

## **Cancer Incidence in California Flight Attendants**

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## Abstract

Unusual exposure opportunities to flight crews from chemicals, cosmic radiation and electric and magnetic fields have made them the subject of considerable interest for certain health outcomes. To date, however, few studies have evaluated the cancer experience of people in these occupations. This project, a collaboration between the California Department of Health Services' environmental and occupational health programs and the Association of Flight Attendants (AFA), was designed to provide an initial evaluation of the incidence of cancers of the breast and other sites among California AFA members. With an average annual membership of nearly 6000 Californians during the study period, it is the largest such study of cabin crews to date.

AFA membership files were matched to California's statewide cancer registry to identify cancer diagnoses between 1988-1995. During this time a total of 175 newly diagnosed cancers occurred among AFA members with California residential histories: 149 among women and 26 among men. Of the total, 129 were invasive cancers and 46 were *in situ*. The two most common invasive cancer types in this group, female breast cancer (60 cases) and malignant melanoma of the skin (15 cases), also occurred substantially more frequently among flight attendants than would be expected from the general population. Breast cancer incidence was over 30% higher than expected, and melanoma incidence was roughly twice that expected. The observed elevations are not likely to be due to screening, as cohort members did not present at earlier stages of disease compared to the general population. Both of these are cancers that are associated with higher socioeconomic status and have been suggestively associated with various sources of radiation. Consistent with the results from a much smaller European study of cabin crews, these data suggest that follow-up investigations should focus on the potential relative contribution of workplace exposures and lifestyle characteristics to the higher rates of disease for these two cancers.

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## Background

Health problems faced by flight attendants have been of concern to workforce members for some time and were summarized by the National Institute for Occupational Safety and Health in testimony before Congress in 1983.<sup>1</sup> Particular concerns cited included the many hours spent at high altitudes which result in increased exposure to radiation and ozone exposures, greater exposures to carbon monoxide and hazardous components of jet exhaust, and time zone and schedule changes. This risk profile is consistent with at least two potential pathways for increased breast cancer risk in flight personnel: 1) disruption of melatonin production, resulting in increased bioavailability of estrogen, and 2) increased exposure to ionizing radiation. Studying flight personnel offers a particularly unique opportunity to further examine breast cancer associated risks from ionizing radiation, one of the best established environmental risk factors for the disease.

The only published study to date to systematically examine this risk relationship is a recent report from Finland which evaluated whether occupational exposure among Finnair flight attendants was associated with an increased risk of cancer. Using record linkage to the national cancer registry, the study included 1577 female and 187 male flight attendants who had worked for Finnish airline companies. A significant excess of breast cancer, based on 20 observed cases, (standardized incidence ratio 1.87, 95% confidence interval 1.15-2.23) was found among female workers. The risk of breast cancer was highest after 15 years since recruitment. Although based on only 2 cases, the risk of bone cancer was also significantly elevated (SIR=15.1, 95% C.I. Risks of leukemia (SIR=3.47, 95% C.I. 0.43-12.9) and skin melanoma (SIR = 2.11, 95% C.I. 0.43-6.15) were elevated, but not statistically significantly so. This study found concentration of excess risks to primary sites sensitive to radiation suggesting that ionizing radiation during flights may add to the cancer risk of flight personnel<sup>1</sup>. Two letters to the editor following the publication of the Finnish study have reported similar breast cancer excesses in smaller cohorts of flight attendants [Lynge, 1996; Wartenberg, ??]. Larger studies have been needed to follow-up on these observations.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated that the mean annual effective dose to US residents is 240 millirem (2.4 mSv) per year. For the average flying passenger, the added dose of radiation from flying is less than 3 mrems/yr. However, a crewmember flying 70-83 hours per month may receive up to 1000 mrems (10 mSv) /year of additional ionizing radiation exposure. Cosmic rays are the major contributing factor to the increased load of overall radiation among airline passengers and crew members. Dose levels on single non-stop flights may range from as little as .10 mrem (.0001 mSv) for a 30 minute flight from Houston to Austin Texas, to as high as 9.3 mrem (.0093 mSv) for a flight from Athens, Greece to New York. Cumulative dose of radiation for a flight attendant may be roughly estimated by use of a computer program, CARI-2, which is available from the FAA.

