Cancer Incidence in Populations Living Near Chicago O'Hare and Midway Airports, Illinois 1987-1997

A Publication of the
Illinois Department of Public Health
Office of Epidemiology and Health Systems Development
Division of Epidemiologic Studies
Springfield, IL 62761

November 2001

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Acknowledgments

This report would not have been possible without the efforts of the Illinois State Cancer Registry staff, the personnel at the reporting facilities that diagnose or treat cancer patients throughout Illinois, and staff members at other state central cancer registries with data exchange agreements.

Special thanks to Jayneece Bostwick, Gina Johnson, Cheryl Maxson, all administrative assistants in the Division of Epidemiologic Studies, and Jerry Partlow in the Department's Center for Rural Health for providing mapping and graphical supports.

Suggested citation

Shen T, Lehnherr M. Cancer Incidence in Populations Living Near Chicago O'Hare and Midway Airports, Illinois. Epidemiologic Report Series 01:6. Springfield, IL: Illinois Department of Public Health, November 2001.

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ABSTRACT

Background

Because of the documented presence of cancer-causing air pollutants from jet engines, cancer concerns exist for populations living near Chicago's O'Hare and Midway airports. The concerns, however, are based on projected cancer risks from measured pollutants. This study examined actual cancer incidence observed in communities near the two airports.

Methods

Cancer cases reported to the Illinois State Cancer Registry from 1987 to 1997 were used to calculate age-adjusted incidence rates among populations living near the two airports. Cases were separated by ZIP code into four study groups according to projected cancer risks from a previous study as well as geographic distances to the airports. Standardized rate ratios were computed for each of the study groups relative to a reference group defined as areas at least eight miles away from either airport. Gender- and race-specific rate ratios were evaluated separately for all cancers combined and for each of 22 site-specific cancers.

Results

Between 1987 and 1997, a total of 247,520 cases of invasive cancers were diagnosed for the four study groups and 49,720 cases were diagnosed for the reference group. The standardized rate ratios for all study groups and all cancers combined were 1.0 for white males (95 percent confidence interval, 95%CI, 0.9 to 1.0), 0.8 for non-white males (95%CI, 0.8 to 0.9), 1.0 for white females (95%CI, 1.0 to 1.0), and 0.9 for non-white females (95%CI, 0.9 to 1.0). Across study groups, the ratio was not greater for areas with higher projected cancer risks or closer to the airports. With all study groups combined, the race-, gender- and site-specific standardized rate ratios were statistically greater than 1.0 for two sites (esophagus for non-white males and cervix for white and non-white females) and lower than 1.0 for four sites (cancer of central nervous system for non-white females, colorectum, kidney and renal pelvis for non-white males, and prostate for white and non-white males). The ratio, however, was not statistically different from 1.0 for most cancer sites. No incidence gradient across the study groups was found in any race and gender combination or for any specific cancer site.

Conclusions

No consistent pattern was observed to indicate a general elevation of cancer incidence among populations living near the Chicago O'Hare and Midway airports. Although these data do not support claims of clear, present, and observable cancer danger associated with the airports, due to the lack of information on residency history, they are not sufficient to evaluate cancer risk for a lifelong exposure to airport pollutants as predicted from risk assessment studies.

INTRODUCTION

Large airports with their related infrastructure, business and industrial activities are known to be sources of noise, air and water pollution, and have the potential to adversely affect the health of residents living near the airport (Passchier et al. 2000; Holzman, 1997). The noise associated with frequent jet engine landings and take-offs can cause temporary hearing impairment, stress, lost sleep, inability to concentrate and general degradation of quality of life for both airport employees and residents living within flight patterns (Chen et al, 1992; 1993; 1997; Tubbs et al, 1991; Bronzaft et al, 1998; Morrow, 2001). In contrast to the well-documented noise effect, however, there is a paucity of information on other health conditions. Although several small studies have addressed short-term changes in pulmonary function and found excess upper and lower respiratory tract symptoms among samples of airport workers and nearby residents (Tunnicliffe et al, 1999; Dumser, 1999), long-term health effects have not been examined in large settings. Of those long-term outcomes hypothesized to be associated with aircraft exhaust, cancer is of the most concern. Debate over the elevation of cancer incidence in airport-proximal communities has heated up in recent years as environmental studies identified the presence of such carcinogenic emissions as benzene and 1,3-butadiene, which are known to cause leukemia, lymphomas and possibly other cancers (USDHHS, 2000; USEPA, 1993). Some of these pollutants were reported to exceed the level of non-airport or "comparison" areas and to generate cancer risks greater than the U.S. Environmental Protection Agency's recommended "margin of safety" of one per million for a lifelong exposure (Lindberg et al, 2000; Piazza, 1999).

The cancer concern was clearly an issue in the recent debate about the health impact of

Chicago O'Hare International Airport on its nearby residents (Worthington, 2000). A risk assessment of aircraft-emitted pollutants, conducted by Environ International Corporation, showed lifetime cancer risks exceeding one per million for populations of 96 communities around the O'Hare airport (City of Park Ridge, 2000). An early health risk assessment by the U.S. Environmental Protection Agency (USEPA) of Chicago's Midway Airport found that aircraft engines could be responsible for 10.5 percent of projected cancer cases attributable to air pollution among residents who would live within 16 square miles of the airport for an average of 70 years. A comparison to the southwest Chicago area, however, indicated that the total cancer risk near Midway due to air pollution from all sources was actually lower, by roughly 10-fold (USEPA, 1993), suggesting that the amount of carcinogens released from other toxic sources, such as trucks, cars, trains and other industrial processes, far outweighed that from aircraft.

To date, almost all published cancer risks related to airports, including O'Hare and Midway, have been based on projected or extrapolated probabilities for a lifelong exposure to known carcinogens emitted from airplanes. Such projected risks, though valid in their own right when all assumptions are met, may not correlate well with actual or observed cancer cases. This is because many other factors, including the typically short period of exposure for the majority of populations and the presence of other environmental factors, modify the final expression of the risk. In order to foster sound public health policies to deal with both potential and realized health threats, it is important to examine actual cancer outcomes among populations at risk. Such outcomes provide realistic and direct evidence about the danger of cancer. In this study, cancer incidence in populations living near the O'Hare and Midway airports is examined. Given the findings of the presence of cancer-causing

pollutants by a previous study (City of Park Ridge, 2000), it was hypothesized that excessive cancer cases would be observed in these populations and that the magnitude of the excess would vary with geographic proximity.

METHODS

Study areas around the Chicago O'Hare airport were defined according to an early risk assessment conducted by Environ (City of Park Ridge, 2000), in which cancer risks were projected based on results of air sampling and presented as cancer risk contours around the airport (like the contours on a topographic map). The area outlined by each contour line was defined as one group, and four study groups (i.e., study group 1 through 4) were formed to represent, respectively, a projected cancer risk of 1/100,000, 5/1,000,000, 2/1,000,000, and 1/1,000,000 according to the Environ study. Geographically, each lower risk group represented an area that was farther away from the airport. Thus the study group number indicated the proximity to the airports, with study group 1 being the closest and study group 4, the farthest. The four study groups captured all communities originally included in the Environ study.

This study includes – additionally – communities near Chicago Midway airport, which is about 17 miles southeast of O'Hare. The U.S. Environmental Protection Agency published a cancer risk assessment of Midway airport in 1993 (USEPA, 1993), but the report did not provide a cancer risk contour map. To define study groups around Midway, it was assumed its aircraft pollutants follow the same distribution pattern as that of O'Hare, but differ in distance (or magnitude) due to differences in flight volume between the two airports. Environ's cancer risk contour map for O'Hare was scaled down by half (½) to approximate the reduced frequency of flights at Midway. These scaled-down

contour lines were then superimposed on Midway airport to identify enclosed communities. Four study groups in an increasing geographic distance from Midway were formed and merged with the corresponding O'Hare study groups to generate a single set of study groups for both airports. The final study areas covered, in whole or in part, a total of 116 communities in three counties (Cook, DuPage and Lake). A total of 56 communities outside the study groups (including Naperville, which was used as a control site in the Environ study) were selected as a reference group. The area of the reference group was at least eight miles out from either airport. Appendix A lists all communities included in the study areas.

For all study and reference groups, ZIP codes were used to identify and classify areas because they are the smallest geographic units for which population numbers were available from the U.S. Census. Cancer cases were geocoded by an outside vendor to ZIP code areas according to home addresses recorded on medical records at the time of diagnosis. The success rate of assigning ZIP codes to cancer cases was 100 percent and the accuracy rate of the geocoding was estimated to be 99.2 percent. Some ZIP codes changed over time; these were identified and assigned back to the original codes to avoid mismatches between cancer cases and population numbers. A total of 228 and 71 ZIP code areas were included for the four study groups and the reference group, respectively. Because the separation of different cancer risk regions in the Environ study did not correspond precisely to ZIP code boundaries, using ZIP codes to define study groups might result in different classification for some cases. However, the number of these cases was determined to be small when the distribution map of the study groups was compared with the Environ cancer risk contour map. Figure 1 shows the map indicating geographic distributions of the study and reference groups as defined by ZIP codes. Appendix B lists ZIP codes included in the study by study group and community.

