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**Item ID Number** 01786

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**Report/Article Title** Proportionate Mortality Study of US Army and US Marine Corps Veterans of the Vietnam War

**Journal/Book Title** Journal of Occupational Medicine

**Year** 1988

**Month/Day** May

**Color**

**Number of Images** 8

**Description Notes**

# Proportionate Mortality Study of US Army and US Marine Corps Veterans of the Vietnam War

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*The patterns of mortality among 24,285 US Army and Marine Corps Vietnam veterans were compared with that of 26,685 non-Vietnam veterans using standardized proportional mortality ratios. The veterans were a random sample of deceased Vietnam-era veterans identified in a Veterans Administration computerized benefit file. Military service information was obtained from military personnel records, and cause of death information from death certificates.*

*Statistically significant excess deaths were observed among Army Vietnam veterans for motor vehicle accidents, non-motor vehicle accidents, and accidental poisonings. Similar findings have been reported in other studies of Vietnam veterans. Suicides were not elevated among Vietnam veterans. The Marine Corps Vietnam veterans appeared to have an increased mortality from lung cancer and non-Hodgkin's lymphoma. Although exposure to several environmental factors may be speculated, this study did not investigate possible etiologic factors for these elevated malignancies.*

There is concern in the United States that post-service mortality among Vietnam veterans is unusually high and certain causes of death are disproportionately elevated. Traumatic deaths such as motor vehicle accidents, suicides, and homicides are often cited as possible health outcomes associated with military service in Vietnam.<sup>1-6</sup> Concern also persists that, as a result of exposure to Agent Orange and other chemicals in Vietnam, Vietnam veterans may be at increased risk for soft tissue sarcomas and other cancers.<sup>7-9</sup> Approxi-

mately 2 million US military personnel served a one-year tour in Vietnam during the Vietnam war.

Findings of mortality studies of Vietnam veterans reported to date are not consistent with each other.<sup>1-6</sup> Whether the variations among the studies are the result of the relatively small number of deaths analyzed, therefore reflecting lack of adequate statistical power, or whether they suggest an underlying difference in the mortality experience among the different Vietnam veteran study populations is not obvious. The number of deaths analyzed in these studies ranged from 246 to 923.

In view of the public concern about the potential adverse health effects of military service in Vietnam and inconsistent findings in the scientific literature, a proportional mortality study of Vietnam veterans was undertaken. Approximately one third of all deaths which have occurred among the Vietnam veterans who served in the US Army or Marine Corps was analyzed in the study.

## Materials and Methods

### Selection of Study Subjects

Study subjects were restricted to ground troops, men who served in the US Army or Marine Corps at anytime from July 4, 1965 through March 1, 1973. Data published by the US Department of Defense indicate that over 80% of those who served in Vietnam were ground troops.<sup>10</sup> Those having served in the Air Force, Navy, or Coast Guard were excluded because it is difficult to determine whether personnel who were considered to have served in the Vietnam theatre of operation were

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0096-1736/88/3005-412\$02.00/0

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ever actually "in country" Vietnam. Female veterans were also excluded from the study.

It was determined that at least 50,000 eligible cases would be needed for the study in order to obtain adequate statistical power. The sample size of 50,000 deceased Vietnam era veterans would provide statistical power of over 90% for detecting a twofold increased relative risk of non-Hodgkin's lymphoma or lung cancer. The study would have excellent power to detect small increases in certain common causes of death.

Potential study subjects who were reported to be deceased as of July 1, 1982 were randomly selected from the Veterans Administration Beneficiary Identification and Record Locator Subsystem (BIRLS). The VA maintains the automated information retrieval system to identify and locate records of veterans who have received any of a wide variety of veterans' benefits including death benefits to their families. A study by the National Academy of Sciences indicates that the names of at least 94% of all deceased Vietnam-era veterans identified through independent means are in BIRLS.<sup>11</sup>

A subfile of 186,000 deceased Vietnam-era veterans who served in the Army or Marine Corps and whose service dates included the period 1964-1975 was assembled from BIRLS. If the service data (branch, service dates) were missing in BIRLS, veterans whose birth dates were between 1935 and 1957 (inclusive) were selected because of the high likelihood that they may have served during the Vietnam era. To achieve the desired sample size of approximately 50,000 eligible veterans, a random sample of 75,617 names was selected from the target population. Extra names were selected to allow for the exclusion of ineligible cases.