In general, risks for adult cancer (solid tumors and leukemia) due to radiation exposure have been obtained from the cohort of atomic bomb survivors, and those exposed to diagnostic or therapeutic radiation. The National Research Council (US) and National Radiological Protection Board (UK) have provided risk coefficients showing excess cancer deaths in adults: 6.3 in 100,000 per mSviii.iv. Friedberg evaluated cosmic radiation exposure for 32 flights. He estimated that the increased risk of dying from cancer due to galactic radiation received from 20 years of flying ranges from 0.3 to 11 per 1000 crewmembersv.

The overall objective of this study was to evaluate the incidence of cancer in a large cohort of flight attendants resident in California between 1988 and 1995. Specific objectives included:

- Assessment of the observed vs. expected incidence of breast cancer among all female California flight attendants.
- Assessment of the clinical characteristics of breast cancers among flight attendants compared to the general population.
- Assessment of the observed vs. expected incidence of all cancers among California flight attendants.

The primary hypothesis of this study was that flight attendants have an increased risk of breast cancer. Exposure to ionizing radiation is one of the best established environmental risk factors for breast cancer. Although cosmic radiation levels may be substantial to flight personnel, this risk association has been little studied. The present study offers a first step at evaluating whether known higher exposure levels in a very specialized occupational group may be associated with increased incidence of breast cancer, and other cancers thought to be radiogenic. This study also offers an opportunity to evaluate the breast cancer incidence experience in a substantially larger cohort of female flight personnel than has been studied to date.

## **Methods**

### ***Data Sources***

We linked data from the Association of Flight Attendants and the California Cancer Registry in order to ascertain the incidence of cancer in a large cohort of flight attendants.

The Association of Flight Attendants (AFA) is the world's largest flight attendant union with more than 46,000 members at 26 airlines. The AFA provided us with data on their current and former members, which included personal identifiers, current address, demographic data, and employment data. The AFA also provided us with some data on former union members who had been removed from the membership database because they had died, were fired, or left the union for another reason. Additionally, the AFA provided mid-year statistical reports for our study period, which we used to estimate the person-years at risk.

The California Cancer Registry (CCR) maintains a statewide surveillance system for all newly diagnosed cancer cases in California. Registration is estimated to be 98% complete. For this study, we included all newly diagnosed invasive and *in situ* tumors among state residents from January 1, 1988 through December 31, 1995.

### ***Record Linkage***

We conducted a computer match of the AFA and cancer registry files using AUTOMATCH, a computer program used to conduct automated probabilistic record linkage [Jaro, 1995]. The matching variables used included name, date of birth, gender, and social security number. Individual's addresses and their occupation code from the cancer registry, if available, were used to confirm possible matches. AUTOMATCH used all of the matching variables to determine the probability that a pair of records from the respective datasets represented the same individual. The probability score is based on the agreement or disagreement of the matching variables common to the two datasets, the error rates of the matching variables in the respective datasets, and how likely agreement is to have occurred by chance.

### ***Statistical Analysis***

#### ***Proportional Incidence Ratios***

We calculated Proportion Incidence Ratios (PIRs) for selected cancer types by dividing the observed number of site-specific cancers by the number expected in the AFA cohort. The observed number of each cancer type in the flight attendants was obtained from our record linkage. The expected number was derived by multiplying the site-specific proportion of all cancers for each 5-year age group in our CCR reference groups, by the total number of flight attendant cancers in each age group, and summing over all age groups. Since race/ethnicity is not routinely collected by the AFA, we used two comparison groups for PIRs: all races combined, and non-Hispanic whites. In calculating PIRs for males, we excluded Kaposi's sarcoma (KS) from both the total observed flight attendant cancers and from the denominator used to calculate the site-specific proportions in the comparison groups, since KS accounted for a disproportionate number of all invasive cancers in male flight attendants. PIRs were calculated for the age range 20 to 64, which included all incident flight attendant cancers. Confidence intervals for the PIRs were determined by the Vandenbroucke method with UIm adjustment [UIm, 1990]. The use of this method for PIRs has been described by van der Gulden [van der Gulden, 1992].

