UNIVERSITY OF ICELAND

Mortality among Icelandic airline pilots

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1. Abstract

1.1 Introduction

Aircrews are exposed to cosmic radiation and other possible determinants of health. In recent years possible cancer risk among pilots has become a matter of interest. Higher incidence and mortality from malignant melanoma has been reported in several epidemiological studies but results have been inconclusive. The aim was to study the mortality of Icelandic airline pilots.

1.2 Material and methods

A cohort study was carried out on 454 male commercial pilots followed up between January 1st 1960 and December 31st 2009 in the National Cause-of-Death Registry. Furthermore, the cohort was divided into Icelandair and non Icelandair pilots. Standardized mortality ratio (SMR) and 95% confidence intervals (CI) were calculated using the Icelandic male population as reference.

1.3 Results

Seventy eight deaths were observed during the follow-up period. Mortality for all causes (SMR = 0,94, 95% CI = 0,85-1,30), cardiovascular diseases (SMR = 0,52, 95% CI = 0,30-0,85) and all cancers (SMR = 0,95, 95% CI = 0,61-1,41) were decreased. Malignant melanoma mortality among Icelandair pilots was significantly increased (SMR = 8,27, 95% CI = 1,00-29,85) and mortality from aircraft accidents was prominent (SMR = 44,57, 95% CI = 29,86-64,18).

1.4 Conclusion

The results are in accordance with previous observations. Icelandic airline pilots have a lower overall mortality than the general population. Increased risk of malignant melanoma and aircraft accidents was confirmed. Increase in cancers linked to exposure of ionizing radiation was not found in excess. However, cosmic radiation cannot be excluded as a possible determinant of malignant melanoma.

Frequently used Abbreviations and Notations

Standardized mortality ratio (SMR)

Standardized incidence ratio (SIR)

Confidence interval (CI)

Millisievert (mSv)

International Agency for Research on Cancer (IARC)

Observed (Obs)

Expected (Exp)

2. Introduction

2.1 Background

In general, airline pilots are in better health than the general population. This could be explained by the healthy worker effect; they need to fulfill strict health requirements in order to gain and maintain their licences (1). Among pilots a common pattern of causes of death are malignant melanoma (2) and aircraft accidents (2,3). Very few socioeconomic groups are comparible with pilots due to socioeconomic status (4), shift work (5), travel through time zones (5) and healthy worker effect (2).

2.2 Health requirements and lifestyle

Pilots undergo health checks every six to twelve months to meet airline safety requirements. This could possibly serve as a motivation for a healthier lifestyle. However, airmansship includes exposure to possible risk factors such as cosmic radiation (6), shift work and transmeridian flights (5). In addition, commercial pilots have easy access to tax-free alcohol beverage and tobacco products (7).

2.3 Cancer

Results from previous cohort studies of cancer incidence (7) and mortality (2) among pilots have been inconsistent. Some studies have demonstrated an increased risk of cancers of the brain (8), rectum (8), prostate (9), colon (9) and acute myeloid leukemia (10,11). These are single studies and the results have not been confirmed in other and larger studies, however thes have shown no significant increase in cancers other than malignant melanoma (2,7).

Several studies show an increased risk of malignant melanoma among pilots (2,9,10,12) and that is also found in an Icelandic study (13). This has mostly been related to recreational exposure of ultraviolet radiation (7), but concerns have arisen over the possible relation between cosmic radiation and melanoma (7,14). According to an Icelandic study on sunbathing habits, use of sunscreen and history of sunburns among pilots and cabin crew, there was not a significant difference in magitude of these risk factors as compared to a sample from the general population, which have in previous studies as a comparison population (13,14).

Radiation related cancer as defined as cancers of the oesophagus, stomach, large intestine, bladder and other urinary tract, thyroid gland and other endocrine, and all leukemias have not been found in excess in mortality studies (2). Non chronic lymphatic leukemias are of particular interest in relation to radiation related cancers.