All cases of invasive cancers diagnosed during 1987-1997 were identified. *In situ* cancers were not included except for bladder cancer for which the separation of invasive and *in situ* carcinomas is difficult. The source of these data was the Illinois State Cancer Registry (ISCR), the only population-based cancer surveillance system in Illinois. Cancer cases among Illinois residents are reported to ISCR, as mandated by state law, by health care facilities in the state where cancer is diagnosed and treated. For cancer cases among Illinois residents who are diagnosed outside the state, ISCR has agreements to exchange data with state cancer registries in Arkansas, California, Florida, Indiana, Iowa, Kentucky, Michigan, Mississippi, Missouri, North Carolina, Washington, Wisconsin and Wyoming, and with Barnes-Jewish Hospital in St. Louis and the Mayo Clinic in Minnesota. Out-of-state diagnoses among residents in the study and reference areas accounted for less than 2 percent of the total cases reported and were added to the study. Cases identified through death certificate clearance and follow back, which also accounted for less than 2 percent of the total cases, were included as well. The overall data completeness for registry data, assessed using the North American Association Central Cancer Registries (NAACCR) standard method (NAACCR, 1996), was estimated to be above 92 percent for the period 1987-1997.

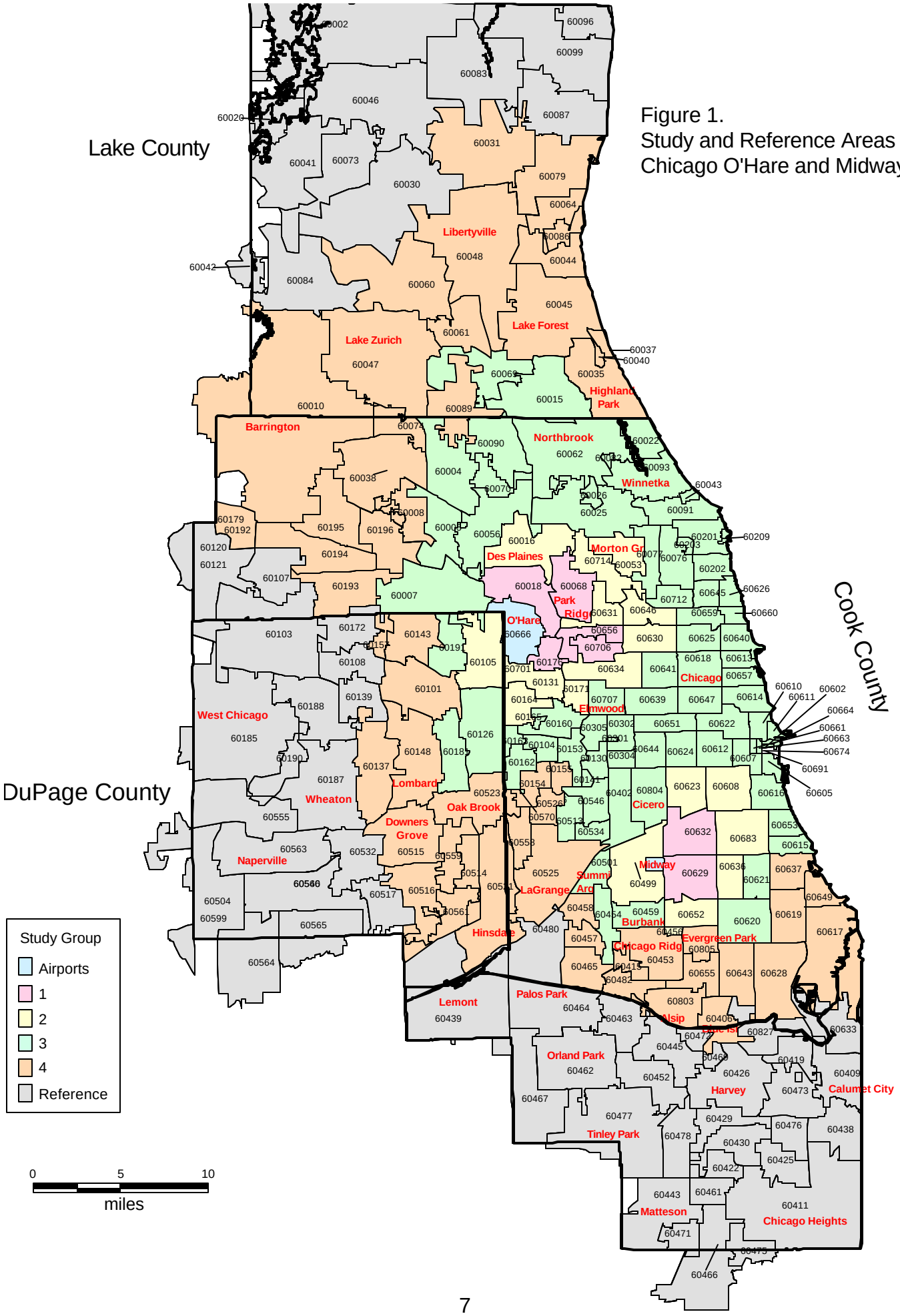


Figure 1.
Study and Reference Areas around
Chicago O'Hare and Midway Airports

The *International Classification of Diseases for Oncology, Second Edition* (ICD-O-2) codes and the major and minor cancer sites of the Surveillance, Epidemiology and End Results (SEER) program of the National Cancer Institute (NCI) were used to define cancer sites. Additionally, the International Agency for Research on Cancer's *International Classification of Childhood Cancer, 1996*, was used to classify cases for a few selected sites of pediatric cancers. These widely used and standardized classification schemes allow comparisons of cancer incidence with many published state and national cancer statistics (Dolecek et al., 2000). Cancer cases also were grouped by gender (male and female) and race (white and non-white) for stratified analyses.

Population numbers at the ZIP code level for the study areas were obtained from the 1990 U.S. Census (U.S. Bureau of Census, 1992). As for cancer cases, these numbers were further separated by gender and race. Across the study groups, the size of population varied from slightly more than a quarter million to more than 2 million per group, whereas the ratio of whites to non-whites changed from 5.1 to 1.6.

Cancer incidence rates were calculated and age adjusted by the direct method to the 1970 U.S. standard million population. An age-adjusted rate (AAR) is a weighted average of crude rates, where the crude rates are calculated for different age groups and the weights are the proportions of persons in the corresponding age groups of a standard population. Formulas used for the calculation of AAR and its standard error (SE) are displayed in Appendix C. The SEER*Stat software 3.0.8, developed by Information Management Services Inc. for the National Cancer Institute (NCI), was used to calculate AARs and SEs (NCI, 2000).

To compare age-adjusted rates between the study and reference groups, standardized rate

ratios (SRRs) and their 95 percent confidence intervals were calculated. SRR is the numeric ratio between two directly age-adjusted rates and is equivalent to the relative risk of cancer in the study group compared to the reference group. The statistical significance of the ratio is estimated through calculating 95 percent confidence intervals, using an approximated formula (Boyle and Parkin, 1991) (Appendix C).

To assess whether cancer incidence was greater among populations who lived closer to the airports, trend analyses were performed by fitting a linear regression line to SRRs across study groups (Boyle and Parkin, 1999). The magnitude and statistical significance of the slope coefficient of a ratio trend were used to judge the presence of a "dose-response" relationship between cancer incidence and exposure to airport pollutants. Specifically, because high study group numbers represented longer distances to the airports, a statistically significant and negative slope coefficient (i.e., a significant and negative trend in SRR) would support the study's hypothesis that cancer incidence was higher among populations living nearer the airports.

SAS software, V8, was used to perform the analyses on SRRs (i.e., confidence intervals and trends) (SAS, 1999).

RESULTS

Between 1987 and 1997, there were 247,520 cases of invasive cancers diagnosed in the study areas and 49,720 cases diagnosed in the reference area (Table 1). The age and gender distributions of study groups as a whole were similar to those of the reference group. Whites were in higher proportion in the study groups than in the reference group, although they accounted for more than two-thirds of the

cases in both groups. Among individual study groups, case distributions were similar with respect to age and gender but not to race, which showed about a 20 percent differential from study group 1 to study group 4. This racial heterogeneity between study groups highlighted the need to use race-specific rates for comparisons. The majority of all cases were from Cook County for both the study and reference groups, although the proportion from two other counties, DuPage and Lake, was higher in the study groups.

Age-adjusted incidence rates per 100,000 population for all cancers combined were 358 for white females, 453 for white males, 298 for non-white females, and 471 for non-white males. Compared with the reference group, these rates were similar or lower (Figure 2). The first line of both Table 2 and Table 3 show corresponding standardized rate ratios (SRRs) and their 95 percent confidence intervals for these comparisons.

Site-specific SRRs for all study groups combined are shown in Table 2 for females and in Table 3 for males. The SRR was statistically greater than 1.0 for cervix among both white and non-white females and for esophagus among non-white males, suggesting cancer incidence rates were significantly higher (about 30 percent for cervix and 60 percent for esophagus) in the study population than in the reference population. The SRR was statistically lower than 1.0 for four sites: cancer of central nervous system for non-white females, colorectum, kidney and renal pelvis for non-white males, and prostate for both white and non-white males. The reduction in cancer incidence for these sites in the study groups ranged from 10 percent for prostate to 50 percent for nervous system. The SRR for the overwhelming majority of other cancer sites, genders and racial groups, however, was not statistically different from 1.0, i.e., the level of the reference group.

