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## GEOGRAPHIC VARIATION IN HUMAN IMMUNODEFICIENCY VIRUS SEROCONVERSION RATES IN THE U.S. NAVY

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## Geographic Variation in Human Immunodeficiency Virus Seroconversion Rates in the U.S. Navy

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**Summary:** The Navy population is centered around 19 U.S. home ports and several inland duty stations. This is a study of variation in human immunodeficiency virus (HIV) seroconversions in Navy enlisted men by location in the United States, based on 949,570 enzyme-linked immunosorbent assays and 812 seroconversions during 1987-90. Seroconversion rates were higher in personnel in San Francisco ( $p = 0.0004$ ), Washington, D.C. ( $p = 0.001$ ), and Orlando, FL ( $p = 0.04$ ) than in other areas. They were lower in Charleston, SC, New London, CT, Seattle; and Brunswick, ME ( $p < 0.05$ ). Black men had triple the seroconversion rate of all other men ( $p < 0.0001$ ). After adjustment for race, age, marital status, and occupation, risk of seroconversion remained high in San Francisco ( $p = 0.02$ ) and Orlando ( $p = 0.03$ ). The risk of seroconversion in San Francisco was twice that of other areas in a cohort that did not change location ( $p = 0.01$ ). In contrast to declining trends overall in the Navy, rates did not decrease in Washington, D.C., a result consistent with previous calculations indicating a delayed second wave of HIV infection in the region. **Key Words:** HIV—Seroconversion rates—U.S. Navy.

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The Navy population is primarily centered around 19 U.S. home ports on the Atlantic and Pacific coasts, Hawaii, and Lake Michigan, and several inland duty stations. Rates of human immunodeficiency virus (HIV) seroprevalence and AIDS incidence vary greatly in the civilian population in states with Navy home ports (1-5). The annual in-

cidence rate of AIDS in states with Navy ports ranged from five per 100,000 in Maine to 117 per 100,000 in Washington, D.C. (6).

Considerable geographic diversity in HIV seroprevalence rates has been noted in teenaged applicants for military service (7,8), with seroprevalence in applicants from heavily urbanized areas such as Washington, D.C. reported as more than 20 times that of applicants from less urbanized areas (7). This study assessed HIV seroconversion rates in active-duty Navy enlisted personnel in geographically dispersed home ports and duty stations throughout the U.S. during 1987-90. The population and procedures used have been described (9-11). A previous investigation reported the absence of an association between visits to foreign ports and subsequent risk of HIV infection (11), but no pre-

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vious study has examined variation in seroconversion rates in the Navy or in any active-duty military population by residence within the United States.

## METHODS

### Data Sources

The Naval Health Research Center (NHRC) maintains the Navy HIV Central Registry, which contains results of all enzyme-linked immunosorbent assay (ELISA) and Western blot test results for Navy personnel (12), along with individual demographic and career histories obtained from the Naval Military Personnel Command (13). Records of all HIV seropositive personnel are confirmed by the Navy Bureau of Medicine and Surgery and the Naval Health Research Center.

### Study Design

The residence for most of the Navy population is a home port or duty station. For this study, each active-duty enlisted person was categorized as residing at one of 19 home ports or duty stations, or at an inland duty station east (Eastern region) or west (Western region) of the Mississippi River. Most duty stations in the Eastern inland region were aviation facilities centered around Memphis, and smaller facilities in Alabama, Georgia, and Mississippi. Most duty stations in the Western inland region were aviation facilities in central and western Texas and Nevada. Smaller stations were grouped with nearby larger facilities. The HIV testing and career histories were linked to determine home port or duty station at the time of testing. For individuals who did not have a designated home port, the home port was designated according to the zip code of the duty station to which the individual was assigned when tested. Individuals for whom no home duty station address or zip code was available in official Navy records or whose home duty stations were outside the United States were included in a residual unspecified/overseas category.

