

Incidence of cancer among Nordic airline pilots over five decades: occupational cohort study

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Abstract

Objective To assess the incidence of cancer among male airline pilots in the Nordic countries, with special reference to risk related to cosmic radiation.

Design Retrospective cohort study, with follow up of cancer incidence through the national cancer registries.

Setting Denmark, Finland, Iceland, Norway, and Sweden.

Participants 10 032 male airline pilots, with an average follow up of 17 years.

Main outcome measures Standardised incidence ratios, with expected numbers based on national cancer incidence rates; dose-response analysis using Poisson regression.

Results 466 cases of cancer were diagnosed compared with 456 expected. The only significantly increased standardised incidence ratios were for skin cancer: melanoma 2.3 (95% confidence interval 1.7 to 3.0), non-melanoma 2.1 (1.7 to 2.8), basal cell carcinoma 2.5 (1.9 to 3.2). The relative risk of skin cancers increased with the estimated radiation dose. The relative risk of prostate cancer increased with increasing number of flight hours in long distance aircraft.

Conclusions This study does not indicate a marked increase in cancer risk attributable to cosmic radiation, although some influence of cosmic radiation on skin cancer cannot be entirely excluded. The suggestion of an association between number of long distance flights (possibly related to circadian hormonal disturbances) and prostate cancer needs to be confirmed.

Introduction

Airline pilots are occupationally exposed to ionising radiation, with doses of 2-6 mSv per year compared with an annual dose from background gamma radiation of approximately 1 mSv. In 1990 the International Commission on Radiological Protection recommended that in-flight exposure of jet aircrew to natural radiation should be regarded as an occupational exposure.¹ Flight personnel may also be exposed to electromagnetic fields from cockpit instruments, jet fuel, and substances emanating from materials used in aircraft construction. In addition, it has been suggested

that disruptions in sleep-wake cycles associated with flying across time zones may increase the risk of cancer by suppressing secretion of melatonin² or by some other hormone related mechanism. The aim of this paper is to describe cancer incidence among male commercial airline pilots from all five Nordic countries.

Methods

We identified national cohorts of airline pilots from various registers in the Nordic countries.³⁻⁶ We linked the cohorts to the national population registers and obtained the correct personal identifier and the possible dates of emigration, immigration, or death for every cohort member. We followed up the cohort for incident cancer cases through record linkage with the national countrywide cancer registries existing in all Nordic countries.

Follow up for cancer for each participant started at the date of first employment, at immigration, or on the date of the start of cancer registration, whichever was latest, and ended at emigration, at death, or on a common closing date (the date until which cancer registration is complete), whichever was first. The cancer follow up period was 1943 to 1996 in Denmark, 1953 to 1997 in Finland, 1984 to 1997 in Iceland, 1962 to 1996 in Norway, and 1961 to 1996 in Sweden.

We collected the numbers of block hours (that is, time from departure gate to arrival gate) in different types of flights. An expert panel classified the aircraft into low altitude, intermediate distance, and long distance categories, similarly in all countries. To quantify the radiation exposure, we converted the aircraft specific block hours to effective doses (mSv).⁷

We counted the numbers of observed cases of cancer and person years at risk by five year age groups and five year calendar periods. We calculated the expected numbers of cases for total cancer and for specific types of cancer by multiplying the number of person years in each stratum by the corresponding national cancer incidence rate. To calculate the standardised incidence ratios, we divided the observed numbers of cases by the corresponding expected numbers. We used Poisson regression to adjust for the effects of calendar period and broad age categories (<60, ≥60), to assess possible interactions between the factors.

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Table 1 Observed and expected numbers of cases of cancer and standardised incidence ratios among male airline pilots in the Nordic countries