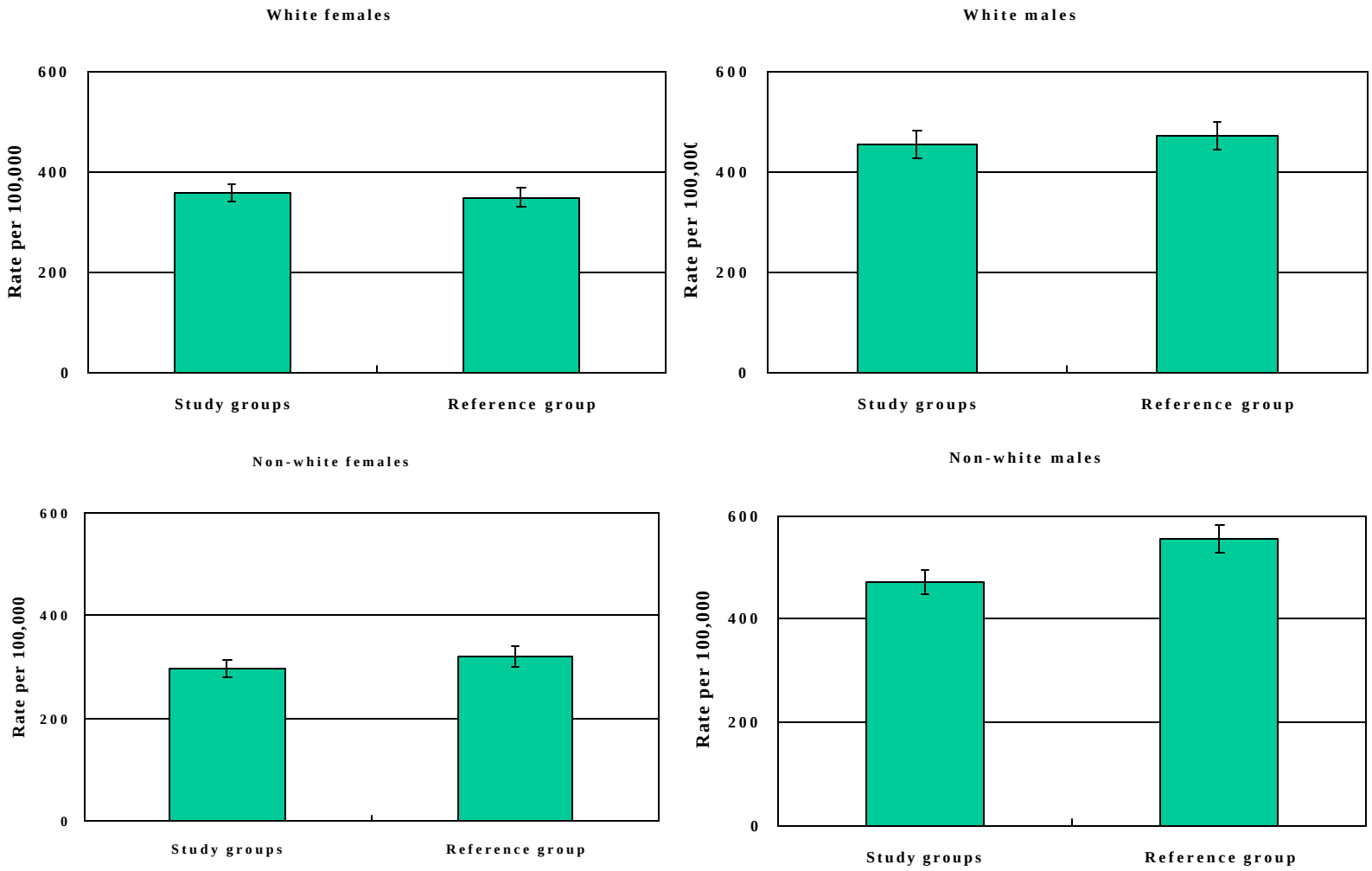
Table 1. Demographic Characteristics of Cancer Patients Diagnosed in Populations near O'Hare and Midway Airports, 1987-1997, Illinois

Reference group	Characteristic	Study group 1	2	3	4	All
Total cases		15,361	39,307	120,485	72,367	247,520	49,720
Age	<20	145 (1.0)	390 (1.0)	1,234 (1.0)	702 (1.0)	2,471 (1.0)	770 (1.5)
	20 - 40	630 (4.1)	1,989 (5.1)	8,156 (6.8)	4,180 (5.8)	14,955 (6.0)	3,683 (7.4)
	41 - 60	3,031 (19.7)	8,567 (21.8)	29,262 (24.3)	19,002 (26.2)	59,865 (24.2)	13,594 (27.3)
	61 - 84	10,525 (68.5)	25,873 (65.8)	72,930 (60.5)	44,175 (61.0)	153,503 (62.0)	29,018 (58.4)
	$85	1,027 (6.7)	2,488 (6.3)	8,903 (7.4)	4,308 (6.0)	16,726 (6.8)	2,655 (5.4)
Gender	Male	7,732 (50.3)	19,802 (50.4)	59,130 (49.1)	35,797 (49.5)	122,461 (49.5)	24,648 (49.6)
	Female	7,629 (49.7)	19,505 (49.6)	61,355 (50.9)	36,570 (50.5)	125,059 (50.5)	25,072 (50.4)
Race	White	14,806 (96.4)	32,710 (83.2)	92,213 (76.5)	52,095 (72.0)	191,824 (77.5)	44,077 (88.7)
	Non-white	554 (3.6)	6,597 (16.8)	28,273 (23.5)	20,272 (28.0)	55,696 (22.5)	5,643 (11.3)
County	Cook	15,361 (100.0)	38,416 (97.7)	114,380 (94.9)	46,800 (64.7)	214,957 (86.8)	30,764 (61.9)
	DuPage	0	889 (2.3)	4,662 (3.9)	13,815 (19.1)	19,368 (7.8)	12,340 (24.8)
	Lake	0	2 (0)	1,443 (1.2)	11,752 (16.2)	13,195 (5.4)	6,616 (13.3)

Source: Illinois Department of Public Health, Illinois State Cancer Registry, December 1999

Note: Numbers in parentheses are percentages.

Figure 2. Age-adjusted Incidence Rates for All Cancers Combined in Populations near O'Hare and Midway Airports, 1987-1997: All Study Groups vs. Reference Group



Note: None of these comparisons indicated higher rates for the study group.

Table 2. Standardized Rate Ratios for Cancer Incidence near O'Hare and Midway Airports, 1987-1997, All Study Groups Combined, Females

	White		Non-white	
Sites	Ratio	95% CI	Ratio	95% CI
All Sites	1.0	1.0 - 1.0	0.9	0.9 - 1.0
Oral Cavity	1.0	1.0 - 1.2	1.1	0.8 - 1.4
Esophagus	1.1	0.9 - 1.3	1.0	0.7 - 1.5
Stomach	1.1	1.0 - 1.3	1.2	0.9 - 1.6
Colorectal	1.0	1.0 - 1.0	0.9	0.8 - 1.0
Liver	1.0	0.8 - 1.2	1.0	0.6 - 1.6
Pancreas	1.0	0.9 - 1.1	0.9	0.7 - 1.2
Lung	0.9	0.9 - 1.0	0.9	0.8 - 1.0
Bone	0.9	0.6 - 1.3	1.3	0.5 - 3.0
Melanomas	0.9	0.8 - 1.0	1.2	0.5 - 3.3
Breast	1.0	1.0 - 1.1	1.0	0.9 - 1.0
Cervix	1.3	1.2 - 1.5§	1.3	1.1 - 1.6§
Corpus Uteri	1.1	1.0 - 1.1	0.9	0.7 - 1.1
Ovary	1.0	1.0 - 1.1	1.0	0.8 - 1.3
Bladder	1.0	0.9 - 1.1	1.0	0.7 - 1.4
Kidney and Renal Pelvis	1.0	0.9 - 1.1	0.8	0.6 - 1.1
Nervous System	1.0	0.9 - 1.1	0.5	0.4 - 0.8†
Hodgkin's Lymphoma	1.0	0.8 - 1.1	0.7	0.4 - 1.2
Non-Hodgkin's Lymphoma	1.0	0.9 - 1.1	0.8	0.6 - 1.1
Myelomas	0.9	0.8 - 1.1	0.9	0.7 - 1.3
Leukemias	1.0	0.9 - 1.1	0.7	0.5 - 1.0
Other Sites	1.0	1.0 - 1.1	0.9	0.8 - 1.0

Source: Illinois Department of Public Health, Illinois State Cancer Registry, December 1999

§ Elevated incidence, study vs. reference. † Reduced incidence, study vs. reference.