### Statistical Procedures

The HIV seroconversion rates were calculated by dividing the annual number of HIV seroconverters at a home port or duty station by the number of individuals tested who had a prior negative ELISA. Rates were age adjusted using the indirect method (14). Statistical significance was assessed using 95% confidence intervals derived from the Poisson distribution (14). For comparisons within racial groups, the seroconversion rate for men of each race in each location was compared to that of all other male Navy personnel of the same race. Temporal trends were examined using chi-squared tests, including tests for trend (15). Statistical significance was tested using chi-squared and Fisher's exact test (15). All *p* values were two-sided. Similar analyses were performed for a cohort that remained in the same home port for the entire study period. The number of female seroconverters (<20 individuals) was too few for computation of age-adjusted rates by geographic area, so women were not included in this study.

### ELISA and Western Blot Confirmation

Navy-wide HIV screening began in the first quarter of 1986 (16). Seroconverters were defined as all male active-duty U.S. Navy personnel who had a negative ELISA blood test for HIV followed after at least 30 days by two positive ELISAs from blood samples drawn on different dates, and at least one positive Western blot or immunofluorescent antibody (IFA) assay. The diagnoses of a total of 99.3% of HIV seroconverters in the Navy were confirmed by a Western blot assay meeting Centers for Disease Control criteria for positivity, consisting of at least two of three bands present at p24, gp41, and both gp120 and 160 (17). The diagnosis was made by a positive IFA assay in the <1% (0.7%) of subjects who had indeterminate Western blots. Seroconversion must have occurred at least 120 days after entry to active-duty service. The average time interval between HIV ELISA tests during this study was 10 months. The study identified individuals who had seroconversion between Jan. 1, 1987, and Dec. 31, 1990. Screening procedures have been described in detail previously (9).

Rosters of individuals tested were completed at 26 medical treatment facilities that collected blood for ELISA and Western blot assays. Names, identification numbers, and dates of birth of persons receiving tests were provided by Biotech, Inc., Rockville, MD, and North American Biologicals, Inc., Miami, FL, which performed the tests. Identifying information was matched against the NHRC Career History File for verification of identity. Race was categorized as white, black, or other, based on official records. The category "white" included individuals of Hispanic origin except those specifically designated as black. The category "other" included Oriental, Asian-American, Pacific Islander (including Philippine, Hawaiian, and Polynesian), American Indian, Eskimo, and Aleut. Further stratification into ethnic groups was not possible.

### Adjustment for Covariates

Adjustment for covariates was performed using Poisson regression (18,19). Individuals were combined into unique groups based on home port or duty station, age in years (17-19, 20-29, or 30+), race (white, black, or other), marital status (ever married, never married), and occupation (medium or low HIV seroprevalence, high HIV seroprevalence). An individual was considered to be in an occupation with high seroprevalence if the occupation was ranked in the top 20% of all Navy occupations in seroprevalence rates (not shown). Poisson regression was performed using the LOGISTIC procedure in SAS. For events with small probabilities of occurrence, such as HIV seroconversion in this population, this procedure closely approximates the Poisson regression method (20). Poisson regression analyses were also performed for the cohort of men who remained in the same home port or duty station throughout the study period. Odds ratios obtained from regression were used as the estimates of relative risk of seroconversion, with *p* values derived from the Wald chi-squared test (20). Norfolk, the home port with the greatest number of person-years at risk, was used as the reference port for regression analyses.

## RESULTS

There were 812 seroconverters in 949,570 persons tested with a previous negative ELISA (Table

1). Seroconverters included 455 white men, 310 black men, and 47 men of other races.

### Geographic Variation

Overall age-adjusted HIV seroconversion rates in San Francisco, ( $p = 0.0004$ ), Washington, D.C. ( $p = 0.001$ ), and Orlando, FL ( $p = 0.04$ ) were higher than in all other areas (Table 1). Areas with significantly low rates included Charleston, SC; New London, CT; Seattle; and Brunswick, ME ( $p < 0.05$ ).

### Trends

There was an overall downward trend in HIV seroconversion rates ( $p < 0.001$ ) (Table 2). Rates declined between 1987-8, with apparent stabilizing in most areas during 1989-90. There were some excep-

tions to the declining trend, such as an increasing trend of borderline significance ( $p = 0.10$ ) in Washington, D.C., which experienced its highest seroconversion rate during 1990.

