohort members. In particular, block hours obtained in service for other companies would be underrepresented or completely missing. This would contribute to a misclassification of block hours, probably underestimating total exposure and exposure to “high altitude, long distance” flights. It is possible that this has contributed to the lack of association between total block hours and “high altitude, long distance” block hours, respectively, and cancer incidence in this study. This source of error cannot, however, explain the associations or lack of associations seen in analyses of all cabin crew, irrespective of classification according to block hours or aircraft type.
Information about cumulative block hours was available from 1979 and onwards. In analyses of exposure to “high altitude, long distance” flights the numbers of cases was often small. Since the flight duty of cabin attendants in Sweden during the 1960s and 1970s mostly concerned propeller planes flying at lower altitudes it is unlikely that inclusion of these earlier years would have substantially increased the number of cases exposed to “high altitude, long distance” flights. We therefore probably not missed so many of the highly exposed individuals and could not have increased the power to detect differences in cancer incidence due to differences in exposure.

We did not use latency time in the analysis of cancer incidence. In an Icelandic study observation time started 15 years after employment time so the cancer cases should have time to develop [Rafnsson 2001]. However only small differences with or without latency time were presented in that Icelandic study. Since different cancer types takes more or less time to develop and the purpose of our study was mainly descriptive we decided to only do analyses without latency time. Therefore it is possible that we have not captured the optimal time window for exposure in our analyses.

5.2 STUDY II

Our study confirms the low overall and cardiovascular mortality among pilots and female cabin crew and no reduced all-cause mortality among male cabin attendants [Blettner 2003; Zeeb 2003; Hammer 2014]. Furthermore, it shows that the low cardiovascular mortality is at least in part explained by a reduced incidence of AMI. Among pilots, a low cardiovascular risk may be related to the recruitment of healthy persons into the occupation.
In addition, pilots go through regular medical examinations covering risk factors for cardiovascular diseases among other things. The yearly demand for physical fitness at work and long working time spent doing physical exercise among military flying personnel probably also contributes to a low AMI incidence even after retirement.

Exposure to occupational risk factors (e.g. job strain, shift work and exhaust fumes) among flying personnel would tend to increase the risk of AMI, but in spite of this the risk is low. The internal comparison within the cohort showed a higher AMI incidence among military compared to commercial airline pilots aged <70 years. In the absence of information on individual and occupational cardiovascular risk factors, it is not possible to determine the causes of this difference.

There is probably a low prevalence of smoking in this cohort since they had a low lung cancer incidence [Hammar 2002; study I]; a low smoking prevalence was found in other flying cohorts [Nicholas 2001; Pizzi 2008]. This tends to reduce the AMI incidence. The trend in AMI incidence has been decreasing in Sweden during the study period [Rosén 2000; Linnersjö 2000], which – combined with lower relative risks over time for flying personnel – would mean a greater reduction of the AMI incidence among flying personnel than among the general population.

It is an important new finding that cabin crew have a low AMI incidence. Cabin crew have to fulfil some demands regarding height, weight as well as good physical and mental shape. This means that the obese and overweight will be underrepresented in this group and that possibly a healthier lifestyle in general is promoted. This may have had a favourable influence on mortality and AMI incidence [Cameron 2009]. The male cabin crew did not have an improved all-cause mortality in part due to an increased mortality in AIDS and alcohol-related causes of deaths probably related to lifestyle.

5.2.1 Potential misclassification of outcome

Military pilots, navigators, and mechanics recorded in the medical records 1957–1994 in the Swedish Armed Forces' Aero Medical Centre were included in the study. During 1957–1967, the first medical examination was done at 40 years of age, and since 1968 the medical examinations starts at 25 years. In the beginning of the inclusion period, military flying personnel who quit or died before they were 40 were not included in the cohort. This means that we probably did not identify all deaths due to aircraft accidents in the 1960s.