2.4 Radiation

Cosmic radiation at the cruising altitude of commercial jet aircrafts is composed of neutron and gamma rays, which are secondary radiation of galactic and solar origin (15,16). The typical annual effective dose from cosmic radiation in the general population is 0.39 mSv. However, the annual radiation dose for airline pilots is 2-6 mSv (16). Absorbed dose rate increases with altitude and geomagnetic latitude. Radiation dose is also determined by solar activity; interactions between galactic and solar radiation cause fluxations in radiation intensity. Radiation inside aircrafts consists mostly of cosmic radiation (16) and non-ionizing radiation from cockpit instruments (17) . Ultraviolet radiation is largely blocked from aircrafts material and windows (18). Currently, there is limited information on the exact effect of neutron exposure on human health (6).

Potential cancer risk to irradiated airline crew has been disputed. Few studies demonstrate a relationship between occupational exposure and certain radiation related cancer, such as acute myeloid leukemia (10,11), brain cancer (8) and rectal/colon cancer (9). Several studies have shown a significant increase in malignant melanoma incidence (7,12) and mortality (2) among airline pilots and other crew members (19). An Icelandic study on the prevalence of risk factors for malignant melanoma among aircraft crew compared to a sample from the general population did not show a significant difference that could solely explain the high malignant melanoma incidence (14). Studies on atomic bomb survivors (20,21), nuclear industry workforces (22,23), nuclear test participants (24,25,26), radiologic technologists (27) and patients who have undergone radiotherapy (28) have been conducted and indicate that a relationship between ionizing radiation and malignant melanoma exits, however results from other studies have not confirmed these findings.

2.5 Circadian rhythm disturbances

Flight personnel experience considerable circadian rhythm disruption due to transmeridian flights, shift work and night work throughout their career. In 2007, International Agency for Research on Cancer, IARC, classified chronic circadian disruption as a probable human carcinogen (5). Circadian disruption may lead to suppression of the chronobiotic hormone melatonin and melatonin is considered to have anti-cancer properities (29,30). Studies on the role of circadian disruption on the cancer risk among aircrews are lacking.

2.6 Aircraft accidents

Aviation safety has evolved over the years (http://www.faa.gov/about/initiatives/iasa). Regulations have been set regarding minimum rest requirements for commercial pilots, aircraft equipment has developed and committees investigating aircraft accidents have been established and reinforced. In spite of this, the number of aircraft accidents and incidents is in direct proportion with the major increase in flight over the past decades. Although very uncommon in the general population, aircraft accidents have been a prominent factor in previous mortality studies (2,9)

2.7 Purpose of this study

The aim of this research was to study the mortality among Icelandic airline pilots.

3. Material and methods

This is a cohort study carried out on 454 commercial pilots licenced in Iceland according to the Icelandic Aviation Authority. The pilots were all male. Information on employment years was obtained from Icelandair (Flugfelag Islands, Icelandair established 1937 and Loftleiðir,Icelandic Airline, established 1944). Icelandair has operated regular routes to Europe and North-America since 1952, and in 1970 jets were taken into use. The cohort was thus divided into Icelandair and non-Icelandair pilots.From this information a file was compiled with the indetification number of each pilots enabling a record linkage with the National Registry which is also registred on identification number in order to obtain date of death or emigration for each pilot. A second record linkage was made to the National Cause-of-Death Registry. Pilots entered the study at beginning of employment and were followed up between January 1st 1960 and December 31st 2009, the year 1960 was the first year available in the registries. Subjects with last known vital status before 1960 were thus excluded from the study.

Person-years were calculated for each subject from beginning of employment to date of death, date of emigration or end of follow up on December 31st 2009, whichever came first. Expected number of deaths was calculated by multiplying person-years from the cohort by the Icelandic male population mortality rates for 5 year calendar and age intervals. Observed number of deaths was compared with expected number of deaths, and standardized mortality ratio (SMR) and 95% confidence intervals (CI) were computed assuming a Poisson distribution (31).

Survival for event (death due to aircraft accidents) free proportions was shown for the Icelandair pilots and the non-Icelandair pilots by Kaplan-Meier curves censored at December 31st 2009 (32).

The National Bioethic Committee, and the Data Protection Commission approved the study.