### White Men

There was considerable geographic variation in HIV seroconversion rates in white men during the early part of the study period (Fig. 1). The rate in Orlando during 1987 ( $p = 0.0001$ ) and 1989 ( $p = 0.0001$ ) was statistically significantly higher than that of all white men in the Navy. An apparently high seroconversion rate in white men in the Western inland region in 1990 was of borderline significance ( $p = 0.06$ ) (Fig. 1).

### Black Men

The seroconversion rate in black men overall was approximately triple that of all male Navy person-

TABLE 1. Age-adjusted human immunodeficiency virus seroconversion rate per 1,000 tested by home port or duty station, active-duty U.S. Navy enlisted personnel, men, 1987-90

Home port or duty station	No. of seroconverters	No. in population tested with previous negative test	Age-adjusted seroconversion rate per 1,000	95% confidence interval on age-adjusted rate	
				Lower	Upper
<b>West</b>					
San Francisco	98	81,030	1.2 <sup>a</sup>	1.0	1.5
San Diego	161	153,646	1.0	0.9	1.2
Pearl Harbor, HI	36	44,557	0.8	0.6	1.1
Long Beach, CA	43	50,830	0.8	0.6	1.1
Seattle	17	43,289	0.4 <sup>b</sup>	0.2	0.6
<b>Mid-Atlantic</b>					
Washington, D.C.	28	17,345	1.6 <sup>a</sup>	1.1	2.3
Philadelphia	28	21,493	1.3	0.9	1.9
Norfolk, VA	169	172,977	1.0	0.8	1.1
New York	2	6,199	0.3	0.0	1.2
<b>New England</b>					
Newport, RI	6	8,220	0.7	0.3	1.6
Boston	2	4,265	0.5	0.1	1.7
New London, CT	12	29,370	0.4 <sup>b</sup>	0.2	0.7
Brunswick, ME	0	5,653	0.0 <sup>b</sup>	0.0	0.5
<b>Great Lakes</b>					
Chicago	17	29,058	0.6	0.4	1.0
<b>Southeast</b>					
Miami	7	4,324	1.6	0.6	3.3
Orlando, FL	15	9,926	1.7 <sup>c</sup>	1.0	2.8
New Orleans	39	36,757	1.1	0.8	1.6
Jacksonville, FL	44	57,822	0.8	0.6	1.0
Charleston, SC	34	61,866	0.5 <sup>b</sup>	0.4	0.7
<b>Other</b>					
Western inland	2	3,386	0.6	0.1	2.2
Eastern inland	2	10,666	0.2	0.0	0.8
Unspecified/overseas	50	96,891	0.6 <sup>b</sup>	0.4	0.7
<b>Total</b>	<b>812</b>	<b>949,570</b>	<b>0.9</b>	<b>0.8</b>	<b>0.9</b>

<sup>a</sup> Statistically significantly high,  $p < 0.001$ .

<sup>b</sup> Statistically significantly low,  $p < 0.05$ .

<sup>c</sup> Statistically significantly high,  $p < 0.05$ .

TABLE 2. Age-adjusted human immunodeficiency virus seroconversion rate per 1,000 tested, by home port or duty station, race, and year, active-duty U.S. Navy enlisted personnel, men, 1987-90