#### ***Standardized Incidence Ratios***

We calculated Standardized Incidence Ratios (SIRs) for selected cancer types by dividing the observed number of site-specific cancers by the number expected in the AFA cohort. As with the PIRs, the observed number of each cancer type in the flight attendants was obtained from our record linkage. The expected number of cancers in flight attendants was calculated by multiplying published California statewide sex-and age- and site-specific incidence rates for the time period 1989 through 1993 [Perkins, 1996] by the

number of age- and sex-specific person-years at risk for the AFA cohort who were California residents. Since no race/ethnicity was available for AFA members, we used all races combined and non-Hispanic white reference rates. Confidence intervals for SIRs were calculated using the Vandenbroucke method with UIm adjustment [UIm, 1990].

### *Person-years at Risk*

Since home address for AFA members was only known for December 1997 (when we received the membership database), it was necessary to use mid-year statistical reports provided by the AFA to determine the denominator for our SIRs. These reports provided membership totals for each union council (a political division similar to a union local) for the duration of our study period. Since there was no record of which AFA members were California residents during our study period, we assumed that the members of each AFA council had the same probability of being a California resident during the entire study period as they did in December 1997. By multiplying the annual council membership totals by the estimated percentage of California residents for each council and summing over all councils, we obtained our estimate of the annual number of person-years at risk for AFA California residents. Since the AFA statistical reports didn't present the council membership totals by age or gender, we retrospectively estimated the sex and sex-specific age distributions for each year of the study period from those present on the December 1997 file. We weighted each individual's contribution to these distributions by their probability of being a California resident (again determined from their union council membership in 1997). We then multiplied these annual sex and sex-specific age distributions by the annual estimate of person-years at risk and summed over all years of our study period to obtain estimates of the total age- and sex-specific person-years at risk for the AFA cohort who were California residents.

### ***Breast Cancer in AFA members vs. the general population***

The characteristics of the invasive breast cancer cases occurring among the AFA cohort were compared to those occurring in the general female California population. For the purposes of this analysis, cases among the general California population were defined as all females aged 20-64 who were diagnosed with invasive breast cancer between 1988 and 1995 and whose occupation in the CCR database was not listed as a flight attendant (n=74,990). Frequency distributions were constructed and Pearson chi-square statistics were calculated to evaluate differences between cases in the cohort and in the general population.

## **Results**

Characteristics of California AFA members were compared to those of the international membership (*Table 1*). The AFA workforce consists primarily of young (born 1960 or later) women. California members tend to be slightly older and have somewhat longer tenure. United Airlines is the primary employer for union members as a whole (46%), and dramatically dominates the California membership (74%). California flight

attendants are more likely to be assigned to international domiciles (32%) than is the general union membership (19%).

**Table 1. Demographic and industry characteristics of the Association of Flight Attendants membership, December 1997.**

<i>Characteristic</i>	<i>Total A.F.A.</i>		<i>A.F.A. with California Residence</i>	
	<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>
<b>Gender</b>				
Female	44,021	83%	6,895	85%
Male	8,720	17%	1,216	15%
Totals	52,741	100%	8,111	100%
<b>Decade of Birth</b>				
Before 1940	638	1%	182	2%
1940s	7,946	15%	2,161	27%
1950s	9,145	17%	1,620	20%
1960s	15,975	30%	2,284	28%
1970s	6,621	13%	813	10%
1980 or later	131	<1%	11	<1%
unknown	12,285	23%	1,040	13%
<b>Joined AFA</b>				
Before 1970	4,376	8%	1,365	17%
1970s	6,031	11%	1,415	17%
1970s	16,899	32%	1,965	24%
1980s	24,266	46%	3,349	41%
1990s	1,169	2%	17	<1%
<b>Airline</b>				
United	24,457	46%	5,982	74%
US Airways	10,612	20%	921	11%
Others	17,672	34%	1,208	15%
<b>Domicile/Assignment</b>				
Domestic	42,943	81%	5,552	68%
International	9,798	19%	2,559	32%

### ***Record Linkage Results***

The files from the AFA (58,848 active and retired members) were matched to those of over a million newly diagnosed cancers among California residents between 1988-1995 (*Figure 1*). A total of 207 cancers were diagnosed during this time period among AFA members. Cases which occurred among members who were hired after 1995 (n=14), who were otherwise hired after their date of diagnosis (n=8), or who were purged from the AFA database prior to diagnosis (n=10) were eliminated from the analyses.