A strength of this study is that there was essentially no loss of deaths and diagnosed AMI during the follow-up among subjects residing in Sweden due to the excellent coverage of the Swedish national cause of death, population, and hospital discharge registers [Socialstyrelsen.se quality AMI, death and hospital discharge register; de Faire 1976]. The Swedish national cause of death and hospital discharge registers cover all deaths among permanent residents of Sweden, irrespective of whether the death occurred in Sweden or abroad, and every hospitalization regarding acute medical cases in Sweden respectively. These registers were linked to the cohort of flying personnel using the personal identification number, unique to every resident of Sweden. Only 0.5% of the deaths in the national cause of death register lacked information on cause. Less than 1% of hospital discharges in the national hospital discharge register lacked personal identification number and <1% lacked main diagnosis.

There was a fairly extensive migration out of Sweden in the commercial airline cohorts (15%). Unless the migrants represented a less healthy part of the cohort, migration out of Sweden is not a likely explanation to the low observed mortality in these cohorts.

The regular medical health examinations mandatory for flying personnel may give a higher awareness of signs and symptoms of cardiovascular disease, but can also give a sense of increased control of one's health [Boulware 2007]. These examinations also give the possibility to discover health problems early and potentially reduce cardiovascular mortality because of earlier detection of risk factors and a greater propensity to seek medical care when cardiac symptoms occur.

The strong selection into the cohort as well as the fact that healthy people are more likely to stay in the occupation results in a healthy worker effect [Baillargeon 2001; Fox 1976]. One strength of this study is that we follow the flying personnel in national cause of death and hospital discharge registers irrespective of whether they still are working in the occupation or not. We observed large reductions in mortality lasting even after retirement which may suggest that the reduced mortality is not only explained by the healthy worker effect. A similar finding was seen among American pilots [Qiang 2003].

In the beginning of their careers, some of the commercial airline pilots were military pilots. We categorized the pilots in the group where they had worked the longest part of their career.

Socioeconomic factors may also have contributed to the low mortality among flying personnel. If we could compare with people from the same social class, the SMR and SIR would probably have been higher (i.e. closer to unity). This was the case in an investigation of Swedish physicians [Gustavsson 2003].

6 FUTURE RESEARCH

The reason behind the reduced mortality in cardiovascular diseases and of acute myocardial infarction incidence among flying personnel is not well studied [Hoiberg 1983 & 1985; Qiang 2005]. In pilot recruitment a selection related to health and physical fitness is used, which initially gives a reduced risk. Military pilots thereafter continue to undergo compulsory regular medical examinations dedicated mostly to cardiovascular health [FHS.se, Forsvarsmakten.se]. This can also contribute to a reduced mortality and incidence in these diseases. A possible mechanism for this is influence on well-known established risk factors for cardiovascular disease through fewer smokers, lower prevalence of overweight, lower prevalence of high blood pressure and dyslipidaemia [Rosengren 1988]. Another possibility is that these risk factors plays a minor roll and/or is compensated by other factors for example heredity, physical fitness, physical activity or social factors.

One important aim for future studies is to describe if well-known established risk factors explains the reduced mortality and cardiovascular incidence among military pilots, navigators and flying mechanics and how these risk factors changes with age in this selected group using data from aeromedical examinations.

7 CONCLUSIONS

Cabin crew are occupationally exposed to several factors that may be associated with an increased risk of cancer and acute myocardial infarction, including cosmic ionizing radiation. Previous studies have shown an excess risk of breast cancer among female cabin crew. This was given some further support in study I where a tendency to an increased incidence of breast cancer among Swedish female cabin crew was found. An increased incidence of malignant skin melanoma was seen for cabin crew of both genders, and of non-melanoma skin cancer for men. This increased incidence may be due to exposure to UV radiation at work or outside work.

Findings from this cohort of Swedish flying personnel confirm the low overall and cardiovascular mortality in these occupational groups. Furthermore, it shows that flying personnel have a low AMI incidence that stays low even after retirement. Although workforce selection most likely is of importance for these findings, they suggest that cardiovascular morbidity and mortality can be substantially reduced under specific circumstances and in specific settings.
We can also conclude that cabin crew have about the same overall cancer incidence as the general Swedish population. An increased incidence of malignant skin melanoma and a possibly increased incidence of breast cancer in female cabin crew need to be further addressed with regard to possible causes at work or outside work and preventive actions.

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