Home port or duty station	White				Black				Total			
	1987	1988	1989	1990	1987	1988	1989	1990	1987	1988	1989	1990
<b>West</b>												
San Francisco	2.8	1.0	0.5	0.5	7.5	4.2	2.1	2.3	3.6	1.5 <sup>a</sup>	0.7	0.7
San Diego	1.8	1.1	0.7	0.7	6.2	2.0	1.1	1.5	2.6	1.3	0.7	0.8
Pearl Harbor, HI	1.5	0.5	0.8	0.4	3.5	2.5	0.6	1.8	2.0	0.8	0.8	0.6
Long Beach, CA	1.0	0.9	0.7	0.5	1.7	1.6	2.0	1.1	1.0	0.9	0.9	0.7
Seattle	0.4	0.2	0.2	0.3	4.1	2.5	1.0	0.7	0.6	0.4	0.3	0.4
<b>Mid-Atlantic</b>												
Washington, D.C.	2.4	0.6	0.7	1.0	0.0	3.1	4.3	8.5 <sup>b</sup>	1.8	1.0	1.3	2.8 <sup>b</sup>
Philadelphia	1.9	0.9	0.2	0.5	6.2	4.3	1.4	1.3	4.1	1.7	0.6	0.8
Norfolk, VA	1.5	0.5	0.3	0.5	7.6	2.9	2.2	2.1	2.8	1.0	0.7	0.9
New York	5.1	0.0	0.0	0.7	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.7
<b>New England</b>												
Newport, RI	0.0	0.0	1.0	0.6	0.0	0.0	3.5	7.4	0.0	0.0	1.3	1.6
Boston	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0
New London, CT	0.0	0.8	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.3
Brunswick, ME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<b>Great Lakes</b>												
Chicago	0.9	0.6	0.3	0.4	10.1	1.9	0.7	0.8	2.1	0.8	0.4	0.5
<b>Southeast</b>												
Miami	3.1	2.5	0.0	1.2	0.0	3.8	0.0	0.0	2.6	2.5	0.0	1.0
Orlando, FL	13.9 <sup>b</sup>	0.0	4.3 <sup>b</sup>	0.5	0.0	0.0	0.0	4.8	13.3 <sup>b</sup>	0.0	3.5 <sup>a</sup>	1.3
New Orleans	1.3	0.8	0.5	0.6	9.7	3.5	2.0	1.1	2.8	1.2	0.9	0.7
Jacksonville, FL	0.8	0.6	0.6	0.4	5.4	1.4	1.4	0.9	1.8	0.8	0.7	0.5
Charleston, SC	0.5	0.6	0.4	0.4	2.4	1.1	0.6	0.8	0.8	0.6	0.4	0.5
<b>Other</b>												
Western inland	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Eastern inland	0.0	0.0	0.0	0.0	0.0	1.8	3.8	0.0	0.0	0.2	0.7	0.0
Unspecified/overseas	1.6	0.5	0.3	0.3	8.4	1.0	0.8	0.9	2.5	0.5	0.3	0.4
<b>Total</b>	<b>1.7</b>	<b>0.7</b>	<b>0.5</b>	<b>0.5</b>	<b>5.7</b>	<b>2.3</b>	<b>1.5</b>	<b>1.6</b>	<b>2.3</b>	<b>0.9</b>	<b>0.6</b>	<b>0.7</b>

<sup>a</sup> Statistically significantly high,  $p < 0.01$ .

<sup>b</sup> Statistically significant high,  $p < 0.0001$ .

nel ( $p < 0.001$ ). For the entire period, black men in Washington, D.C., had an age-adjusted seroconversion rate more than twice that of all black men in the Navy ( $p = 0.001$ ), a rate in San Francisco 1.7 times that of all black men ( $p = 0.002$ ), and a rate in Norfolk 1.3 times that of all black men ( $p = 0.004$ ). Unlike most duty stations, rates in black men in Washington D.C., did not decrease during the study period, although an apparent increase (Fig. 2) was not statistically significant ( $p = 0.32$ ). The seroconversion rate was statistically significantly higher for black men in Washington, D.C., in 1990, however, than that of all black men in the Navy ( $p < 0.0001$ ). Apparently increasing time trends in seroconversion rates in black men were not significant in Newport, RI ( $p = 0.26$ ) and Orlando ( $p = 0.24$ ). The rate in Newport in 1990 was higher than that of all black men, although the difference was of borderline significance ( $p = 0.11$ ), while the rate in Orlando in 1990 did not differ significantly from that of all black men ( $p = 0.35$ ). Tables providing further

detail on trends by race and location are available from F.C.G.

