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LONG-TERM EFFECTS OF ENVIRONMENT ON HEALTH AND PERFORMANCE OF ANTARCTIC WINTER-OVER PERSONNEL

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SUMMARY

Problem

Although the prolonged isolation of enlisted Navy personnel at small Antarctic research stations during the austral winter does not appear to have any adverse effects on subsequent health and performance, extreme variations in altitude, climate, and station size may negatively affect the health and performance of personnel assigned to certain stations.

Objective

The object of this study was to determine if variations existed in the risk to health and well-being of personnel who winter-over in Antarctica which were related to the station to which they are assigned, and if so, which environmental factors were responsible for these variations.

Approach

Subjects were 327 enlisted Navy personnel who wintered over between 1963 and 1974. A fifteen year period between 1965 and 1979 was established for follow-up. Four types of data were examined: demographic characteristics obtained from the Operation Deep Freeze and the Navy Enlisted History Files; inpatient medical data, including all first hospitalizations for all diagnoses which occurred after entry into the study; service history information, including number of promotions, demotions, unauthorized absences, desertions, medical and physical evaluation board hearings, deaths, and type of discharge; and environmental characteristics of six small research stations, including mean annual temperature, altitude, latitude, and average number of winter-over personnel.

Results

Results indicated that there was no relationship between the rates of first hospitalization and the severity of station environment. Personnel assigned to Palmer Station and personnel at small stations had significantly higher rates than the standard incidence of all winter-over personnel. However, these may reflect Type I statistical errors because of the small sample size. No significant differences were observed on any of the performance indicators.

Conclusions

The results suggest that there are no negative long-term effects on health and performance associated with any of the environmental variables examined. Rather, the data support the view that man is capable of adapting to a variety of extreme, isolated environments for long periods of time.

Recommendations

This study should be viewed as exploratory in nature because of the relatively small sample size. Additional follow-up data should be collected on personnel who have wintered-over since 1974. Screening of personnel should continue.

Long-Term Effects of Environment on Health and Performance of Antarctic Winter-Over Personnel

It is a small wonder that there are no permanent human inhabitants of the continent of Antarctica. With an environment characterized by extreme temperatures, high altitudes, low humidity, and extreme light-dark cycles, the continent is barely capable of supporting resident plant and animal life, much less human communities. The ill-fated expeditions of Shackleton and Scott testify to the dangers associated with this harsh and stressful environment. Although research stations have supported human life on a year-round basis since 1957, the harsh climate, isolation from the outside world, lack of sensory stimulation, and poor living conditions remain as potential threats to the health and well-being of station personnel. Previous research has documented the impact of prolonged exposure to this environment which include: hypoxia, hypocapnia, and mild alkalosis associated with high altitude (Guenter et al., 1970); dry skin associated with low humidity which sometimes leads to fissures, bleeding, and loss of function (Bodey, 1978); immunosuppression associated with residence in a germ-free environment and the resultant increase in infectious and respiratory diseases upon return to the outside world (Allen, 1973; Holmes et al., 1976; Muchmore et al., 1970; Muchmore et al., 1974); insomnia (Shurley, 1970); increases in carboxyhemoglobin associated with poor ventillation (Guenter et al., 1970); decreased blood pressure (Budd and Warhaft, 1966; Hicks, 1967); increased risk of myocardial infarction (Sotaniemi et al., 1970); and increased psychological disturbances (Gunderson, 1963; Gunderson, 1968; Mullin, 1960; Palmai, 1963).

The environments of Antarctic research stations are not homogeneous, however. As Table 1 indicates, there is considerable variation in several key environmental conditions of six of the U.S. stations which have been in operation since 1957. Byrd Station is located 885 miles from McMurdo Sound on the inland ice cap at an elevation of 5,000 feet above sea level. The station consists of prefabricated buildings placed in long tunnels 40 feet deep, roofed over with steel arches and overlaid with packed snow. The slow movement of the ice sheet bends the arches and pushes tunnel walls together, requiring constant maintenance and repair (Gunderson, 1974). There are laboratory facilities for seismological, meteorological, ionospheric, auroral, and radio noise research. Since 1972, Byrd Station has only operated during the summer months.