4. Results

A compilation of 459 male commercial pilots was made. Five pilots had either died or ended their employment in Iceland prior to January 1st 1960 and had to be excluded from the analysis. Thus, 454 pilots were qualified for follow-up with a total of 12900 person years. During the follow-up 62 pilots emigrated and 78 died, as seen in Table 1.

Table 1. Cohort characteristics.

	No.	%
Total eligible	454	100
Icelandair	265	58.4
Non-Icelandair	189	41.6
Emigrated	62	13.7
Death during follow-up	78	17.2
Icelandair	45	9.9
Non-Icelandair	33	7.3

	Years
Mean age at beginning of employment	
Icelandair	26.4
Non-Icelandair	24.7
Mean age at death	
Icelandair	60.4
Non-Icelandair	52.1
Person-years	
Icelandair	8471.0
Non-Icelandair	5190.2

Figure 1. Overview of causes of death among Icelandic airline pilots 1960-2009.

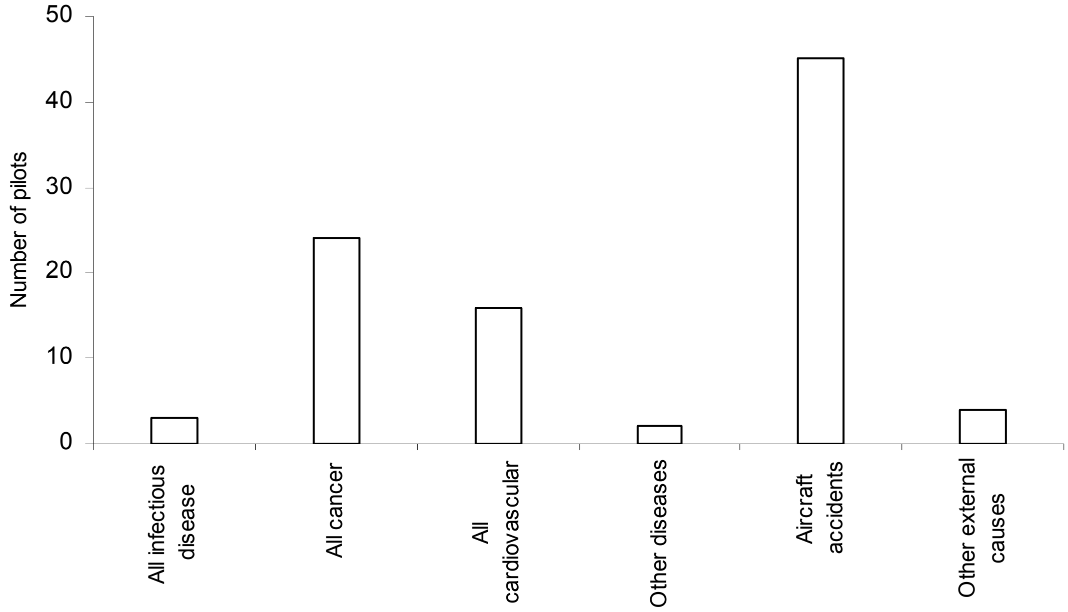


Figure 1 demonstrates the number of selected causes of death among Icelandic male airline pilots. Noticeably, aircraft accidents is a major cause of death, yielding an SMR of 44.57 (95% CI = 29.86 to 64.18) (Table 2). Four pilots died from other external causes, which is considerably lower than expected in the general public (SMR = 0.37; 95% CI =0.10 to 0.94). These other external causes were poisoning, motor vehicle accident and suicide. Three pilots died from infectious diseases; two from pneumonias and one from gastroenteritis and colitis, origin unspecified. Mortality from cancer overall was lower than in the general population (SMR = 0.95; 95% CI 0.61 to 1.41). The SMR for malignant melanoma, prostate cancer and brain cancer was increased, however non-significantly. Airline pilots had a significantly lower mortality from cardiovascular diseases (SMR = 0.52; 95% CI = 0.30 to 0.85) and all causes except aircraft accidents than the general population (SMR = 0.59; 95% CI = 0.44 to 0.78) (Table 2).

Table 2. Observed (Obs) and expected (Exp) number of deaths, standardized mortality ratio (SMR), and 95% confidence intervals (CI) among 454 Icelandic airline pilots 1960-2009 for all causes, and selected causes of death.