Primary site (ICD-7 code)	Observed	Expected	Standardised incidence ratio (95% CI)
All sites (140-208)*	466	455.6	1.02 (0.93 to 1.12)
Stomach (151)	21	21.8	0.96 (0.59 to 1.47)
Colon (153)	31	32.9	0.94 (0.64 to 1.34)
Rectum (154)	19	22.4	0.85 (0.51 to 1.32)
Pancreas (157)	12	13.0	0.92 (0.48 to 1.61)
Larynx (161)	9	7.59	1.19 (0.56 to 2.29)
Lung (162)	51	66.5	0.77 (0.57 to 1.01)
Prostate (177)	64	52.9	1.21 (0.93 to 1.54)
Testis (178)	21	18.9	1.11 (0.69 to 1.70)
Kidney (180)	14	18.5	0.76 (0.41 to 1.27)
Bladder (181)	29	33.8	0.86 (0.57 to 1.23)
Skin melanoma (190):	56	24.4	2.29† (1.73 to 2.98)
Head and neck (190.0-4)‡	7	2.81	2.49† (1.00 to 5.14)
Trunk (190.5)‡	32	13.7	2.33† (1.60 to 3.30)
Limbs (190.6-7)‡	14	6.12	2.29† (1.25 to 3.84)
Other skin (191)*:	27	13.0	2.08† (1.74 to 2.79)
Kaposi's sarcoma‡	0	0.29	0.00 (0.00 to 12.7)
Brain, nervous system (193)	18	21.4	0.84 (0.50 to 1.33)
Thyroid (194)	3	3.40	0.88 (0.18 to 2.58)
Bone (196)	0	1.53	0.00 (0.00 to 2.41)
Soft tissue (197)	3	3.33	0.90 (0.19 to 2.63)
Leukaemia (204-208):	15	12.3	1.21 (0.68 to 2.00)
Chronic lymphatic‡	4	3.88	1.03 (0.28 to 2.64)
Other‡:	11	8.46	1.30 (0.65 to 2.33)
Acute myeloid‡	6	4.27	1.41 (0.52 to 3.06)
Not included above			
Basal cell carcinoma of the skin§	61	24.8	2.46† (1.88 to 3.16)

*Excludes basal cell carcinoma and, in Denmark, all non-melanoma skin cancers diagnosed before 1979.

†Significant at P<0.05.

‡Subcategory also included in main category.

§Only Denmark (1979-96) and Finland (1953-97).

Results

The cohort consisted of 10 032 men under follow up, amounting to 177 244 person years. The mean length of follow up was thus 17 years. Almost 30% of the person years were in the category of at least 20 years' follow up since the time of first employment.

During the follow up, 466 cases of cancer were diagnosed compared with 456 expected, giving a standardised incidence ratio of 1.02 (table 1). The standardised incidence ratio was increased for various categories of skin cancer. The relative risk of skin melanoma increased significantly with increasing estimated exposure to radiation during flight (P for linear trend=0.0007) (table 2) (see also bmj.com) and decreased towards more recent calendar periods. In comparison with the reference period 1994-7, the relative risks were 1.71 (95% confidence interval 0.77 to 3.80) for the period 1943-82, 1.62 (0.72 to 3.64) for

1983-7, and 1.16 (0.54 to 2.49) for 1988-93. Some indication of increasing risk with increasing radiation dose existed for other types of skin cancer and overall cancer but not for any subcategory of leukaemia or any other cancer site (see bmj.com).

The relative risk of prostate cancer in pilots aged over 60 increased with the number of block hours in long haul aircraft: eight cases occurred among pilots with more than 10 000 block hours—relative risk 3.88 (1.26 to 11.9) in comparison with the category of 1-4999 hours (P for linear trend=0.01). We observed no increase in risk with the number of block hours in long haul aircraft in younger pilots, in whom hereditary factors are assumed to have a major role.

Discussion

Few areas outside the Nordic countries have a history of several decades of population based registration of

Table 2 Observed numbers of selected cancers among male airline pilots in the Nordic countries and relative risk (95% confidence interval) estimates derived from Poisson regression model, by estimated cumulative dose. Adjusted for age and calendar period

Cumulative dose (µSv)	All sites*		Skin melanoma		Other skin*		Basal cell carcinoma†		Leukaemia, excluding chronic lymphatic	
	No	Relative risk	No	Relative risk	No	Relative risk	No	Relative risk	No	Relative risk
1-2999	149	1 (reference)	14	1 (reference)	7	1 (reference)	7	1 (reference)	3	1 (reference)
3000-9999	52	1.12 (0.81 to 1.53)	9	2.10 (0.91 to 4.87)	1	0.52 (0.06 to 4.26)	6	1.83 (0.70 to 4.79)	2	1.90 (0.32 to 11.5)
10 000-19 999	93	1.19 (0.92 to 1.54)	13	2.20‡ (1.03 to 4.72)	6	1.50 (0.50 to 4.48)	8	1.42 (0.60 to 3.41)	2	1.42 (0.23 to 8.70)
≥20 000	137	1.19 (0.93 to 1.51)	17	2.78‡ (1.30 to 5.93)	12	1.92 (0.74 to 4.98)	32	1.86 (0.98 to 3.54)	3	1.78 (0.32 to 10.0)
P trend		0.13		0.007		0.14		0.17		0.53

*Excludes basal cell carcinoma and, in Denmark, all non-melanoma skin cancers diagnosed before 1979.