Eights station, located near the base of the Antarctic Peninsula at about 1,400 feet above sea level, was a temporary camp consisting of eight portable buildings transported to the site by air and arranged in two parallel rows, with flooring and roofing placed between the rows to create a large nine-room building (Gunderson, 1974). The station operated year-round from 1963 through 1965. Living and working conditions at this station were considered to be relatively difficult (Gunderson, 1968).

Hallett Station was operated jointly by the United States and New Zealand and was supplied by sea and air. Buildings were all on the surface and the climate was less severe than that of the other research stations with the exception of Palmer. By 1965, Hallett had nine buildings for scientific use and thirteen for general use, with approximately 418m

Table 1

Station Characteristics

	Byrd	S. Pole	Hallett	Palmer	Eights	Plateau
Terrain	inland ice	inland ice	glacial moraine	bedrock	inland ice	inland ice
Latitude	79 59'S	90 S	72 19'S	64 45'S	75 15'S	79 30'S
Air Distance from McMurdo (miles)	885	820	380	2,360	1,525	1,350
Feet above Sea Level	4,941	9,184	16	25	1,380	11,890
Method of Supply	air	air	air,sea	sea	air	air
No. of Buildings	15	11	16	2	11	8
Mean Annual Temperature	-19 F	-57 F	+4 F	+20 F	-13 F	-69 F
Approximate No. of Winter Personnel						
Man	9	7	5	5	5	4
	18	13	9	4	6	4

for living areas (Gunderson, 1974). Loss by fire of the biological laboratory in 1964 contributed to the decision to convert the station to a summer-only operation, and conclusion of a major six-month study led to the station's abandonment in early 1973.

Palmer Station on the Antarctic Peninsula was established in 1965 and remains one of three U.S. research stations which maintains year-yound operations, the other two being McMurdo Station and the Amundsen-Scott South Pole Station. Palmer Station can only be reached by ship, and serves as a primary shore facility and as an operational base for R/V Hero. Ship and station together comprise a research station that can support ship-based and shore-based research projects throughout the peninsula area. In 1967-68 a new two-story building was constructed, increasing the living area from 172m at the old station to more than 470m at the new station. Because of its coastal location, biological studies are emphasized. Climatic conditions are less extreme here than at other stations. In fact, Palmer's climate compares with that of Nome, Alaska, although Palmer's summers are cooler, and winters warmer.

Plateau Station, established in 1966, consisted of five portable vans linked together. The Station accommodated four Navy personnel and four scientists who conducted studies in aurora, airglow, geomagnetism, very low frequency (VLF) radio propagation, and radiation climatology. The Station is located in an inaccessible region high on the polar plateau between the geographic south pole and Queen Maud Land at an altitude of almost 12,000 feet above sea level. A low temperature of -116.4 F was recorded at Plateau Station in 1967, and it is expected that temperatures may fall as low as the record of -126.9 F established at the Soviet Union's Vostok Station. Plateau Station was closed for year-round operations in January 1969.

The Amundsen-Scott South Pole Station is at the geographic south pole at an elevation of approximately 9,200 feet above sea level. The mean annual temperature at the South Pole

is -57 F and during the winter months the extremely low temperature of -110 F has been recorded. The air also is extremely dry. There is an annual cycle of six months of light and six months of darkness. The station, supplied entirely by air, is completely isolated from February until November except for intermittent radio communication. Buildings at South Pole, although initially constructed on the surface, were in tunnels under the ice because of the accumulation of drifting snow (Gunderson, 1974). Only a few structures containing scientific equipment were on the surface. The crushing weight of accumulating snow and the continuous movement of the ice in spite of constant reinforcement of wooden and metal beams supporting the tunnel roof threatened the station with collapse. In 1975 the station was rebuilt as a geodesic dome 50 meters wide and 16 meters high that, with steel archways, covers modular buildings and equipment. Extending out from the dome on opposite sides are two cylindrical quonset huts of corrugated steel--one housing the power plant, machine shop, and garage, and the other the fuel bladders. Scientific programs are carried out in aurora, airglow, ionospheric studies, meteorology, and seismology.