Cause of death	Obs	Exp	SMR (95% CI)
All causes	78	83.34	0.94 (0.85 to 1.30)
All causes except aircraft accidents	49	82.69	0.59 (0.44 to 0.78)
All cancer	24	25.19	0.95 (0.61 to 1.41)
Malignant melanoma	2	0.35	5.79 (0.70 to 20.90)
Prostate cancer	5	3.13	1.60 (0.52 to 3.73)
Brain cancer	2	1.18	1.69 (0.20 to 6.10)
Radiation related cancer[1]	6	6.80	0.88 (0.32 to 1.92)
Non-radiation related cancer[2]	18	18.37	0.98 (0.58 to 1.55)
All cardiovascular	16	30.53	0.52 (0.30 to 0.85)
Aircraft accidents	29	0.65	44.57 (29.86 to 64.18)
All external except aircraft accidents	4	10.93	0.37 (0.10 to 0.94)

[1] Cancer of oesophagus, stomach, large intestine, bladder and other urinary tract, thyroid and other endocrine, multiple myeloma and leukemia.

[2] All cancer except radiation related cancer.

The SMRs for Icelandair and non-Icelandair pilots can be viewed separatly in Tables 3 and 4. Both of the malignant melanoma mortalities were among Icelandair pilots, yielding an SMR of 8.27 with a statistical significance (95% CI 1.0004 to 29.85) Four mortalities from prostate cancer (SMR = 1.74; 95% CI = 0.47 to 4.46) and two mortalities from brain cancer (SMR = 2.55; 95% CI = 0.31 to 9.22) were observed in the Icelandair group versus one and none in the non-Icelandair group, respectively.

SMRs for aircraft accidents were prominent in both groups and statistically significant. Seventeen mortalities from aircraft accidents were observed in the non-Icelandair group, compared to 12 among Icelandair pilots.

Table 3. Observed (Obs) and expected (Exp) number of deaths, standardized mortality ratio (SMR), and 95% confidence intervals (CI) among 265 Icelandair pilots 1960-2009 for all causes of death and selected causes of death.

Cause of death	Obs	Exp	SMR (95% CI)
All causes	45	58.35	0.77 (0.56 to 1.03)
Malignant melanoma	2	0.24	8.27 (1.00 to 29.85)
Prostate cancer	4	2.29	1.74 (0.47 to 4.46)
Brain cancer	2	0.78	2.55 (0.31 to 9.22)
Radiation Related cancer[1]	3	4.80	0.63 (0.13 to 1.83)
Aircraft accidents	12	0.43	27.99 (14.47 to 48.99)

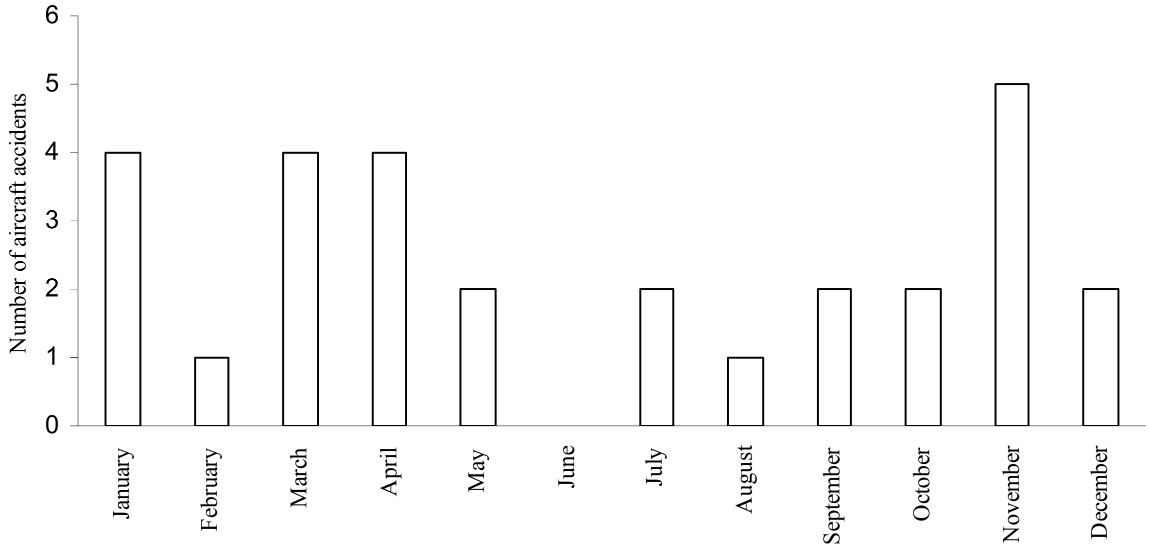
[1] Cancer of oesophagus, stomach, large intestine, bladder and other urinary tract, thyroid and other endocrine, multiple myeloma and leukemia.