### Adjustment for Covariates

#### Geographic Variation

After adjustment for race, age, and other covariates by regression, using Norfolk as the reference home port, personnel in San Francisco ( $p = 0.02$ ) and Orlando ( $p = 0.03$ ) had statistically significantly high relative risks of seroconversion during the entire study (Table 3). After adjustment for covariates, Orlando had the highest multiple adjusted relative risk of seroconversion in 1987 and 1989, while Miami had the highest in 1988. In 1990, only personnel in Washington, D.C. had a significantly high adjusted relative risk of seroconversion ( $p = 0.0003$ ). Relative risks were low in Charleston, New London, and Seattle during 1987-1990 ( $p < 0.05$ ).

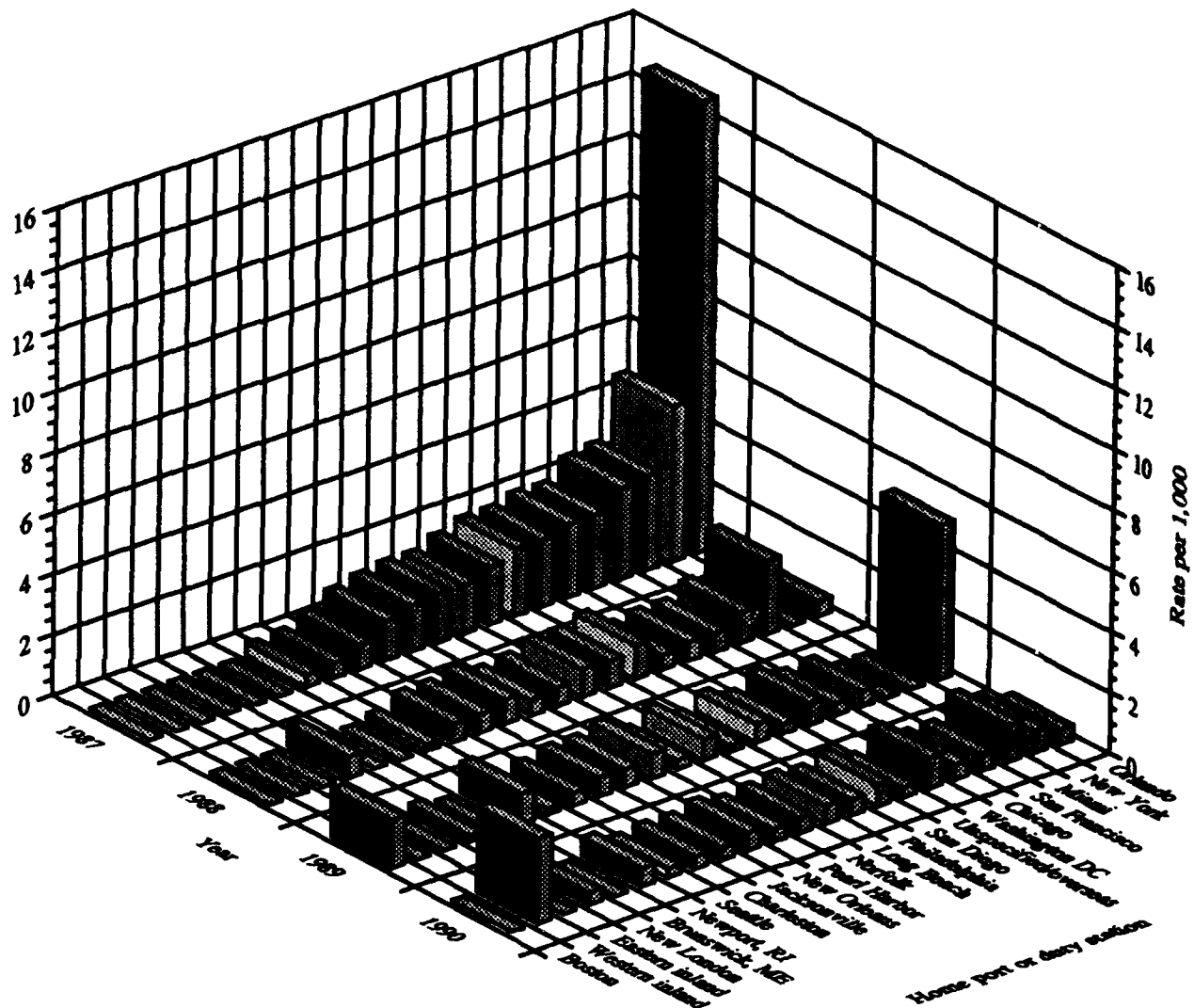


FIG. 1. Age-adjusted seroconversion rate per 1,000 tested, by home port or duty station and year, U.S. Navy enlisted personnel, white men, 1987-90.