Given the wide differences in station environments, we might expect that the risk to the health and well-being of personnel who winter-over in these stations varies with the station to which he is assigned. The object of this paper is to explore this relationship by examining the long-term impact of different station environments on the health and performance of enlisted U.S. Navy personnel who winter-over in the Antarctic.

METHODS

Subjects were 327 enlisted Navy personnel who wintered over at one of these six stations between 1963 and 1974. All of these individuals had been given favorable combined evaluations by a screening team consisting of a clinical psychologist and psychiatrist. An additional 11 enlisted men who wintered over but who had been given unfavorable evaluations were excluded from the study because of the potential confounding effects between evaluation, health, and performance. Only Navy enlisted personnel were selected for follow-up because of the availability of medical and service history data on these individuals. The Naval Health Research Center maintains an Inpatient Medical Data File which contains records on all hospitalizations, medical and physical examination board hearings, and deaths for all active duty enlisted Navy personnel for the period 1965-1981. Data files obtained from the Navy Manpower and Personnel Management Information System (NMPC 15642) contain service history information on all enlisted personnel during this period as well. These two files were searched for all medical and service history information on the Navy enlisted personnel identified from the Operation Deep Freeze File.

A fifteen year period from 1965 to 1979 was established for follow-up. This was based on the period of time for which medical and service history information was available at the time the study was conducted. The start date for participation was established as 1 January 1965 or the year an individual was evaluated for the Operation Deep Freeze Program if after this date. Withdrawal was defined as the date of last discharge or 31 December 1979, whichever came first.

Three types of data were examined in this study. Demographic characteristics were obtained from the Operation Deep Freeze and Navy Enlisted History Files and included age, race, education, pay grade, occupation, and years served at the time of application to Operation Deep Freeze. The Operation Deep Freeze File also identified where in Antarctica a subject was stationed for a winter. Inpatient medical data included all first hospitalizations for all diagnoses which occurred after entry into the study (i.e. subsequent to screening for Operation Deep Freeze). Diagnoses were in accordance with the Eighth Revision, International Classification of Disease Adapted for Use in the United States (ICDA-8). Age at hospitalization, medical and physical evaluation board hearings, and death records also were obtained from the Inpatient Medical Record. Service history information obtained from the Navy Enlisted History File included number of promotions, demotions, unauthorized absences, and desertions, and last change which includes type of discharge.

Three types of comparisons were made in this study. The first included comparisons of demographic characteristics, incidence rates, and performance indicators by each station. The second included comparisons by station size with Byrd and South Pole categorized as large stations and the remaining four as small stations. The third included comparisons among stations grouped according to the severity of their environment, defined in terms of mean temperature and altitude. Hallet and Palmer were defined as stations of low severity, Byrd and Eights as stations of moderate severity, and Plateau and South Pole as stations of extreme severity.

Because of the small sample size and number of hospitalizations, comparisons were made of both independent and dependent rates. In the latter type of comparison, incidence rates of each station, station size group and environment severity group were compared with the incidence rates of the entire sample. Because winter-over personnel generally have lower incidence rates than other enlisted personnel (Palinkas, 1985), dependent rates were employed in order to take into consideration the potential "healthy worker effect" (Helmkamp and Bone 1985). Moreover, because certain stations maintained winter-over personnel only for a brief period of time, stations which operated only during the first few years of the study period would have high rates which reflect the generally higher incidence rates found in the Navy during that time. Use of dependent rates helps to control for potential confounding caused by disease incidence at different points of the study period.