The military personnel records for all 75,617 potential study subjects were requested from the National Personnel Record Center in St. Louis, MO. Demographic data and information on military service such as branch of service, length of service, rank at discharge, and military occupational specialty were abstracted. In addition, for those who served in Southeast Asia, dates of service, principal duty, and unit addresses while in the theatre of combat were obtained.

Of the 75,617 Vietnam-era veterans selected, 23,332 (29.5%) veterans were found to be ineligible upon reviewing their military personnel records. The ineligible cases included duplicate names; men who did not serve in the military from July 4, 1965 through March 1, 1973; men who served in the Navy, Coast Guard, or Air Force; men who were killed in action or were reported missing in action and subsequently declared dead; men who died in service before 1974; men who died of war-related injuries; and all women. Eligibility for the study could not be determined for 1,082 veterans (1.4%) and they were excluded. The final sample consisted of 52,253 men who died between July 4, 1965 and July 1, 1982 and who served in the US Army or Marine Corps during the period July 4, 1965 through March 1, 1973.

Death certificates were available from the VA files for about 70% of the sample; for the remaining 16,000 cases, the veteran's death certificate was requested from the state of his last known residence. The place of the

veteran's death was identified by checking files of the VA, Social Security Administration, Internal Revenue Service, and National Center for Health Statistics National Death Index.

Although death certificates were the preferred source of information, casualty reports issued by the Department of Defense were also used for active duty personnel or reservists who died outside the country and for whom no death certificate could be obtained. Most of these deaths were accidents and probably little additional information would have been obtained from the death certificate if it were available. Death certificates were the source of cause of death information for 96.9% of all cases. This was equally true for both those who served in Vietnam and those who did not. The underlying causes of death were coded by experienced nosologists at the National Center for Health Statistics using the International Classification of Diseases, 8th Revision (ICDA-8).<sup>12</sup> The nosologists had no knowledge of the military service status of the veteran.

Cause of death was ascertained for 51,421 veterans or 98.4% of the men determined to be eligible for the study. The cause of death for the remaining 1.6% was not obtained for one of the following reasons: the veteran died overseas and no certificate or cause of death information was available or the veteran's place of death had not been identified, and therefore the death certificate could not be located.

Of the 51,421 men for whom military service data and cause of death information were available, 26,685 had not served in Southeast Asia; 24,235 had served in Vietnam. The remaining 501 were either known to have served elsewhere in Southeast Asia or their place of service in Southeast Asia was unknown. Analyses of mortality data were based on 24,235 Vietnam veterans and 26,685 non-Vietnam veterans. These procedures used to select the subjects are outlined in the Figure.

### Statistical Analyses

The deaths observed among the Vietnam veterans were compared with expected numbers computed by applying the age- and race-specific proportions of deaths for each cause among the non-Vietnam veterans to the total number of deaths in the study group. Differences between observed and expected number of deaths for each cause were summarized in the form of the proportional mortality ratio (SPMR) which is the ratio of the number of deaths observed to that expected.<sup>13</sup> The statistical significance of each ratio was tested by a  $\chi^2$  with 1 *df*.<sup>14</sup> The 95% confidence intervals for the SPMRs were also computed.<sup>15</sup>

Proportional mortality ratios standardized for age and race (SPMRs) were calculated separately for Army and Marine Corps Vietnam veterans for all major causes of death and for selected causes of death. The PMR analysis by branch of service was performed because these groups might have had different types of environmental exposure in Vietnam either by virtue of the