Table 3. Standardized Rate Ratios for Cancer Incidence near O'Hare and Midway Airports, 1987-1997, All Study Groups Combined, Males

	White		Non-white	
Sites	Ratio	95% CI	Ratio	95% CI
All Sites	1.0	0.9 - 1.0	0.8	0.8 - 0.9
Oral Cavity	1.1	1.0 - 1.2	1.2	1.0 - 1.5
Esophagus	1.0	0.9 - 1.2	1.6	1.3 - 2.1§
Stomach	1.2	1.0 - 1.3	0.8	0.6 - 1.0
Colorectal	1.0	0.9 - 1.0	0.8	0.7 - 0.9†
Liver	1.1	0.9 - 1.2	1.0	0.7 - 1.4
Pancreas	1.0	0.9 - 1.1	0.8	0.6 - 1.0
Lung	0.9	0.9 - 1.0	1.0	0.9 - 1.1
Bone	0.8	0.6 - 1.1	2.2	1.0 - 4.6
Melanomas	1.0	0.9 - 1.1	0.6	0.2 - 2.2
Prostate	0.9	0.9 - 0.9	0.8	0.7 - 0.8†
Testis	1.0	0.9 - 1.2	0.8	0.4 - 1.5
Bladder	0.9	0.9 - 1.0	0.7	0.5 - 1.0
Kidney and Renal Pelvis	1.0	0.9 - 1.0	0.7	0.5 - 0.9†
Nervous System	1.0	0.9 - 1.1	0.7	0.5 - 1.2
Hodgkin's Lymphoma	0.9	0.8 - 1.1	0.6	0.3 - 1.0
Non-Hodgkin's Lymphoma	1.1	1.0 - 1.2	0.8	0.6 - 1.1
Myelomas	0.9	0.8 - 1.1	0.7	0.5 - 1.0
Leukemias	0.9	0.9 - 1.0	0.7	0.5 - 1.0
Other Sites	1.0	1.0 - 1.1	1.0	0.8 - 1.1

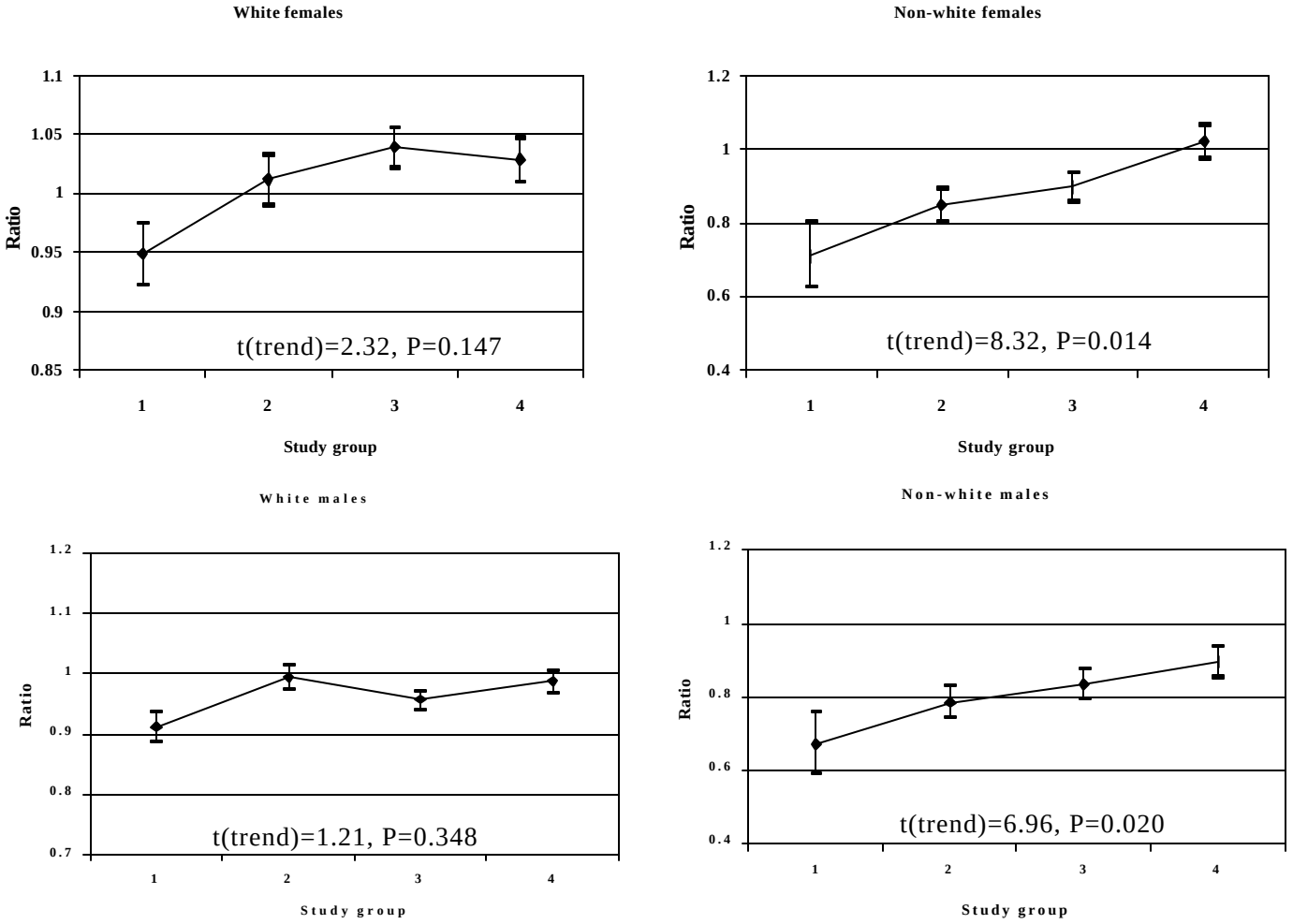
Source: Illinois Department of Public Health, Illinois State Cancer Registry, December 1999

§ Elevated incidence, study vs. reference. † Reduced incidence, study vs. reference.

The SRRs for individual study groups are displayed in Figure 3, for all cancers, by gender and race. The ratio varied considerably from one group to another and showed a strong linear trend among non-whites. The trend, however, was in an opposite direction to what would be expected from the study hypothesis that cancer incidence would be higher in populations living closer to the airports. The observed trend indicated that cancer incidence decreased in these populations, as higher study group numbers were a proxy for longer distances away from the airports. None of the individual SRRs in Figure 3 exceeded 1.0, which confirmed the lower-than-average cancer incidence in the study groups.

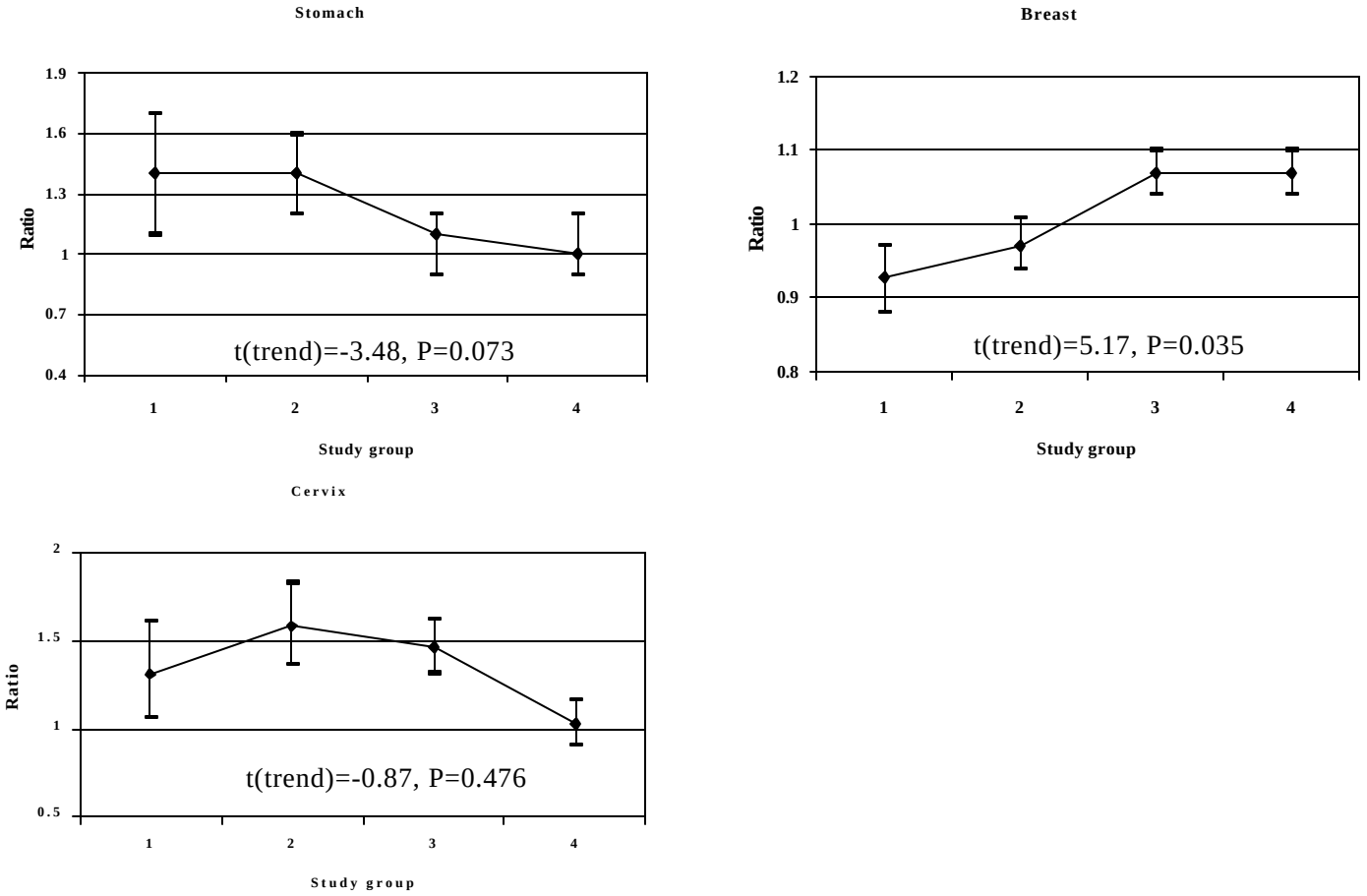
The site-specific SRRs also varied across groups. Due to space limitations, only trends based on at least one SRR that was statistically greater than 1.0 are presented. For white females (Figure 4), stomach cancer appeared to decrease as the distance from the airports increased, but the trend was not significant. For white and non-white females, the trend for breast cancer was significant but in an opposite direction (Figure 4, 5). This pattern was true also for melanoma among white males (Figure 6). None of the other trends among males was significant. Leukemias and lymphomas as defined by the IARC classification for pediatric cancers are presented in Figure 8. These two sites were selected because they represent major pediatric cancers and are often postulated to be related to environmental factors. Trends in the SRR for these two sites were not statistically significant.