Age-adjusted rates for total first hospitalizations and diagnostic categories of first hospitalizations were calculated using the direct method of adjustment (Lilienfeld and Lilienfeld, 1980). The standard population was comprised of all study participants. The rates for the winter-over groups and the standard rates of all winter-over personnel were compared to obtain estimates of relative risk by taking the ratio of rates for the winter-over groups to the standard rates. Levels of significance of these associations were obtained using 95 percent confidence intervals for both the dependent and independent rates (Daniel, 1983). One way analysis of variance and chi-square tests were employed to

determine levels of significance for observed differences in the demographic characteristics and service history outcomes of winter-over groups.

RESULTS

Demographic Characteristics

A comparison of the demographic characteristics of the winter-over personnel by station is presented in Table 2. Significant differences exist with respect to mean age, pay grade, length of service, and occupational group. Personnel who wintered-over at Eights Station were older and more experienced than the enlisted personnel of the other stations. Although not reported here, these differences also were found in comparisons of personnel by station size and environmental severity. Larger stations had higher percentages of blue collar personnel (primarily construction personnel) than were found in the small stations. In a comparison of occupational groups by environmental severity, no significant differences in distribution of personnel were observed.

Table 2

Characteristics of Antarctic Winter Over Personnel by Station, 1963-1974

	Byrd		South Pole		Hallett		Palmer		Eights		Plateau	
	N=126		N=119		N=16		N=46		N=13		N=7	
Mean Age	26.46		27.01		28.43		27.96		31.08		24.71	
$F = 2.25$ $p. < .05$												
Mean Pay Grade (E1-E9)	4.82		5.20		5.56		5.65		5.69		4.57	
$F = 7.05$ $p. < .001$												
Mean Length of Service	7.29		8.27		9.37		9.09		12.25		6.43	
$F = 2.49$ $p. < .03$												
Education												
8th Grade or Less	8	6.5	7	5.9	2	12.5	2	4.4	0	0	0	0
Grades 9 to 11	34	27.6	38	31.9	5	31.3	9	19.6	6	50.0	1	14.3
High School Graduate	72	58.5	59	49.6	9	56.3	29	63.0	6	50.0	5	71.4
College	9	7.3	15	12.6	0	0	6	13.0	0	0	1	14.3
Missing Data	3								1			
$\chi^2 = 13.83$ $d.f. = 15$	N.S.											
Race												
White	122	96.8	115	96.6	15	93.8	45	97.8	13	100.0	7	100.0
Nonwhite	4	3.2	4	3.3	1	6.3	1	2.2	0	0	0	0
$\chi^2 = 1.34$ $d.f. = 5$	N.S.											
Occupational Group												
Blue Collar	79	62.7	65	54.6	6	37.5	17	37.0	3	23.1	1	14.3
Electronic/Technical	23	18.3	24	20.2	5	31.3	8	17.4	4	30.8	3	42.9
Administrative/Cooks	15	11.9	19	16.0	3	18.8	12	26.1	3	23.1	3	42.9
Hospital Corpsmen	9	7.1	11	9.2	2	12.5	9	19.6	3	23.1	0	0
$\chi^2 = 28.67$ $d.f. = 15$	$p. < .05$											

First Hospitalizations

The age-adjusted incidence of total first hospitalizations is represented in Table 3. Because of the relationship between age, pay grade, and length of service among Navy personnel in general, controlling for differences in age among these groups also controls in part for differences in these other demographic characteristics. Individual diagnostic categories are not reported here because of the relatively few cases in each category. When a comparison of independent rates is made, no significant differences among the stations are observed. When the rates of each station are compared with the standard

Table 3

Total Age-Adjusted First Hospitalization Rates by Station, Antarctic Winter-Over Personnel, 1965-1979