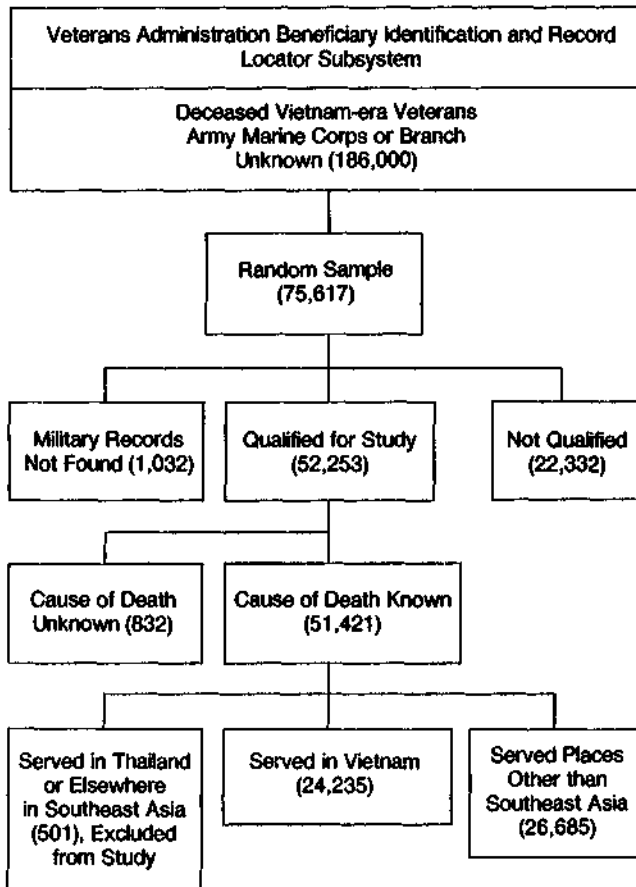


Figure. Selection process of study subjects.

location of their units or the types of duties they performed. Unlike the Army units, the Marine Corps units were primarily located within the I Corps area of South Vietnam. South Vietnam was divided into four tactical combat zones, I Corps being in the northernmost part of South Vietnam.

## Results

The demographic characteristics of the sample are given in Tables 1 and 2. More than 50% of the veterans died at ages 25 through 34. Some died at ages less than 25 (5.5% of Vietnam and 11.7% of non-Vietnam veterans) and some died at ages older than 65 (0.74% of Vietnam and 2.6% of non-Vietnam veterans).

There seemed to be no remarkable differences in the major cause of death categories between the men who served in Vietnam and their counterparts who did not serve in Vietnam with a few exceptions (Table 3). Deaths from external causes (ICDA codes E800-E989) were relatively more frequent among veterans who served in Vietnam than among those who did not. However, this excess is statistically significant only for Army veterans (PMR, 1.03;  $P < .01$ ).

More than half of all the deaths in the study population were due to accidents, accidental poisonings, or violence. Within this broad category, approximately 35% of the deaths were due to motor vehicle accidents

TABLE 1  
Racial Characteristics of the 50,920 Deceased Vietnam-era Veterans by Branch and Vietnam Service

Race	Army		Marines	
	Service in Vietnam		Service in Vietnam	
	Yes (N = 19,708), %	No (N = 22,904), %	Yes (N = 4,527), %	No (N = 3,781), %
White	78.1	79.5	83.5	82.5
Black	19.2	17.7	13.7	14.9
Other	2.7	2.8	2.8	2.6
Unknown	—*	—*	—*	—*
Totals	100	100	100	100

\* Less than 0.1%.

TABLE 2  
Military Rank of the 50,920 Deceased Vietnam-era Veterans by Branch and Vietnam Service

Rank	Army		Marines	
	Service in Vietnam		Service in Vietnam	
	Yes (N = 19,708), %	No (N = 22,904), %	Yes (N = 4,527), %	No (N = 3,781), %
Enlisted	92.8	93.4	93.6	95.8
Warrant officer	2.1	1.0	0.9	0.3
Officer	5.1	5.5	5.5	3.9
Unknown	—*	—*	—*	—*
Totals	100	100	100	100

\* Less than 0.1%.

(Table 4). Although the magnitude of the relative excess of motor vehicle accidents was about the same in both branches, only the SPMR for Army veterans was statistically significant (PMR, 1.05;  $P < .025$ ). "Other transport accidents" were seen to be in excess primarily among Army personnel (PMR, 1.36;  $P < .01$ ); 51% of these were aircraft accidents. Of the men who died in aircraft accidents, 22% had been helicopter pilots or crewmen and 84% of these had served in Vietnam. Many of these died while working as helicopter pilots or crewmen in civilian life; others died in aircraft accidents while still in the military after the war. The category of "accidental poisonings" was elevated among both Army and Marine Corps veterans who served in Vietnam. In reviewing a sample of 100 of these deaths, it was found that 98% of these deaths were due to narcotic overdose, mostly heroin.

Among enlisted Vietnam veterans, veterans with combat-related military occupations died from homicide significantly more frequently than veterans with non-combat-related military occupations: 9% excess for Army veterans ( $P < .05$ ), 24% excess for Marine Corps veterans ( $P < .01$ ). It also appeared that the excess deaths from motor vehicle accidents and accidental poisonings were greater during the first ten-year period of observations than the later years of observation for both Army and Marine Corps Vietnam veterans (Table 5).