Figure 3. Standardized Rate Ratios for Cancers near O'Hare and Midway Airports by Study Group, 1987-1997, All Cancer Sites Combined



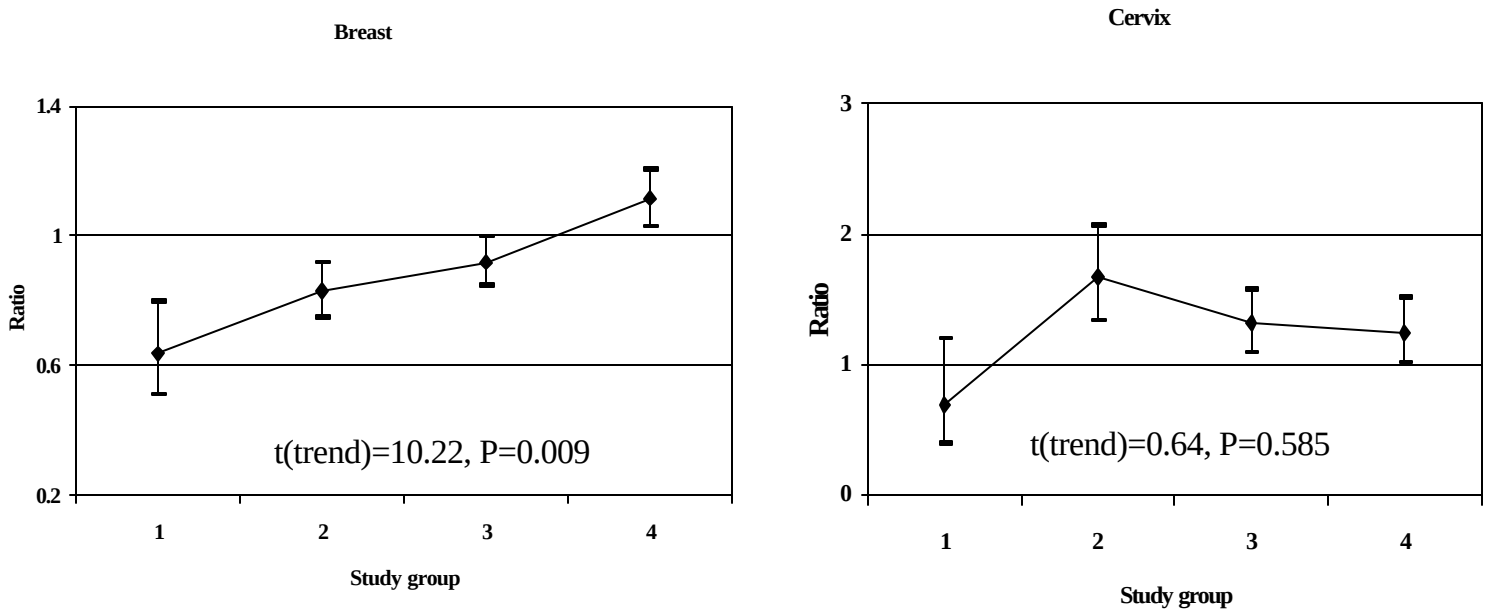
Note: 1=closest to airport; 4=farthest from airport

Figure 4. Standardized Rate Ratios for Selected Cancer Sites near O'Hare and Midway Airports by Study Group, 1987-1997, White Females



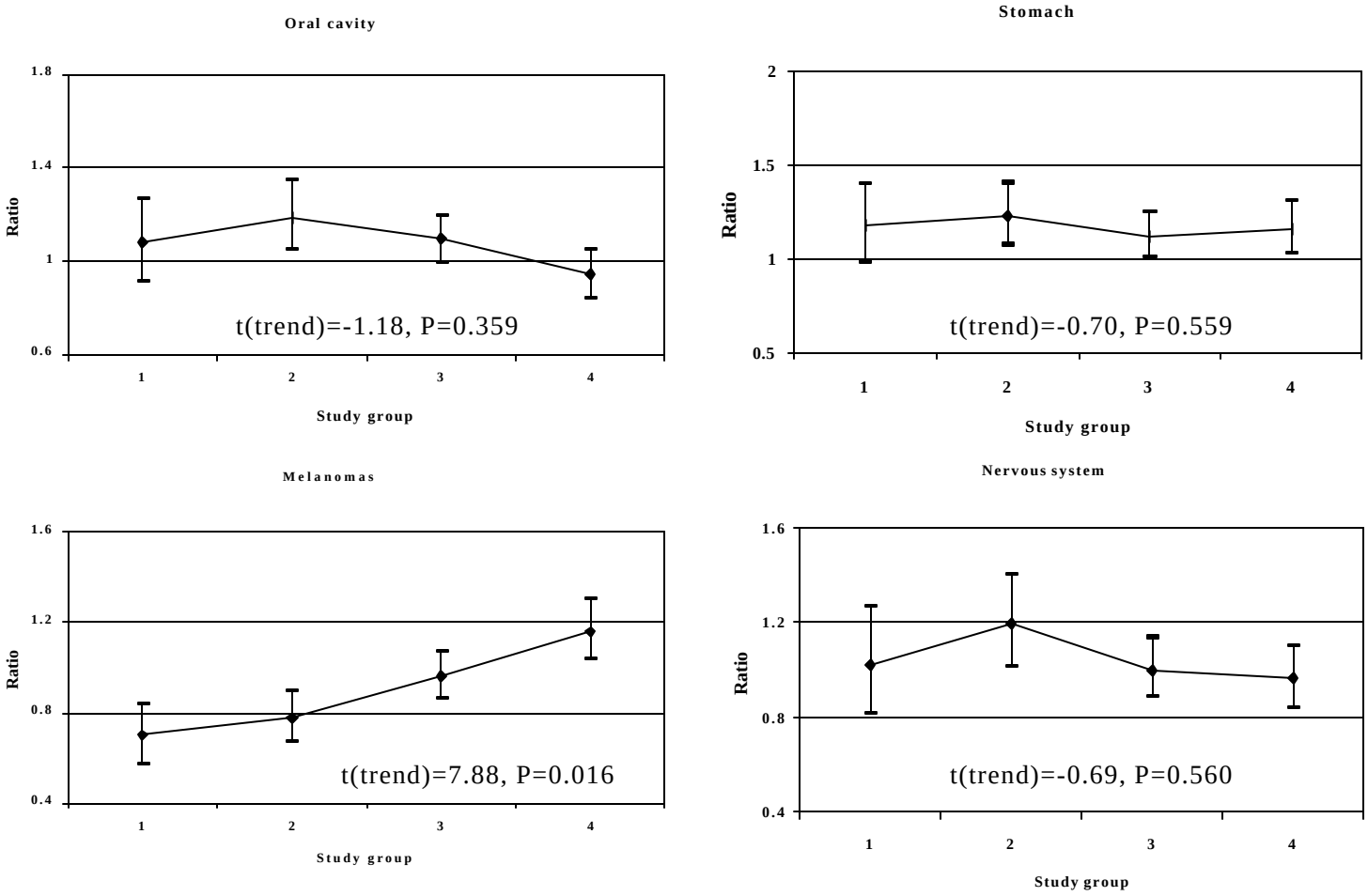
Note: 1=closest to airport; 4=farthest from airport

Figure 5. Standardized Rate Ratios for Selected Cancer Sites near O'Hare and Midway Airports by Study Group, 1987-1997, Non-white Females