Age Groups	Byrd		South Pole		Hallett		Palmer		Eights		Plateau		Standard All Stations	
	N	Rate†	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
17-24	0	-	3	333.3	0	-	0	-	0	-	0	-	3	133.33
25-29	13	597.7	4	210.0	2	1000.0	6	983.6	0	-	4	2352.9	29	556.62
30-34	19	710.3	13	502.9	0	-	14	1222.7	0	-	2	1600.0	48	673.68
35-39	16	1039.0	25	1785.7	3	1090.9	9	1374.0	0	-	0	-	53	1310.26
40+	8	1355.9	6	1290.3	1	3333.3	3	1200.0	5	14285	0	-	23	1666.67
Total	56	712.1	51	721.2	6	710.8	32	1052.0	5	985.2	6	1182.4	156	740.32
Lower CL		525.5		523.2		142.1		687.7		119.3		236.5		624.15
Upper CL		898.7		919.2		1279.4		1416.3		1851.1		2128.3		856.49
Relative Risk		0.96		0.97		0.96		1.42*		1.33		1.60		1.00
Person Years at Risk		788.0		725.5		97.0		286.0		60.0		44.5		2001.0

† per 10,000 person years. Total rates are age-adjusted using the direct method with total winter-over person years as the standard population

* p. < .05

incidence of first hospitalizations among the total sample, the personnel stationed at Palmer are found to have a significantly higher rate than the norm with a relative risk of 1.42. Because this difference is not confirmed by a comparison of independent rates, however, the possibility of a Type I statistical error must be entertained.

Comparisons of age-adjusted incidence of total first hospitalizations by station size and environmental severity are presented in Table 4. No significant differences are observed between the independent rates of large and small stations. When the rate of the small stations is compared with the incidence rate of the total sample, the small station rate is significantly higher. However, this difference too, may be due to a Type I statistical error because of the lack of a statistically significant difference between the independent rates. No significant differences are observed among the independent or dependent rates of stations in relatively mild, moderate, and severe environments.

Table 4

Total Age-Adjusted First Hospitalization Rates by Station Size and Severity of Environment: Antarctic Winter-Over Personnel, 1965-1979

Age Groups	Station Size				Severity of Environment					
	Large		Small		Mild		Moderate		Severe	
	N	Rate†	N	Rate	N	Rate	N	Rate	N	Rate
17-24	3	166.7	0	-	0	-	0	-	3	303.0
25-29	17	416.7	12	1061.9	8	987.6	13	559.1	8	385.5
30-34	32	608.4	16	857.9	14	930.2	19	652.9	15	553.5
35-39	41	1394.6	12	1086.0	12	1290.3	16	961.0	25	1724.1
40+	14	1327.0	9	2769.2	4	1428.6	13	2080.0	6	1263.2
Total	107	717.3	49	992.5	38	947.7	61	715.7	57	767.2
Lower CL		525.5		714.6		669.8		536.1		568.0
Upper CL		898.7		1270.5		1249.3		895.4		966.4
Relative Risk		0.97		1.34*		1.28		0.97		1.04
Person Years at Risk		1513.5		487.5		383.0		848.0		770.0

† per 10,000 person years. Total rates are age-adjusted using the direct method with total winter-over person years as the standard population

* p. < .05

Performance Indicators

Table 5 provides a summary of selected service history and performance indicators of the two groups after they have returned from the Antarctic. No significant differences were observed on any of the performance indicators in comparisons between stations or by station size or severity.

Table 5

Service History of Winter Over Personnel by Station, 1965-1979

	Byrd		South Pole		Hallett		Palmer		Eights		Plateau	
	N	%	N	%	N	%	N	%	N	%	N	%
Promotions	81	64.3	72	60.5	8	50.0	31	67.4	5	38.5	6	85.7
Demotions	1	0.8	1	0.8	1	6.3	2	4.3	0	0	0	0
Unexcused Absences	3	2.4	4	3.4	0	0	0	0	0	0	1	14.3
Desertions	1	0.8	0	0	0	0	0	0	0	0	1	14.3
Separation from Service												
Released to Inactive Duty	93	73.8	77	64.7	13	81.3	27	58.7	11	84.6	4	57.1
Honorable Discharge	13	10.3	18	15.1	3	18.7	6	13.0	0	0	1	14.3
General Discharge	1	0.8	1	0.8	0	0	0	0	0	0	0	0
Bad Conduct Discharge	1	0.8	0	0	0	0	0	0	0	0	1	14.3
Other Discharge	3	2.4	4	3.4	0	0	0	0	1	7.7	1	14.3
Died	0	0	1	0.8	0	0	2	4.3	0	0	0	0
Total Separations	111	88.1	101	84.9	16	100.0	35	76.1	12	92.3	7	100.0
Medical Disposition												
Medical Boards	4	3.2	4	3.4	0	0	3	6.5	0	0	1	14.3
Physical Evaluation Boards	1	0.8	3	2.5	0	0	2	4.3	0	0	0	0
Died in Service	0	0	1	0.8	0	0	2	4.3	0	0	0	0