Deaths coded as suicide were relatively less frequent among those who served in Vietnam than among those who did not serve in Vietnam for both Army and Marine Corps veterans.

**TABLE 3**  
Number of Deaths and Proportional Mortality Ratios (PMRs) Among Vietnam Veterans by Major Causes and Branch

Cause (ICDA No.)	Army*			Marines†		
	Observed	PMR	95% Confidence Interval	Observed	PMR	95% Confidence Interval
All other causes (210-228, 290-315, 740-759, 780-796)	709	0.91		150	0.94	
Infective and parasitic diseases (000-136)	127	0.80	0.63-1.01	19	1.02	0.89-1.17
Malignancies (140-209, 230-239)	2,452	0.97	0.93-1.02	521	1.20	1.0-1.45
Endocrine, nutritional, and metabolic (240-279)	135	0.85	0.67-1.08	22	0.66	0.22-2.01
Blood and blood-forming organs (280-289)	32	0.68	0.45-1.03	8	3.22	0.51-20.5
Nervous systems and sense organs (320-389)	167	0.95	0.77-1.18	27	0.86	0.17-4.44
Circulatory diseases (390-458)	3,578	0.98	0.95-1.01	647	0.98	0.86-1.12
Respiratory diseases (460-519)	408	0.93	0.89-1.25	62	0.95	0.75-1.21
Digestive diseases (520-577)	1,001	0.99	0.94-1.04	169	0.87	0.70-1.08
Genitourinary diseases (580-629)	80	0.77‡	0.60-0.99	13	0.67	0.33-1.35
Skin and subcutaneous tissues (680-709)	8	0.76	0.05-11.19	2	0.50	0.06-4.18
Musculoskeletal and connective tissues (710-738)	29	1.55	0.8-3.0	7	0.87	0.22-3.41
Accidents, poisonings, and violence (E800-989)	10,984	1.03§	1.02-1.04	2,880	1.00	

\* Army: deaths observed = 19,708. Expected numbers are based on 22,904 deaths in Army non-Vietnam veteran comparison group.  
 † Marines: deaths observed = 4,527. Expected numbers are based on 3,781 deaths in Marine non-Vietnam veteran comparison group.  
 ‡  $P < .05$  for  $\chi^2$  with 1 *df*.  
 §  $P < .01$  for  $\chi^2$  with 1 *df*.

**TABLE 4**  
Number of Deaths from Accidents, Accidental Poisonings, and Violence and Proportional Mortality Ratios (PMRs) Among Vietnam Veterans, by Branch

Cause (ICDA No.)	Army*			Marines†		
	Observed	PMR	95% Confidence Interval	Observed	PMR	95% Confidence Interval
Motor vehicle accidents (E810-E827)	3,884	1.05‡	1.01-1.09	1,011	1.07	0.97-1.18
Other transportation accidents (E800-E807, E830-E845)	493	1.36§	1.19-1.56	117	0.75	0.56-1.01
Accidental poisonings (E850-E877)	461	1.15‡	1.02-1.30	120	1.10	0.93-1.30
All other accidents/injury (E880-E949, E970-E989)	2,323	1.05	0.99-1.11	593	1.01	0.98-1.04
Suicide (E950-E959)	2,003	0.93§	0.88-0.98	542	0.93	0.86-1.01
Homicide (E960-E969)	1,816	1.01	0.73-1.40	497	0.98	0.89-1.08

\* Army: deaths observed = 19,708. Expected numbers are based on 22,904 deaths in Army non-Vietnam veteran comparison group.  
 † Marines: deaths observed = 4,527. Expected numbers are based on 3,781 deaths in Marine non-Vietnam veteran comparison group.  
 ‡  $P < .025$  for  $\chi^2$  with 1 *df*.  
 §  $P < .01$  for  $\chi^2$  with 1 *df*.

When all malignancies were grouped together, Vietnam veterans did not exhibit an excess of cancer when compared to their counterparts who did not serve in Vietnam. Differences between the services, however, were seen for specific cancer sites among those who served in Vietnam relative to men who did not (Table 6). The most interesting differences were the statistically significant elevation for lung cancer (PMR, 1.58;  $P < .025$ ) and non-Hodgkin's lymphoma (PMR, 2.10;  $P < .025$ ) seen in the Marines who served in Vietnam relative to Marines who served elsewhere. The risk for soft tissue sarcoma was not elevated among Vietnam veterans as a whole or in any subgroup of these veterans.