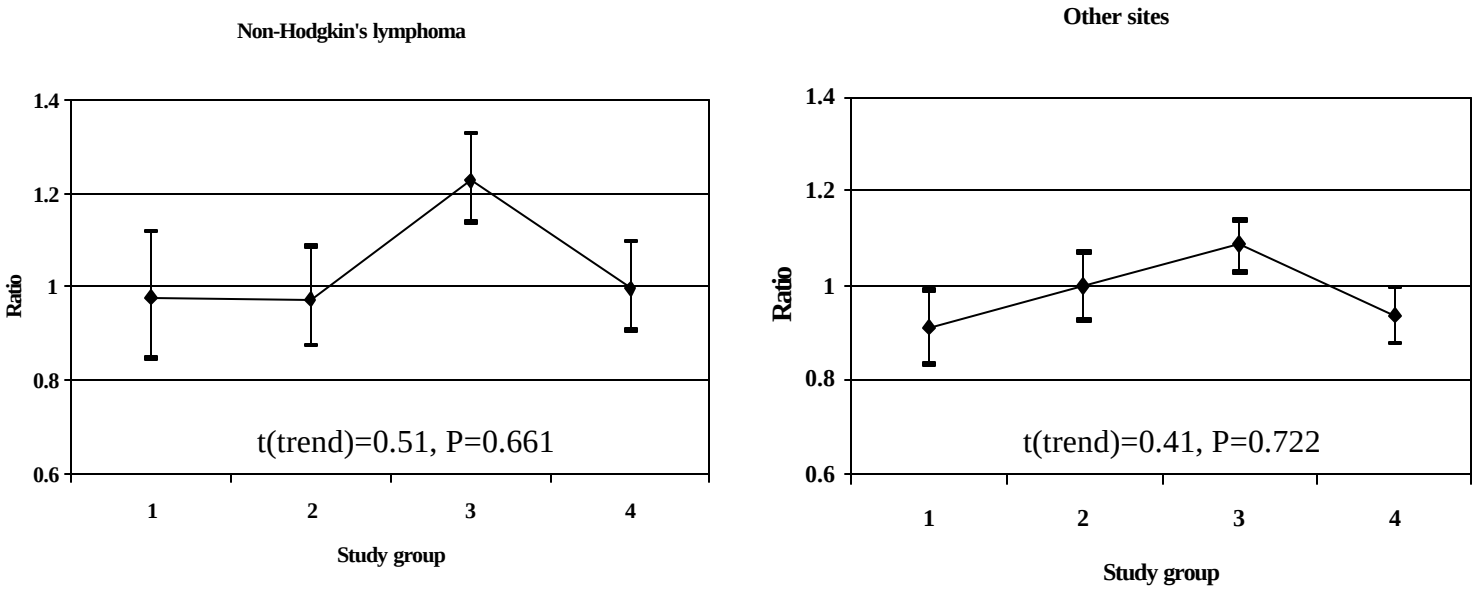
Note: 1=closest to airport; 4=farthest from airport

Figure 6. Standardized Rate Ratios for Selected Cancer Sites near O'Hare and Midway Airports by Study Group, 1987-1997, White Males



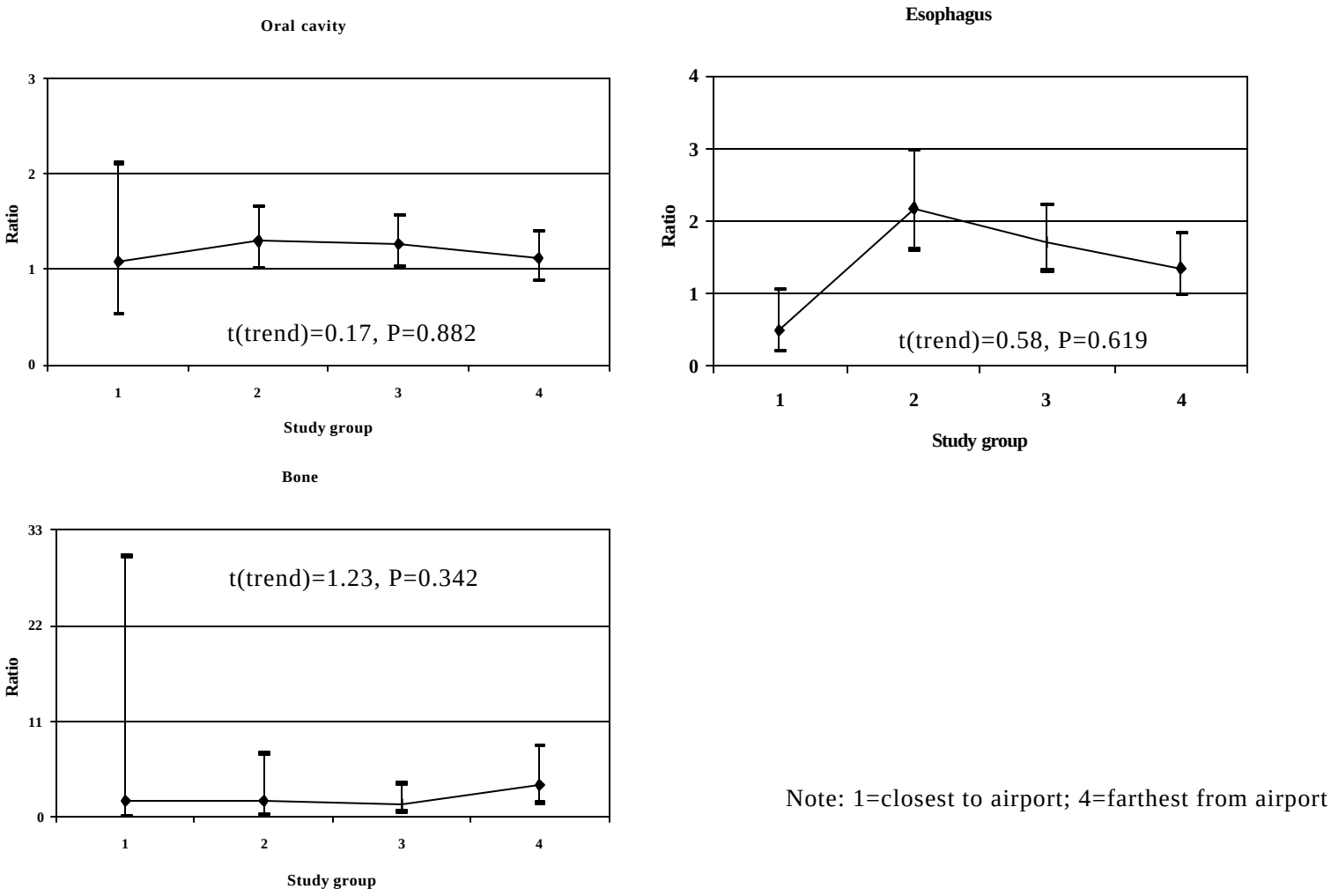
Note: 1=closest to airport; 4=farthest from airport

Figure 6. Standardized Rate Ratios for Selected Cancer Sites near O'Hare and Midway Airports by Study Group, 1987-1997, White Males (Cont'd.)



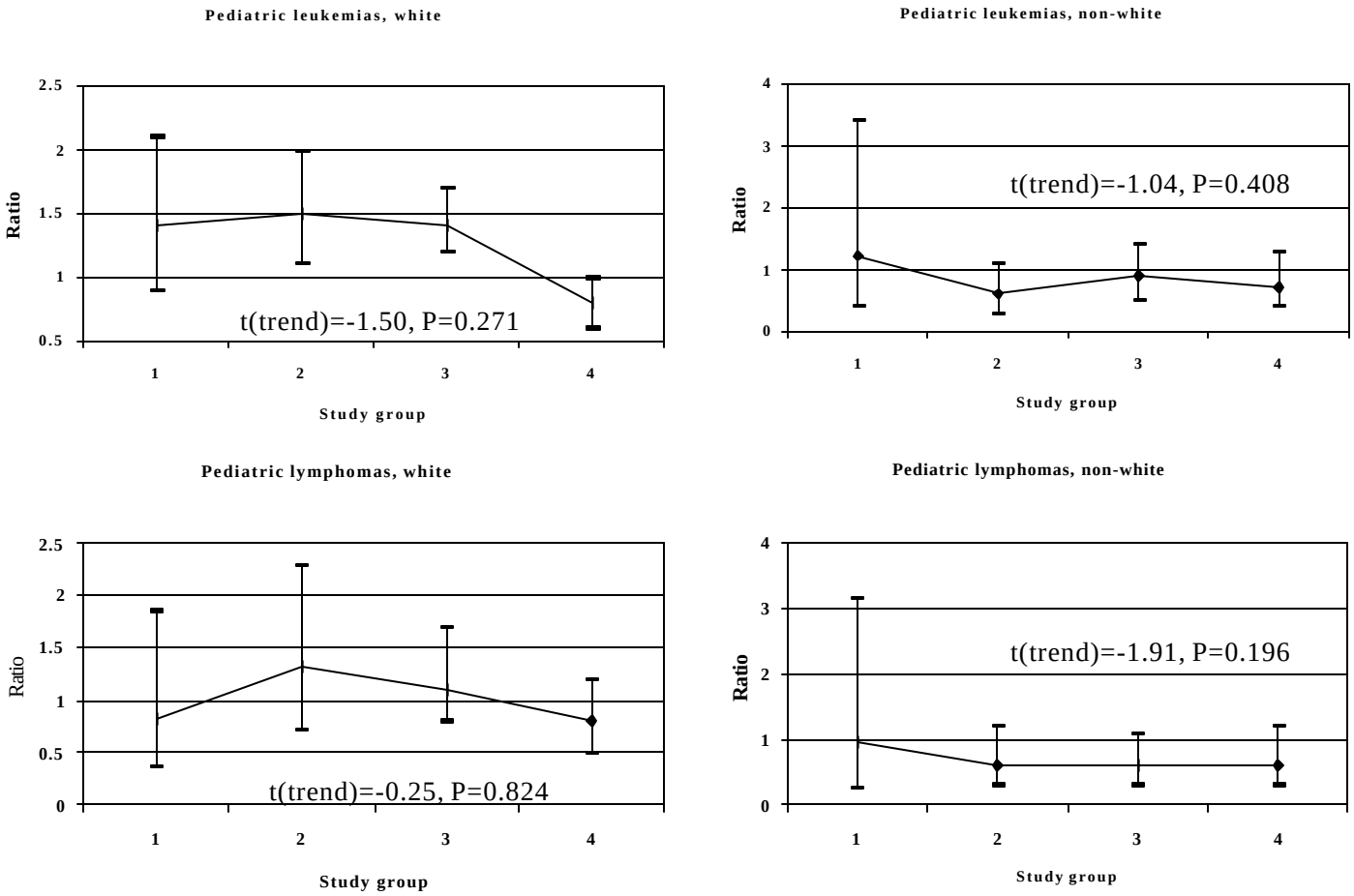
Note: 1=closest to airport; 4=farthest from airport