DISCUSSION

The small sample size and the wide range of confidence intervals preclude the drawing of any definite conclusions from this study on the relationship between environment and health in the Antarctic. Rather, this study should be viewed as an exploratory effort which could be used as a model for further research, both in the Antarctic and in similar environments where small groups are isolated for long periods of time. For instance, sophisticated multivariate analyses are required to identify the independent contributions of each environmental variable to overall disease incidence and career performance.

Previous research (Palinkas, 1985) has indicated that, as a group, the enlisted Navy personnel who have wintered-over in the Antarctic between 1963 and 1974 had fewer first hospitalizations than a control group of Deep Freeze candidates who were rated as acceptable for Antarctic duty but who did not winter-over. No differences were observed on any of the performance indices. The self-selection of candidates and the Operation Deep Freeze screening and selection process both act to select a healthy and well-adjusted group for this assignment.

While the results indicate that no relationship exists between environmental severity and the long-term risk for hospitalization, personnel who were assigned to Palmer Station had a significantly higher rate of first hospitalizations than the standard rate for all winter-over personnel. Also, the overall incidence rate for personnel assigned to small

stations was significantly higher than the standard rate. However, because of the small sample size and the lack of significant differences in comparisons of variable-specific rates, it is likely that these differences are due to chance. Given this possibility, caution should be exercised in drawing any conclusions from these data.

The lack of a relationship between environmental severity and disease incidence or performance may be attributed to several different factors. Despite differences in outside temperature, altitude, and light-dark cycles, the internal environment of these stations is relatively uniform. Improvements in these facilities also has enhanced living and working conditions and improved the quality of life during the winter-over period. Gunderson (1968), however, notes that improved living and working conditions have not significantly reduced the incidence of physical complaints and symptoms at the stations during the winter. Nevertheless, studies have shown that most of the physiological and psychological changes which occur either during the winter or immediately afterwards are short-term and personnel usually return to normal after six months (Guenter et al., 1970; Muchmore et al., 1970; Muchmore et al., 1974; Oliver 1979).

While the conclusions drawn from this study are limited in scope, the data do indicate that there are no negative long-term effects on health and performance associated with any of the environmental variables examined. Rather, the data support the view that man is capable of adapting to a variety of extreme, isolated environments for long periods of time.

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The object of this study was to determine if the risk to health and well-being of personnel who winter-over in Antarctica is related to the station to which they are assigned. Subjects were 327 enlisted Navy personnel who wintered over between 1963 and 1974. A fifteen-year period from 1965 to 1979 was established for follow-up. Demographic characteristics, total first hospitalizations for unique diagnoses, and performance indicators were examined. Comparisons of these variables were made by each station, by station size (large, small), and by the severity of station environment (based on altitude and mean annual tem-

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perature). Comparisons were made of both independent and dependent rates of total first hospitalizations. Dependent rates were based on the total population of enlisted winter-over personnel. Results indicated that there was no relationship between rates of first hospitalization and severity of station environment. When compared with the standard incidence of total first hospitalizations, the personnel assigned to Palmer and personnel at small stations were found to have significantly higher rates than the norm. However, these may reflect Type I statistical errors because of the small sample size. No significant differences were observed on any of the performance indicators in comparisons between stations or by station size and severity of environment. Environment, therefore, appears to have no adverse long-term effect on health and performance.

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