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A total of 175 cases of cancer were included in our analyses, including 129 cases of invasive cancer and 46 cases of *in situ* cancer. Cancer of the female breast was the most common cancer among female flight attendants (*Table 3*). During the eight years of the study a total of 72 cases of breast cancer occurred among California AFA members: 60 cases of invasive breast cancer and 12 cases of *in situ* breast cancer.

**Table 3. Invasive cancers in female flight attendants, 1988-1995.**

Type of Cancer	Invasive	<i>In situ</i>
Breast	60	12
Melanoma of the skin	12	1
Corpus uteri	5	
Ovary	5	
Lung and bronchus	3	
Rectum	3	
Cervix uteri	2	27
Colon	2	
Bladder	2	1
Larynx	2	
Non-Hodgkin's lymphoma	2	
Oral cavity and pharynx	2	
Thyroid	1	
Brain	1	
Vulva	1	4
Stomach	1	
All cancer sites combined	104	45

Kaposi's sarcoma was the most common cancer among male cohort members (*Table 4*). For both men and women the second most common cancer was malignant melanoma of the skin.

**Table 4. Invasive cancers in male flight attendants, 1988-1995.**

Type of Cancer	Invasive	<i>In situ</i>
Kaposi's sarcoma	15	

Melanoma of the skin	3	
Non-Hodgkin's lymphoma	2	
Lung and bronchus	1	
Testis	1	
Larynx	1	
Multiple myeloma	1	
Leukemia	1	
Bladder		1
All cancer sites combined	25	1

### ***Proportional Incidence Ratios***

Proportional incidence ratios were computed for the two most common cancers which occurred among women in the cohort, and for lung cancer because of interest in this particular malignancy among workforce members. Because race/ethnicity information was unavailable for the AFA cohort they were computed two ways: one comparing cohort proportions to those observed for non-Hispanic white women of the same ages, and one comparing the proportions to those for all races combined. Compared to non-Hispanic white women (*Table 5*), AFA members had a significantly higher proportion of breast cancer (PIR=1.35).

**Table 5. Proportional Incidence Ratios of *invasive* cancers among female flight attendants, ages 20-64, 1988-1995, using *non-Hispanic white* cancer reference proportions.**

Type of Cancer	Observed	Expected	SIR	(95% CI)
Breast	60	44.32	1.35	(1.03-1.74)
Melanoma of the skin	12	7.20	1.67	(0.86-2.92)
Lung and bronchus	3	7.90	0.37	(0.07-1.12)

Compared to women of all races, AFA members exhibited similarly elevated breast cancer incidence (*Table 5*), as well as significantly more melanoma.

**Table 6. Proportional Incidence Ratios of *invasive* cancers among female flight attendants, ages 20-64, 1988-1995 *all races* cancer reference proportions.**

Type of Cancer	Observed	Expected	SIR	(95% CI)
Breast	60	42.73	1.40	(1.21-1.63)
Melanoma of the skin	12	5.60	2.14	(1.32-3.49)
Lung and bronchus	3	7.16	0.42	(0.08-1.24)

The most common *in situ* cancer (cancer of the uterine cervix) occurred in about the same proportion among AFA members as in the general population, but *in situ* breast tumors occurred more frequently. These same relationships were evident regardless of which comparison group was used (Tables 6 and 7).

**Table 6.** Proportional Incidence Ratios of *in situ* cancers among female flight attendants, ages 20-64, 1988-1995, using **non-Hispanic white** cancer reference proportions.

Type of Cancer	Observed	Expected	SIR	(95% CI)
Cervix uteri	27	31.85	0.85	(0.56-1.24)
Breast	12	7.49	1.60	(0.82-2.81)

**Table 7.** Proportional Incidence Ratios of *in situ* cancers among female flight attendants, ages 20-64, 1988-1995, **all races** cancer reference proportions.