Figure 7. Standardized Rate Ratios for Selected Cancer Sites near O'Hare and Midway Airports by Study Group, 1987-1997, Non-white Males



Note: 1=closest to airport; 4=farthest from airport

Figure 8. Standardized Rate Ratios for Selected Pediatric Cancer Sites near O'Hare and Midway Airports by Study Group, 1987-1997



Note: 1=closest to airport; 4=farthest from airport

DISCUSSION

This study examined cancer incidence between 1987 and 1997 in populations living in proximity of Chicago O'Hare International and Midway airports. The data showed no general elevation in cancer incidence for all cancers combined among whites, non-whites, males and females. For individual sites and certain gender and racial groups, cervical and esophageal cancers occurred with more frequency whereas cancers of the nervous system, colorectum, kidney and renal pelvis, and prostate occurred with less frequency. The majority of cancer sites showed similar cancer incidence among all study groups and reference groups. Trend analysis revealed no clear gradient indicating higher cancer burden for populations near the airports as compared to populations living farther away. This was true for all cancers combined as well as site-specific cancers.

The two increased cancers are not known to relate to airport pollution. Cervical cancer is closely linked to sexual behavior and to sexually transmitted infections with certain types of human papillomavirus. Other risk factors include cigarette smoking and low socioeconomic status (Schiffman etc., 1996). Esophageal cancer is believed to be related to a host of factors including genetic susceptibility, dietary habits, alcohol and tobacco use, consumption of food with N-nitroso compounds or fungal contamination (e.g., pickled vegetables) and low socioeconomic status (Muñoz and Day, 1996). Risk factor data were not generally available for this study. Tobacco use and alcohol consumption documented at the time of cancer diagnosis by the Illinois State Cancer Registry did appear more common in the study groups than in the reference group (45 percent vs. 42 percent for tobacco and 41 percent vs. 37 percent for alcohol), yet the difference might not be meaningful because the information is missing for almost one-third of the cases. Cervical and esophageal cancers are known

to strongly and inversely correlate with levels of socioeconomic status (Kogevinas et al., 1997). According to the 1990 U.S. census, per capita income and housing values in Cook County were lower than those in DuPage and Lake counties. The disproportionally higher representation of Cook County residents and conversely lower representation of DuPage and Lake residents in the study groups vs. the reference group, therefore, could contribute to the difference observed for the two cancers. The differential representation is due in large part to the geographic location of the two airports within Cook County. Another explanation is chance, which becomes likely when a statistical test is applied multiple times to different site-specific cancers in various gender and racial combinations. A small number of increases and decreases in individual cancer sites simultaneously observed, in absence of any biological plausibility, certainly indicates that chance cannot be ruled out.

Neither the pattern of differences nor the gradient across study groups indicated higher cancer incidence in populations residing adjacent to the airports. The observed cancer distribution contradicts the distribution of projected cancer risks from the Environ study. The Department's finding of no cancer excess, however, is in agreement with an air sampling study recently conducted by the Illinois Environmental Protection Agency (IEPA, 2000), which found that levels of carcinogenic compounds near O'Hare airport were similar to other sites in the Chicago metropolitan area and were comparable to or below levels in other urban areas such as Milwaukee, Detroit, New York and Houston. The IDPH study is also consistent with an early USEPA study that found the level of projected cancer risks near Midway airport was lower than that in the southwest Chicago area (USEPA, 1993). A study conducted by the Washington State Department of Health provided an examination of actual cancer cases near Washington state's SeaTac airport. The initial analysis revealed elevations for all cancers

and for cancer of glioblastoma in a five-mile radius of the airport (WSDH, 1999). The study, however, was based on only a few thousand cases, some of which were recruited from non-registry channels. Furthermore, a later reassessment using multiple years of data and a more stringent analytical tool (e.g., spatial scan statistic [Kulldorff, 1997]) confirmed no statistically significant elevation. Glioblastoma as a sub-site was examined in this IDPH study and its levels were similar between the study and reference groups.

There were several important limitations in this study. It treated living adjacent to the two airports as an approximation for increased likelihood of exposure to carcinogens. Although this was supported by the cancer risk contour map of the Environ study, the approximation would be invalid if people living near airports tended to have a much shorter duration of residence than people living farther out. This lack of knowledge about the length of residence as well as the inability to assess actual exposure of individuals currently and historically renders the use of distance a rather crude and unreliable measure of exposure. Other factors likely to impact the study were population migration patterns, occupational exposures, and personal and lifestyle habits. None of these were assessed in this study.

The 1990 population data were used to construct population denominators for calculating rates and ratios. Although representing a mid point of the study period (1987-1997), the 1990 data were the only population basis available. Population changes in other years might not be linear or occur evenly across all areas. A reassessment of the study question with updated population data would be useful. The study areas around Midway were defined according to the pattern around O'Hare and, for both airports, ZIP codes were the smallest unit by which the areas were assembled. Misclassification seems

inevitable during this process because ZIP code boundaries did not precisely correspond to cancer risk contour lines. Nevertheless, a sensitivity assessment conducted by the authors through testing different classification schemes suggested a small impact: cancer incidence and rate ratios in individual study groups did not change significantly even if up to half of a study area was assigned to an adjacent group. In addition, any misclassification bias between study groups would not change rate ratios for all study groups combined.

It should be pointed out that this study is different from the risk assessment studies, in that it describes *actual* cancer incidence observed in real populations, whereas the risk assessment study was aimed at generating cancer predictions under certain exposure assumptions (e.g., lifetime exposure). The IDPH study cannot be used to directly evaluate the risk predictions from other studies because of the lack of exposure information. More importantly, the present study – despite its large sample size and quality data – simply did not have the statistical power to detect changes predicted by the risk study. This was evident when numbers were compared. For example, assuming the highest cancer risk level from the Environ study – 1/100,000 for all study areas – there would be 52 cases predicted over a 70-year period (risk x population, which was 5,195,000 for the study areas). In this study, this would be equivalent to eight additional cases (52 cases ÷ 70 years x 11 years from 1987 to 1997). Such a small number would be impossible to detect even in a large observational study like this. In fact, a power calculation indicated that to produce a detectable difference in the rate ratio for all cancers combined in the present study, one group would need to have at least 350 more cases than the other group. From a practical point of view, therefore, the utility of the cancer incidence study is not to verify the risk assessment results, but to provide a different look at risks through assessing real observed

cancer cases among populations. To improve public health, both the perceived risk and the realized risk need to be addressed.

In conclusion, this study found no evidence to substantiate a clear and observable elevation of cancer cases among the populations currently residing close to the Chicago O'Hare and Midway airports. Further examination of the issue may be warranted when additional information becomes available. Regardless of the availability of new data, cancer risk predictions from risk assessments cannot be substantiated through observational epidemiologic studies.

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Appendix A

List of Communities Included in Study of Cancer Incidence Near O'Hare and Midway Airports

Addison	Des Plaines	Hinsdale	Melrose Park	Riverside
Arlington Heights	Downers Grove	Hoffman Estates	Mettawa	Riverwoods
Bannockburn	Elk Grove Village	Hometown	Morton Grove	Rolling Meadows
Barrington	Elmhurst	Indian Creek	Mount Prospect	Rosemont
Bedford Park	Elmwood Park	Indian Head Park	Niles	Russell
Bellwood	Evanston	Inverness	Norridge	Schaumburg
Bensenville	Evergreen Park	Itasca	North Chicago	Schiller Park
Berkely	Forest Park	Justice	North Riverside	Skokie
Berwyn	Franklin Park	Kenilworth	Northbrook	Stickney
Blue Island	Glen Ellyn	LaGrange	Northfield	Summit Argo
Bridgeview	Glenbard South	LaGrange Park	Northlake	Techny
Broadview	Glencoe	Lake Bluff	Oak Brook	Vernon Hills
Brookfield	Glenview	Lake Forest	Oak Brook Terrace	Villa Park
Buffalo Grove	Golf	Lake Zurich	Oak Lawn	Waukegan
Burbank	Green Oaks	Libertyville	Oak Park	Westchester
Burr Ridge	Great Lakes	Lincolnshire	O'Hare	Western Springs
Chicago	Gurnee	Lincolnwood	Palatine	Westmont
Chicago Ridge	Harwood Heights	Lombard	Palos Heights	Wheeling
Cicero	Hickory Hills	Long Grove	Park City	Willowbrook
Clarendon Hills	Highland Park	Lyons	Park Ridge	Wilmette
Countryside	Highwood	Maywood	Prospect Heights	Winnetka
Darien	Hillside	McCook	River Forest	Wood Dale
Deerfield	Hines	Medinah	River Grove	Worth
				York Center

Appendix B

ZIP Code Areas Included in Study of Cancer Incidence around O'Hare and Midway Airports

NOTE: Community name may be included in more than one study group because study groups were defined by ZIP code areas, some of which may include parts of more than one city. Some ZIP code areas have changed over the years and they were assigned back to the original ZIP code to avoid mismatches between cancer cases and population numbers.