Table 4. Observed (Obs) and expected (Exp) number of deaths and standardized mortality ratio (SMR), and 95% confidence intervals (CI) among 189 non-Icelandair pilots 1960-2009 for all causes of death, and selected causes of death.

Cause of death	Obs	Exp	SMR (95% CI)
All causes	33	24.99	1.32 (0.91 to 1.85)
Malignant melanoma	0	0.10	-
Prostate cancer	1	0.83	1.20 (0.03 to 6.69)
Brain cancer	0	0.40	-
Radiation related cancer[1]	3	2.00	1.50 (0.31 to 4.38)
Aircraft accidents	17	0.22	76.59 (44.65 to 122.54)

[1] Cancer of oesophagus, stomach, large intestine, bladder and other urinary tract, thyroid and other endocrine, multiple myeloma and leukemia.

Figure 2. Distribution of aircraft fatality among Icelandic airline pilots 1960-2009 in the calendar year.



As seen in Figure 2, aircraft fatalities are equally distributed between the first and second half of the calendar year. However, by splitting the calendar year into winter and summer terms, one from beginning of November to end of April and the other from beginning of May to end of October, shows that approximately 70 percent of all aircraft fatalities among airline pilots in Iceland 1960-2009 occurred during the winter months.

Figure 3. Survival function for death due to aircraft accidents among Icelandair and non-Icelandair pilots 1960-2009.