Type of Cancer	Observed	Expected	SIR	(95% CI)
Cervix uteri	27	33.76	0.80	(0.53-1.17)
Breast	12	6.53	1.84	(0.95-3.22)

### ***Standardized Incidence Ratios***

The overall incidence of cancer among women in the California AFA cohort was not significantly different than that which would be expected from either non-Hispanic white (Table 8) or all races (Table 9) of women of the same ages in the general population. Results for specific cancers were very similar to those from the proportional incidence analysis. Cancer of the female breast and malignant melanoma of the skin occurred more frequently among cohort members, and lung cancer occurred somewhat less frequently (although not significantly less) than might be expected in the general population.

**Table 8.** Standardized Incidence Ratios of **invasive cancers** among female flight attendants, 1988-1995 using **non-Hispanic white** cancer reference rates.

Type of Cancer	Observed	Expected	SIR	(95% CI)
Breast	60	46.43	1.29	(0.99-1.66)
Melanoma of the skin	12	6.55	1.83	(0.94-3.21)
Lung and bronchus	3	8.73	0.34	(0.06-1.02)
All cancer sites combined	104	106.50	0.98	(0.80-1.18)

**Table 9.** Standardized Incidence Ratios of **invasive cancers** among female flight attendants, 1988-1995 using **all races** cancer reference rates.

Type of Cancer	Observed	Expected	SIR	(95% CI)
Breast	60	42.17	1.42	(1.09-1.83)
Melanoma of the skin	12	4.80	2.50	(1.28-4.38)
Lung and bronchus	3	7.32	0.41	(0.08-1.21)
All cancer sites combined	104	99.25	1.05	(0.86-1.27)

The incidence of *in situ* tumors did not differ significantly from what may have been expected among non-Hispanic white women (*Table 10*) or among women of all races (*Table 11*).

**Table 10.** Standardized Incidence Ratios of *in situ* cancers among female flight attendants, ages 20-64, 1988-1995, using **non-Hispanic white** cancer reference proportions.

Type of Cancer	Observed	Expected	SIR	(95% CI)
Cervix uteri	26	25.67	1.01	(0.66-1.49)
Breast	12	8.77	1.37	(0.70-2.40)

**Table 11.** Standardized Incidence Ratios of *in situ* cancers among female flight attendants, ages 20-64, 1988-1995, **all races** cancer reference proportions.

Type of Cancer	Observed	Expected	SIR	(95% CI)
Cervix uteri	26	26.17	0.99	(0.65-1.46)
Breast	12	7.43	1.61	(0.83-2.83)

The observed higher incidence of malignant melanoma of the skin in female flight attendants appeared to also be suggestively elevated among male members of the workforce. Only one case of invasive melanoma might have been expected among AFA men and three cases were observed. This resulted in a PIR of 2.47 (95% CI=0.47-7.32) compared to non-Hispanic white men, a PIR of 3.12 (95% CI=0.50-9.22) compared to all races, an SIR of 2.74 (95% CI=0.52-8.12) compared to non-Hispanic white men, and an SIR of 3.93 (95% CI=0.74-11.62) compared to men of all races.

### ***Characteristics of invasive breast cancer among cohort members***

Characteristics of the cases of invasive breast cancer which occurred among women in the AFA cohort were compared to those among women of working ages with breast cancer from the general California population (*Table 12*). Tumor characteristics were very similar. AFA members presented at similar stages of disease and with tumors of comparable histologies. Perhaps, in part, because AFA cohort members tended to be

somewhat younger than the general population cohort members with breast cancer were more likely to be diagnosed in the younger age groups and were more likely to be alive at follow-up.

**Table 12.** Characteristics of invasive breast cancer cases among AFA cohort members compared to cases among adult females (age 20-64) in the California population, 1988 to 1995.