Study Group 1

Chicago	60629, 60632, 60656, 60706	O'Hare	60666
Des Plaines	60018	Park Ridge	60068
Harwood Heights	60656, 60706	Rosemont	60018
Norridge	60656, 60706	Schiller Park	60176

Study Group 2

Bedford Park	60499, 60638	Morton Grove	60053
Bensenville	60105, 60106, 60399	Niles	60714 (60648)
Chicago	60608, 60609, 60623, 60630, 60631, 60634, 60636, 60638, 60646, 60648, 60652, 60667 (60608), 60683, 60701	Norridge	60634
Des Plaines	60016, 60017, 60019 (60016)	Northlake	60164
Franklin Park	60131	River Grove	60171
Hometown	60456	Rosemont	60019 (60016)
Lincolnwood	60646	Stickney	60638
Melrose Park	60164		

Study Group 3

Arlington Heights	60004, 60005, 60006 (60005)	Lincolnshire	60069
Bannockburn	60015	Lincolnwood	60645, 60659, 60712 (60645),
Bedford Park	60459	Lyons	60534
Bellwood	60104	Maywood	60153, 60155 (60153)
Berkely	60163	Melrose Park	60160, 60161 (60160), 60165
Berwyn	60402	Mount Prospect	60056
Bridgeview	60455	North Riverside	60546
Broadview	60153, 60155	Northbrook	60062, 60065 (60062)
Brookfield	60513	Northfield	60093

Burbank	60459	Oak Brook Terrace	60181
Chicago	60601, 60602, 60603 (60601), 60604 (60601), 60605, 60606, 60607, 60610, 60611, 60612, 60613, 60614, 60615, 60616, 60618, 60620, 60621, 60622, 60624, 60625, 60626, 60635, 60639, 60640, 60641, 60642, 60644, 60645, 60647, 60650, 60651, 60653, 60654 (60610), 60657, 60659, 60660, 60661, 60663 (60607), 60664 (60607), 60665 (60607), 60668 (60607), 60669 (60607), 60670, 60671 (60607), 60672 (60607), 60673 (60607), 60675 (60607), 60677 (60607), 60679 (60607), 60680 (60607), 60681 (60607), 60685 (60607), 60690 (60607), 60691 (60607), 60693 (60607), 60694 (60607), 60699 (60607), 60707 (60635)	Oak Park	60301, 60302, 60303 (60302), 60304
Cicero	60804 (60650)	Prospect Heights	60070
Deerfield	60015	River Forest	60305
Elk Grove Village	60007, 60009 (60007)	Riverside	60546
Elmhurst	60126	Riverwoods	60015
Elmwood Park	60707 (60635)	Russell	60075 (60076)
Evanston	60201, 60202, 60203, 60204 (60203), 60208, 60209	Skokie	60076, 60077
Evergreen Park	60805 (60642)	Stickney	60402
Forest Park	60130	Summit Argo	60501
Glencoe	60022	Techny	60082
Glenview	60025, 60026	Villa Park	60181
Golf	60029 (60026)	Wheeling	60090
Hillside	60162, 60163	Wilmette	60091
Hines	60141	Winnetka	60093
Kenilworth	60043	Wood Dale	60191

Study Group 4

Addison	60101	LaGrange Park	60526 (60525)
Barrington	60011 (60010)	Lake Bluff	60044

Blue Island	60406	Lake Forest	60045
Buffalo Grove	60089	Lake Zurich	60047
Burr Ridge	60521, 60525	Libertyville	60048
Chicago	60617, 60619, 60628, 60637, 60643, 60649, 60655, 60674, 60678, 60684, 60687, 60688, 60697, 60803 (60655)	Lombard	60148
Chicago Ridge	60415	Long Grove	60049, 60060
Clarendon Hills	60514	McCook	60525
Countryside	60525	Medinah	60157
Darien	60561 (60559)	Mettawa	60045, 60048
Downers Grove	60515, 60516	North Chicago	60064, 60086
Glen Ellyn	60137, 60138 (60137)	Oak Brook	60521, 60522 (60521), 60523 (60521), 60570
Glenbard South	60137	Oak Lawn	60453, 60454 (60453)
Great Lakes	60088	Palatine	60038, 60055, 60067, 60074, 60078 (60067), 60094, 60095
Green Oaks	60044, 60048	Palos Hills	60465
Gurnee	60031	Park City	60085
Hickory Hills	60457	Rolling Meadows	60008
Highland Park	60035, 60037	Schaumburg	60159 (60173), 60168 (60173), 60173, 60179, 60192 (60193), 60193, 60194, 60195, 60196
Highwood	60040	Vernon Hills	60061
Hinsdale	60521, 60522 (60521), 60523 (60521), 60570	Waukegan	60079 (60085), 60085
Hoffman Estates	60173, 60179, 60192 (60193), 60194, 60195, 60196	Westchester	60154
Indian Creek	60061	Western Springs	60558
Indian Head Park	60525	Westmont	60559, 60561 (60559)
Inverness	60010, 60067	Willowbrook	60514, 60521
Itasca	60143	Worth	60482
Justice	60458	York Center	60148
LaGrange	60525		

Reference Group

Antioch	60002	Naperville	60540, 60555, 60563, 60564, 60565, 60566 (60565), 60567 (60565)
Aurora	60504	Oak Forest	60452
Bartlett	60103	Olympia Fields	60461
Bloomingdale	60108	Orland Park	60462, 60467 (60462)
Calumet City	60409	Palos Heights	60463
Carol Stream	60188, 60197 (60188)	Palos Park	60464
Chicago	60627, 60633, 60658, 60827 (60627)	Park Forest	60466
Chicago Heights	60411	Posen	60469
Country Club Hills	60478	Richton Park	60471
Dolton	60419	Robbins	60472
Elgin	60120, 60121 (60120)	Roselle	60172
Eola	60519 (60517)	Round Lake	60073
Flossmoor	60422	South Holland	60473
Fox Lake	60020	Steger	60475
Glendale Heights	60139	Streamwood	60107
Glenwood	60425	Thornton	60476
Grays Lake	60030	Tinley Park	60477
Harvey	60426	Wadsworth	60083
Hazel Crest	60429	Wauconda	60084
Homewood	60430	Waukegan	60087
Ingleside	60041	Wayne	60184 (60185)
Island Lake	60042	West Chicago	60185, 60186 (60185)
Lake Villa	60046	Wheaton	60187, 60189 (60187)
Lansing	60438	Willow Springs	60480
Lemont	60439	Winfield	60190
Lisle	60532	Winthrop Harbor	60096
Matteson	60443	Woodridge	60517
Midlothian	60445	Zion	60099

Appendix C

Formulas for Calculating Age-adjusted Incidence Rates and Standardized Rate Ratios

Age-adjusted rate

An age-adjusted rate (AAR) and its standard error (SE) for an age group comprising the ages "x" through "y" were calculated using the following formulae:

$$AAR = \sum_{i=x}^{y} \left[\left(\frac{count_i}{pop_i} \right) \times 100{,}000 \times \left(\frac{stdmil_i}{\sum_{j=x}^{y} stdmil_j} \right) \right]$$

$$SE(AAR) = \left[\sum_{i=x}^{y} \left(\frac{stdmil_i}{\sum_{j=x}^{y} stdmil_j} \right)^2 \times \left(\frac{count_i}{population_i^2} \right) \right]^{1/2} \times 100{,}000$$

where $count_i$ is the number of cancer cases for the ith age group, pop_i is the relevant population count for the same age group, and $stdmil_i$ is the 1970 standard population for the same age group. A total of 18 age groups with five-year increments are used to classify ages between 0 and 85 or older.

Standardized rate ratio confidence intervals

The following formula provides 95 percent confidence intervals for standardized rate ratios:

$$\left(\frac{AAR_{study}}{AAR_{ref}} \right)^{1 \pm \left(\frac{Z_{a/2}}{X} \right)}$$

$$X = \frac{(AAR_{study} - AAR_{ref})}{\sqrt{SE(AAR_{study})^2 + SE(AAR_{ref})^2}}$$

where

and $Z_{á/2} = 1.96$ (at the 95% level) and AAR_{study} and AAR_{ref} are age-adjusted rate for study and reference groups, respectively. At the p value of 0.05, if the confidence interval includes 1.0, the age-adjusted incidence rates between the two groups are not significantly different.

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P.O. # 542241 300 11/01