†Only Denmark (1979-96) and Finland (1953-97).

‡Significant at P<0.05.

cancer. The large joint cohort size and five independent country specific observations in this joint Nordic study reduce the possibility of chance findings, and carefully registered incidence data help to avoid artefacts possibly included in the mortality statistics. Because of the complete population registration systems in all Nordic countries and accurate computerised record linkage procedures, the standardised incidence ratio estimates in this study are not prone to bias attributable to incomplete follow up or failures in record linkages.

Because our cohort included most of the cockpit crew ever certified in the Nordic countries, this study can be considered to have maximum potential to study cancer incidence among pilots. We were able to assess cancer risk by level of exposure, take into account characteristics of cancer (for example, subtypes of leukaemia, tumour latency), and estimate independent effects of exposure, age, and time period of the diagnosis in a way that has not been meaningful in small national settings. Apart from skin cancers, male Nordic pilots seem to have a pattern of cancer typical of that of high social class men in the Nordic countries. Our study shows a need for detailed studies focusing on possible work related factors involved in the evidently raised risk of skin cancer and the suggestive dose-response patterns in prostate cancer.

Contributors: See bmj.com

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Competing interests: RA has been employed by Finnair as an airline pilot since 1988 and has shares in Finnair. He is also an active member of the Finnish Pilots' Association and has been reimbursed by the association for attending medical symposiums and conducting scientific research. HE has worked as a medical consultant for Scandinavian Airlines. The other authors have no connections to airline companies.

What is already known on this topic

Airline pilots are occupationally exposed to cosmic radiation and other potentially carcinogenic elements

In the studies published so far, dose-response patterns have not been characterised

What this study adds

No marked risk of cancer attributable to cosmic radiation is observed in airline pilots

A threefold excess of skin cancers is seen among pilots with longer careers, but the influence of recreational exposure to ultraviolet light cannot be quantified

A slight increase in risk of prostate cancer with increasing number of long haul flights suggests a need for more studies on the effects of circadian hormonal disturbances

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Observational study of vaccine efficacy 14 years after trial of hepatitis B vaccination in Gambian children

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Abstract

Objective To determine the duration of protection from hepatitis B vaccine given in infancy and early childhood.

Design Cross sectional serological study of hepatitis B virus infection in children of various ages 14 years after the start of a trial of vaccination regimens.

Setting Two villages in the Gambia.

Participants Children and adolescents given hepatitis B vaccine in infancy or early childhood: 232 were aged 1-5 years, 225 aged 5-9 years, 220 aged 10-14 years, and 175 aged 15-19 years.

Main outcome measures Vaccine efficacy against infection and against chronic infection in the different age groups.

Results Vaccine efficacy against chronic hepatitis B virus carriage was 94% (95% confidence interval 89% to 97%), which did not vary significantly between the age groups. Efficacy against infection was 80% (76% to

84%). This was significantly lower in the oldest age group (65%, 56 to 73). Of the uninfected participants in this age group, 36% had no detectable hepatitis B virus surface antibody. Time since vaccination and a low peak antibody response were the most powerful risk factors for breakthrough infection ($P < 0.001$ in each case). Low peak antibody response was also a risk factor for chronic carriage (odds ratio 95, 19 to 466).

Conclusions Children vaccinated in infancy are at increased risk of hepatitis B virus infection in the late teens. The risk of chronic carriage after sexual exposure needs further assessment to determine if booster vaccines are necessary.

Introduction

Chronic infection with hepatitis B virus is a leading cause of death from cancer in Africa; a quarter of the 60 million carriers die either of primary hepatocellular carcinoma or cirrhosis of the liver.^{1,2} However,

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