Characteristic	AFA Members n (%)	California Female Adults n (%)	p(X <sup>2</sup> )
<b>Stage at diagnosis</b>			
Localized	36 (58.1)	42,228 (56.7)	0.29
Regional	25 (40.3)	26,349 (35.4)	
Remote	1 (1.6)	3,502(4.7)	
Unknown	0 (0.0)	2,411 (3.2)	
<b>Histologic type</b>			
Ductal	39 (62.9)	52,692 (70.7)	0.22
Lobular	6 (9.7)	4,575 (6.1)	
Ductal & lobular	6 (9.7)	3,780 (5.1)	
Other types	11 (17.7)	13,443 (18.0)	
Multiple Primaries	6 (9.7)	11,822 (15.9)	0.18
<b>Age at diagnosis</b>			
20-40 yrs	5 (8.1)	9,375 (12.6)	< 0.01
40-49 yrs	42 (67.7)	23,530 (31.6)	
50-59 yrs	15 (24.2)	26,033 (34.9)	
60+ yrs	0 (0.0)	15,552 (20.9)	
<b>Year of Diagnosis</b>			
1988	2 (3.2)	8,851 (11.9)	0.13
1989	7 (11.3)	8,681 (11.6)	
1990	4 (6.4)	9,134 (12.3)	
1991	9 (14.5)	9,233 (12.4)	
1992	8 (12.9)	9,597 (12.9)	
1993	13 (21.0)	9,429 (12.7)	
1994	7 (11.3)	9,735 (13.1)	
1995	12 (19.3)	9,830 (13.2)	
<b>Years of follow-up</b>			
< 1 yr.	8 (12.9)	14,796 (19.9)	0.19
1 yr.	12 (19.3)	13,931 (18.7)	
2 yrs.	7 (11.3)	10,177 (13.7)	
3 yrs.	10 (16.1)	8,429 (11.3)	
4 yrs.	10 (16.1)	7,145 (9.6)	
5 yrs.	3 (4.8)	5,986 (8.0)	
6 yrs.	8 (12.9)	4,994 (6.7)	
7 yrs.	2 (3.2)	3,976 (5.3)	
8 yrs.	2 (3.2)	3,246 (4.4)	
9 yrs.	0 (0.0)	1,810 (2.4)	
Alive at last follow-up	59 (95.2)	61,517 (82.6)	< 0.01

## Discussion

This is the largest study of cancer among flight attendants to date. The combined resources of the both largest flight attendant union and the largest population-based cancer registry in the world provided a rich opportunity to evaluate the cancer experience of flight crews in a single comprehensive study. The results provide additional evidence that cancers of the female breast and malignant melanoma of the skin occur more frequently among people in these occupations.

In assessing that evidence some limitations of this study should be considered. In particular, the use of existing data sources presented limitations in the availability of detailed information on cohort members. Because the union membership file was available only for 1997, age, sex and residential distributions needed to be estimated for earlier time periods based on information from a single time period and assuming stability in workforce profiles. Likewise birth date information was missing for some members, so age distributions needed to be imputed for a small proportion of the cohort. Importantly, no information was available on race/ethnicity for cohort members. Flight attendants as a group represent a somewhat residentially mobile population hence complicating estimation of person-years of exposure as California residents. Because of these uncertainties we used alternative strategies to estimate risk relationships. Proportional incidence is not as dependent on correct estimation of the population-at risk as is standardized incidence. Since the race/ethnicity distribution in the cohort was unknown we used two reference groups: one limited to non-Hispanic whites, and another consisting of all races combined. Interestingly, the risk estimates were remarkably similar using each of these methods.

While our results suggest that flight crews may experience higher rates of certain cancers than people of the same ages in the general population, this study cannot provide information on why that might be so. There has been much interest in the potential contribution of occupational exposures unique to this workforce, particularly cosmic radiation and disruption of circadian rhythms, we had no exposure data available for cohort members. It is likewise quite possible that lifestyle differences could explain these observations. Evaluation of the relative contribution these factors would need to be explored in a follow-up study.

In summary, this study provides strong evidence that while the overall cancer experience of flight attendants does not differ from that of the general population, they do experience higher rates of certain cancers, particularly female breast cancer and malignant melanoma of the skin. This observation is consistent with similar suggestions from the limited literature on this topic to date.

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