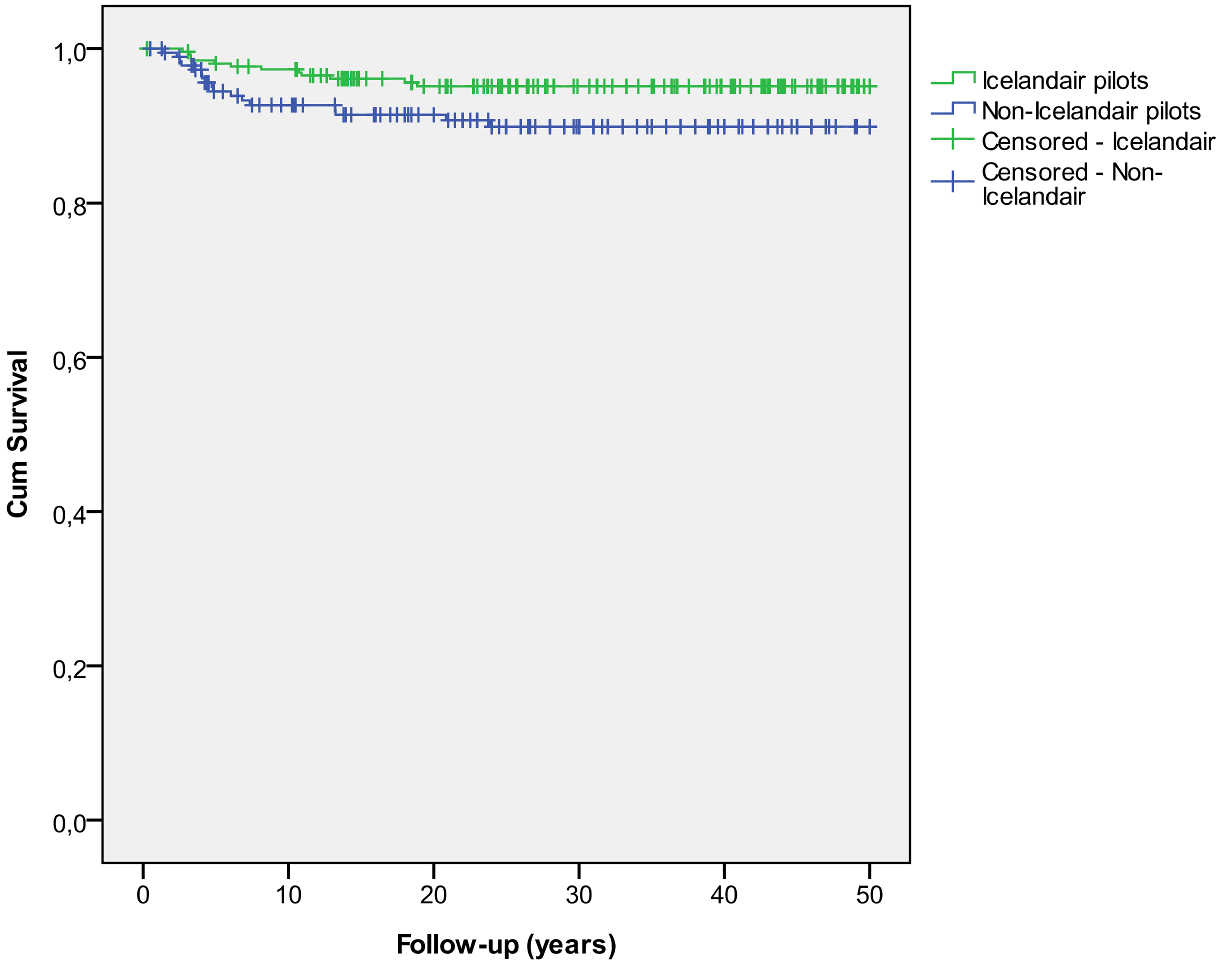


Figure 3. Aircraft fatality among Icelandic airline pilots 1960-2009 with respect to years of service.