## Discussion

For most major causes, the distribution of deaths for veterans who served in Vietnam is not markedly different from those who did not serve in Vietnam except for selected malignancies and "accidents, accidental poisonings, and violence." Four states have conducted mortality studies of Vietnam era veterans: Wisconsin,<sup>1</sup> West Virginia,<sup>2</sup> New York,<sup>3</sup> and Massachusetts.<sup>4</sup> The Centers for Disease Control also reported the postservice mortality of US Army Vietnam veterans.<sup>5</sup> The results of these studies were similar to what was seen here. They

**TABLE 5**  
Deaths from Selected Causes Among Enlisted Vietnam Veterans Who Died Between 1965 and 1982, and Who Had Only One Tour of Duty\*

Cause (ICDA No.)	Army				Marines			
	1965-1975		1976-1982		1965-1975		1976-1982	
	Observed	PMR	Observed	PMR	Observed	PMR	Observed	PMR
Motor vehicle accidents	717	1.11†	2,053	1.06	167	1.18	611	1.01
Other transport accidents	34	0.65	201	1.10	11	1.04	48	0.82
Accidental poisonings	77	1.14	255	1.09	25	2.26†	71	1.04
All other accidents/injury	342	1.00	1,186	1.05	82	1.01	364	0.93
Suicide	212	1.00	1,089	0.94	57	0.65	368	1.05
Homicide	232	0.92	1,008	1.03	68	1.27	314	0.91
Cancers (140-209, 230-239)	89	0.74†	655	0.87†	25	0.81†	176	1.31

\* PMR, proportional mortality ratio of observed to expected numbers of deaths. Expected number was generated based on deaths from non-Vietnam veterans with similar characteristics.

†  $P < .05$  for  $\chi^2$  with 1 *df*.

**TABLE 6**  
Number of Deaths from Malignancies Among Vietnam Veterans by Branch of Service

Cause (ICDA No.)	Army*			Marines†		
	Observed	PMR	95% Confidence Interval	Observed	PMR	95% Confidence Interval
All other causes (000-136, 210-E989)	17,256	1.00		4,006	0.98	
All malignancies	2,452	0.97	0.93-1.01	521	1.20	1.0-1.45
Buccal (140-149)	71	0.92	0.47-1.82	13	1.95	0.54-7.04
Esophagus (150)	46	1.24	0.78-1.98	5	0.39	0.11-1.41
Stomach (151)	88	1.12	0.85-1.47	17	0.82	0.41-1.64
Intestines and other gastrointestinal (152-154, 158, 159)	209	0.96	0.70-1.32	33	1.26	0.71-2.24
Liver, bile ducts (155-156)	34	1.04	0.77-1.41	6	1.21	0.52-2.83
Pancreas (157)	82	0.87	0.64-1.18	18	1.63	0.46-5.75
Upper respiratory (160-161)	29	1.14	0.63-2.07	1	0.18	0.03-1.32
Lung (162)	632	1.03		130	1.58‡	1.09-2.29
Bone (170)	27	0.82	0.39-1.71	11	1.38	0.09-21.48
Soft tissue (171)	30	0.99	0.80-1.23	8	0.71	0.38-1.32
Melanoma of the skin (172)	145	1.02	0.91-1.14	36	0.94	0.59-1.50
Prostate (185)	30	0.92	0.55-1.23	5	1.29	0.16-10.3
Testis (186)	90	1.12	0.84-1.5	26	1.29	0.47-3.57
Bladder (188)	9	0.56	0.27-1.18	4	2.41	0.09-66.35
Kidney (189)	55	0.87	0.50-1.52	13	0.89	0.54-1.46
Brain (191)	116	0.97	0.29-3.20	25	1.07	0.16-7.14
Other nervous system (192)	43	0.55‡	0.38-0.79	11	0.93	0.49-1.78
Thyroid and endocrine (193-194)	15	0.59	0.30-1.17	4	0.57	0.10-3.37
Non-Hodgkin's lymphoma (200, 202)	108	0.81	0.63-1.04	35	2.10‡	1.17-3.79
Hodgkin's disease (201)	92	1.16	0.73-1.85	22	1.33	0.67-2.63
Multiple myeloma (203)	18	0.77	0.23-2.53	2	0.45	0.01-17.13
Leukemia (204-207)	202	0.88	0.73-1.06	42	1.14	0.18-7.14
Other cancers (163, 173-4, 187, 190, 195-9, 208-9, 230-9)	281	1.03	0.93-1.14	54	1.07	0.60-1.91

\* Army: deaths observed = 19,708. Expected numbers based on 22,904 deaths in Army non-Vietnam veteran comparison group.