#### Age and Race

The black-white differential in seroconversion rates remained virtually unchanged after adjustment for all covariates ( $p < 0.001$  in all years) (Table 3). Men 20 years and older tended to have higher rates than younger men.

#### Cohort Remaining in the Same Home Port

For the cohort who remained in the same home port or duty station for the entire study period (181, 189 men, with 195 seroconverters), the relative risk of seroconversion in San Francisco was approxi-

mately twice that of the entire Navy ( $p < 0.01$ ) (Table 3).

#### DISCUSSION

Individuals in San Francisco, Washington, D.C., and Orlando had higher seroconversion rates than those in all other areas, a difference that persisted in San Francisco and Orlando after adjustment by regression for race and other covariates. Apparent fluctuations in seroconversion rates in Orlando (Figs. 1 and 2) were within the range of random variation, since they were based on fewer events than in larger duty stations. The risk of seroconver-



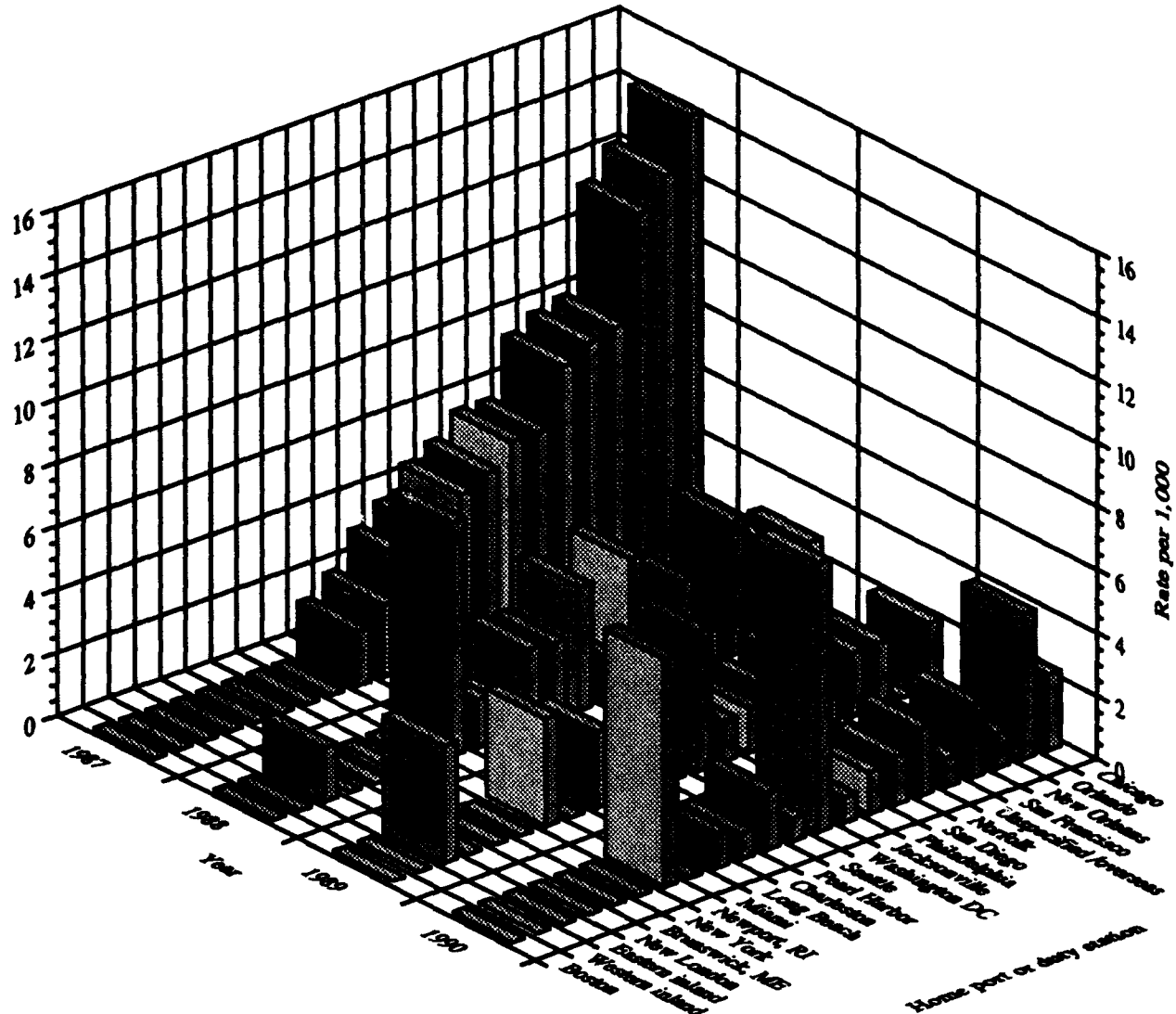


FIG. 2. Age-adjusted seroconversion rate per 1,000 tested, by home port or duty station and year, U.S. Navy enlisted personnel, black men, 1987-90.

sion in the cohort that remained in San Francisco during 1987-90 was twice that of other locations.

Adjustment for covariates was done using Poisson regression, which is well suited to analysis of seroconversion rates in large populations where the outcome is relatively uncommon (18), and has been used previously in studies of HIV seroconversion (21,22). Only men who remained in the Navy long enough to have at least two ELISAs were included in this study, since at least two tests were required to define the occurrence of seroconversion. It is possible that some individuals could have suspected an undetected HIV infection and might have left the Navy after a single negative ELISA. If so, differ-

ences among home ports in early separation due to such suspicion could account for some portion of the results. This appears unlikely, though, as military personnel cannot voluntarily terminate service without serious consequences, such as loss of health care and other benefits. The increased risks of seroconversion in black men, in those 20 years and older, and in never-married men in this study are consistent with findings in the Army (22,23).

The geographic variation in HIV seroconversion rates in this study was also consistent with previously reported variation in seroprevalence rates in the civilian population (21,24), military recruits (7,8,25), and Job Corps participants (26). The high-

TABLE 3. Relative risk adjusted by multiple regression for home port or duty station, age, race, marital status, and occupation<sup>a</sup>, by year, U.S. Navy active-duty enlisted personnel, men, 1987-90