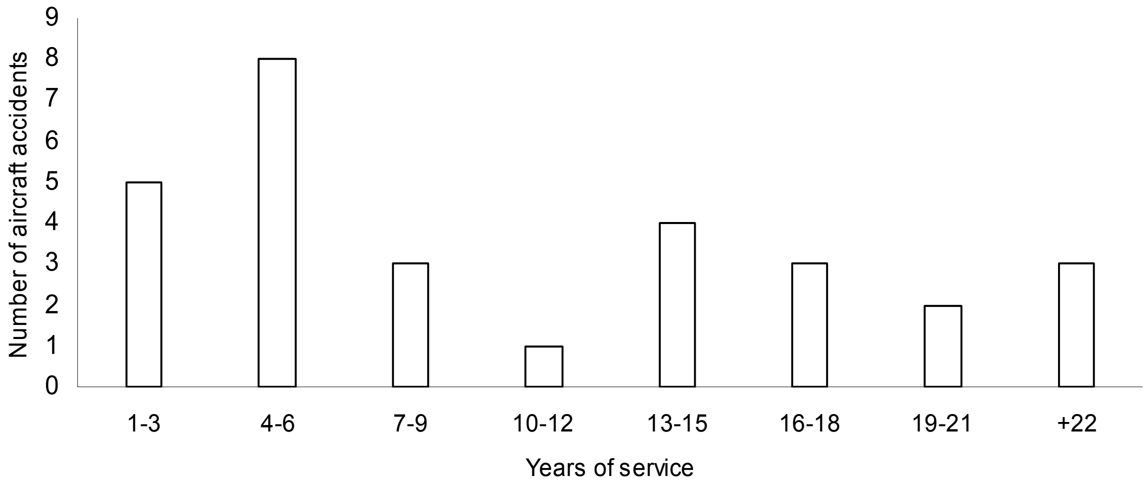
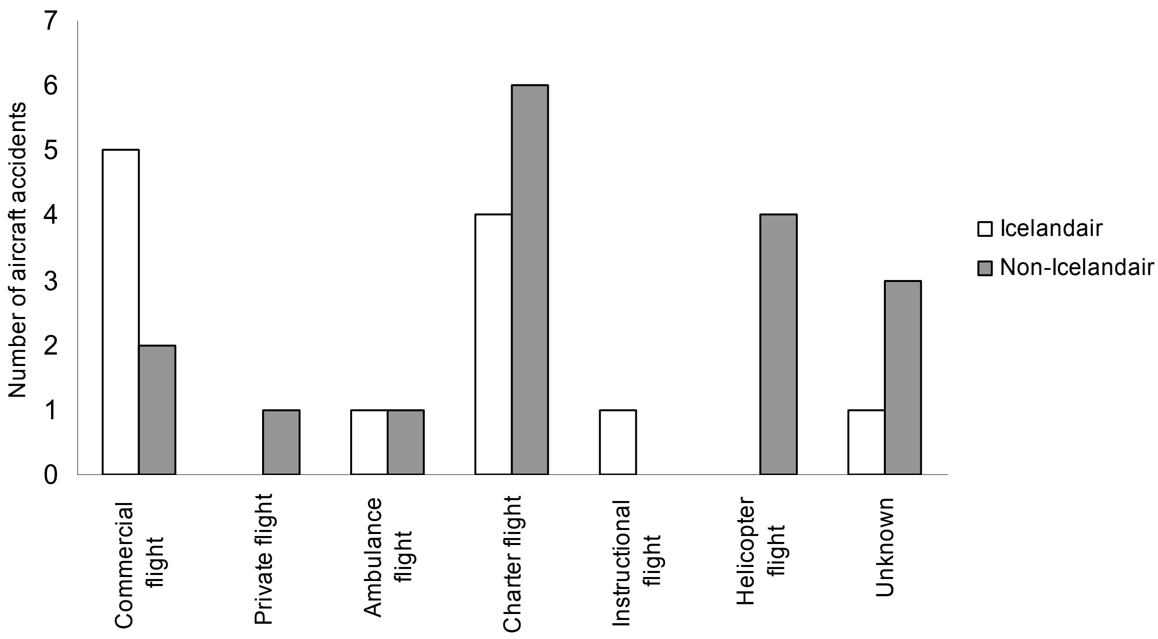


Figure 4. Classification of aircraft fatality among Icelandair and non-Icelandair pilots 1960-2009.



Mean years of service at death from aircraft accident was 12.6 years among Icelandair pilots and 8.9 years among non-Icelandair pilots. Forty five percent of aircraft fatalities occurred during the first six years of the pilot's employment (Figure 4).

Most aircraft fatalities occurred in charter and commercial flights (Figure 5).

5. Discussion and conclusion

Icelandic pilots have a lower overall mortality than other males in the general population, When aircraft accidents is excluded from all mortalities the SMR for all causes of death was 0.59 and the 95% CI did not include unity, confirming a strong healthy worker effect. In this cohort, mortality from cardiovascular diseases was markedly decreased. Mortality from aircraft accidents among all pilots, and malignant melanoma among Icelandair pilots were significantly increased. This has been previously demonstrated in several studies (2,7,8,9).

Aircraft accidents

As supported by other studies, aircraft accidents is a major cause of death among airline pilots. Risk seems to be higher for younger pilots (2,3,9), perhaps due to lack of experience or risk preference, although there seems to be an inverse correlation with traffic accidents on ground. When the data for Icelandair pilots is compared to data for other pilots, we notice that five more pilots died in the non-Icelandair group, despite the group being smaller. Possible explanations could be that the non-Icelandair pilots were more likely to be flying more hazardous flights, such as helicopter flights and rescue missions, whereas Icelandair pilots were mostly flying scheduled flights. Moreover, Icelandair pilots had more work experience at recruitment and mean age of non-Icelandair pilots was lower. Most aircraft accidents occured during the winter months raising questions whether poor weather conditions and visibility are serious determinants of aircraft fatality.