Home port or duty station	Relative risk					
	1987	1988	1989	1990	1987-90	1987-90 cohort <sup>b</sup>
<b>West</b>						
San Francisco	1.32	1.56 <sup>c</sup>	0.98	1.00	1.34 <sup>c</sup>	1.97 <sup>d</sup>
San Diego	0.90	1.28	1.02	0.96	1.10	1.17
Pearl Harbor, HI	0.79	0.89	1.20	0.90	0.94	2.14
Long Beach, CA	0.36	0.92	1.29	0.82	0.89	0.15
Seattle	0.28	0.49	0.45	0.63	0.50 <sup>f</sup>	0.00
<b>Mid-Atlantic</b>						
Washington, D.C.	0.55	0.83	1.51	3.03 <sup>c</sup>	1.47	0.63
Philadelphia	1.29	1.57	0.81	0.93	1.26	0.00
Norfolk, VA	1.00	1.00	1.00	1.00	1.00	1.00
New York	1.42	0.00	0.00	1.06	0.46	0.00
<b>New England</b>						
Newport, RI	0.00	0.00	1.88	1.99	0.80	0.74
Boston	0.00	0.00	2.59	0.00	0.59	0.00
New London, CT	0.00	0.88	0.38	0.51	0.53 <sup>f</sup>	0.00
Brunswick, ME	0.00	0.00	0.00	0.00	0.00	0.00
<b>Great Lakes</b>						
Chicago	0.80	0.97	0.80	0.63	0.80	1.70
<b>Southeast</b>						
Miami	1.12	2.92 <sup>c</sup>	0.00	1.66	2.02	3.95
Orlando, FL	4.93 <sup>c</sup>	0.00	4.36 <sup>d</sup>	1.35	1.80 <sup>c</sup>	2.14
New Orleans	1.15	1.24	1.48	0.84	1.23	1.33
Jacksonville, FL	0.69	0.83	1.04	0.66	0.84	0.78
Charleston, SC	0.29 <sup>f</sup>	0.63	0.60 <sup>f</sup>	0.58	0.55 <sup>f</sup>	0.43
<b>Other</b>						
Western inland	0.00	0.00	0.00	3.40	0.68	0.00
Eastern inland	0.00	0.29	0.89	0.00	0.25	1.55
Unspecified/overseas	0.89	0.51 <sup>f</sup>	0.47 <sup>f</sup>	0.45 <sup>f</sup>	0.52 <sup>f</sup>	1.19
<b>Age, yr</b>						
17-19	1.00	1.00	1.00	1.00	1.00	1.00
20-29	1.92 <sup>c</sup>	4.98 <sup>c</sup>	2.27 <sup>c</sup>	1.51	2.37 <sup>c</sup>	0.49 <sup>f</sup>
35+	1.95	5.40 <sup>c</sup>	3.26 <sup>d</sup>	1.13	2.45 <sup>c</sup>	0.33 <sup>f</sup>
<b>Race</b>						
White	1.00	1.00	1.00	1.00	1.00	1.00
Black	3.40 <sup>c</sup>	2.94 <sup>c</sup>	2.66 <sup>c</sup>	2.95 <sup>c</sup>	2.93 <sup>c</sup>	4.37 <sup>c</sup>
Other	1.79	0.81	0.89	0.94	1.02	0.86
<b>Marital status</b>						
Ever married	1.00	1.00	1.00	1.00	1.00	1.00
Never married	2.27 <sup>c</sup>	3.28 <sup>c</sup>	3.54 <sup>c</sup>	1.96 <sup>c</sup>	2.73 <sup>c</sup>	1.86 <sup>c</sup>

<sup>a</sup> Human immunodeficiency virus seroprevalence data on men in the Navy. As expected based on this definition, the effect of occupation was significant ( $p < 0.001$ ) in each year and for the total of all years, with relative risks ranging from 2.1-3.6.

<sup>b</sup> Based on the cohort of 181,386 men who did not change home port or duty station area during the period Jan. 1, 1987, through June 30, 1990, which included 195 seroconverters.

<sup>c</sup> Statistically significantly high,  $p < 0.05$ .

<sup>d</sup> Statistically significantly high,  $p < 0.01$ .

<sup>e</sup> Statistically significantly high,  $p < 0.001$ .

<sup>f</sup> Statistically significantly low,  $p < 0.05$ .

est AIDS incidence rates in the civilian population in states with Navy home ports were in Washington, D.C., New York, Florida, and California (6). Generally, personnel in Navy home ports or duty stations in states with low incidence rates of AIDS (6) and low seroprevalence rates of HIV (7,8) had low seroconversion rates, with the exception of New York, which had high seroprevalence rates in the civilian population (7,8) but paradoxically low rates in Navy personnel.

Unlike seroconversion rates in most areas, those in Washington, D.C. increased during the study period. This was partly due to an apparent upward trend in seroconversion rates for black men, although the trend was not statistically significant ( $p = 0.32$ ). According to back calculation of HIV infection rates using AIDS incidence rates, there were two waves of HIV infection in the civilian population of Washington, D.C. (27), with the first wave peaking in 1982-3 and the second beginning to

rise in the mid-1980s. The results of this study are consistent with the effects of the second wave of infection deduced from back calculation.

Information on behavioral risk factors in individual Navy men was not available, but the parallels between these data and patterns of incidence of AIDS in the civilian population suggest that geographic differences in sexual behavior, i.v. drug abuse, and socioeconomic factors in the surrounding civilian population (28) account for much of the geographic variation in HIV seroconversion rates in the Navy. This study specifically provides support for previous back calculations of HIV seroconversion rates, including the existence of a second wave of infection in the Washington, D.C., area, and provides a basis for targeting control efforts to the areas with highest seroconversion rates.

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