Cancer

In recent years, researchers have focused on possible cancer risk among pilots due to occupational exposure to ionizing radiation and circadian disruption. Results from previous cancer incidence (1,7,11) and mortality (2,8,9,10) studies have been inconsistent. Some studies have demonstrated an increase in brain cancer (8), colon/rectal cancer (9), prostate cancer (7,10), and acute myeloid leukemia (10,11), but the significant increase in malignant melanoma incidence (1,7,12) and mortality (2,9) has been the most consistent findings.

Malignant melanoma

Five cases of malignant melanoma were observed in a cancer incidence study that was carried out on the same cohort (1). All of the cases were among Icelandair pilots. The standardized incidence ratio (SIR) for malignant melanoma in the study was 10.20 for all pilots and 15.63

for Icelandair pilots, with statistical significance (1). Notably, two of these pilots died from the skin cancer, a disease with a relatively good survival rates. The increase in malignant melanoma incidence and mortality has been very much in focus in epidemiological studies on pilots globally. No conclusion has yet been reached on the question of whether ionizing radiation is a contributing factor. In order to determine whether ultraviolet radiation exposure is confounding the ionizing radiation in the development of malignant melanoma in aircrews, future research is needed (14).

Radiation related cancer

Increase in radiation related cancers, as defined as cancers of the oesophagus, stomach, large intestine, bladder and other urinary tract, thyroid gland and other endocrine, and all leukemias according to the ESCAPE study (2), were not found in excess in the present study, consistet with the results of the ESCAPE study (2).

Brain cancer

Although cancers of the brain are assumed to be radiation related cancer, they were excluded from the radiation related cancer subcategory because definitions from previous research were used (35). SMR for brain cancers was increased although not statistically significantly among Icelandair pilots. A study on Canadian pilots showed significant increased brain cancer incidence and mortality (8), but these results have not been confirmed in larger studies (7).

Prostate cancer

Five deaths from prostate cancer were observed in this study, thereof were four cases among the Icelandair pilots. The SMR for prostate cancer was increased, however not statistical significant. In the Nordic study of pilots the increase in prostate cancer was associated with long carrier (7).

Exposure to cosmic radiation

Icelandic pilots could possibly be somewhat of a special case, due to geographic location. When ionizing particles hit the atmosphere at the equator, the magnetic field causes them to diverge towards the poles. This results in a higher radiation dose with increasing distance from the Equator. Commercial airline routes from Iceland to North America do pass in the vicinity of the north magnetic pole, and a large part of the European routes are also in the polar region (33). Therefore, it may be hypothesized that Icelandic pilots flying trans Atlantic routes regularly receive higher annual radiation dose than other pilots. When jets were taken into use in the 1970s, radiation exposure increased among Icelandair pilots due to higher altitude during flight. Furthermore, pilots passing several time zones are more likely to experience chronobiological disturbances. Notably, all malignant melanoma and brain cancer cases, and four out of five prostate cancer cases were in the Icelandair pilots.

By legislation set by the European Union in the 1990s, airlines in the member states are required to keep radiation exposure to aircrews under control (34) by work schedules and ascertianing that pregant aircrew members are not exposed to more radiation than 1 mSv during pregnancy. Even though previous research has not been conclusive regarding cancer risk, the possible harmful effects of cosmic radiation cannot be excluded (7). Further research on flight crews is needed. Keeping in mind that the etiology of cancer is multicausal, education of the crews about other potential risk factors, for example concerning skin cancers may be important preventive measure.

Further it is important to be aware of that little is known about the effect of cosmic radiation on human health, particularly the neutron component (6). It is a common practice to transfer knowledge between different groups that are exposed to different types and quantity of ionizing radiation, i.e. atomic bomb survivors, nuclear workers and commercial pilots. However, such comparison should be done with caution, as there is a difference in radiation composition, magnitude and duration of exposure in the different studies, and these factors may be important for the understanding of the development of different types of cancer.

Strenght and limitation

The strength of this study involves a detailed follow-up in the National Cause-of-Death Register and the National Register. The small size of the cohort is of course a serious drawback of the study. Moreover accurate information about individual exposure to cosmic and ultraviolet radiation exposure would improve the evaluation of the cancer risk in the study. The results of this study were based on a small number of cases and consequently the confidence intervals were wide.

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