† Marines: deaths observed = 4,527. Expected numbers based on 3,781 deaths in Marine non-Vietnam veteran comparison group.

‡  $P < .025$  for  $\chi^2$  with 1 *df*.

§  $P < .01$  for  $\chi^2$  with 1 *df*.

also reported that Vietnam veterans were more likely to die from "accidents, accidental poisonings, and violence" or from a few selected malignancies than their counterparts who did not go to Vietnam. However, within these two broad categories, the findings reported by these studies were not consistent with each other or with what was found here. It should be noted that the data in the state reports were not strictly comparable to the data given in this report. They differed from this

study in that numbers of deaths studied were much smaller—less than 1,000—and they included Vietnam-era veterans from all branches of service. They also differed somewhat in the analytical methods and used different types of veteran comparison populations. Furthermore, military personnel records of the state study subjects were not reviewed to verify Vietnam service status.

The New York,<sup>3</sup> Massachusetts,<sup>4</sup> and ODC<sup>5</sup> studies

reported nonstatistically significant elevations of risk for suicide when veterans with service in Vietnam were compared with other Vietnam-era veterans. In this study no excess of suicides was seen among the veterans who served in Vietnam when compared with other Vietnam-era veterans. The ratio of observed to expected deaths among the Army and Marine Corps veterans who served in Vietnam relative to their counterparts who did not serve in Vietnam was less than one; for veterans who had served in the Army, the deficit was statistically significant at  $P < .01$ .

Simon<sup>16</sup> reported an association between attempted suicide and combat experience in World War II veterans. In our study there was no data element that indicated whether a man had been in combat. As a surrogate measure, enlisted men whose military occupational specialties would be likely to involve combat, ie, rifleman, artilleryman etc, were compared to the other enlisted men who had served in Vietnam. Among the enlisted men who served in Vietnam, those with "combat-related" occupational specialties in both branches of service had relatively fewer suicides than "non-combat" Vietnam veterans in the same branch of service (Army:  $N = 590$ ,  $PMR = 0.96$ ; Marines:  $N = 228$ ,  $PMR = 0.83$ ). For the Marines, the deficit was statistically significant at  $P < .05$ .

It is known that suicides are underreported on death certificates but there was no reason to believe that they were more underreported among veterans who served in Vietnam than among those who did not. Nor was there any reason to believe that suicide was more apt to be underreported among those likely to have been in combat in Vietnam than among other veterans.

Several researchers suggested that 1.6% to 5% of motor vehicle accidents may be suicides.<sup>17,18</sup> In our study, motor vehicle accidents were relatively less frequent among Vietnam veterans with combat-related occupational specialties than among those with non-combat occupations (Army:  $N = 1,205$ ,  $PMR = 0.99$ ; Marines:  $N = 466$ ,  $PMR = 0.94$ ). Even if one assumes that some of the motor vehicle accidents are "hidden" suicides, it is unlikely that these could account for the overall deficit in suicides among Vietnam veterans since the possible "hidden" suicides among motor vehicle accidents are reportedly relatively small.

The apparent excess of drug-related deaths attributable to heroin use among Vietnam veterans is of concern. This observation was consistent with that of Rohrbaugh et al,<sup>19</sup> who found that, whereas Vietnam veterans were no more likely than other Vietnam-era veterans to use drugs in general, they were more likely to use opiates than other illicit drugs. The CDC also reported that accidental drug poisonings were substantially elevated among Vietnam veterans.

One of the major concerns of Vietnam veterans has been the possibility of developing cancer as a result of exposure to Agent Orange, a mixture of two phenoxy herbicides. Some studies have shown an association between soft tissue sarcomas and exposure to phenoxy herbicides.<sup>7,20,21</sup> Although data from Wisconsin,<sup>1</sup> West

Virginia,<sup>2</sup> and Massachusetts<sup>4</sup> indicated that veterans who served in Vietnam may have an increased risk of soft tissue sarcoma, no excess of soft tissue sarcomas was seen among the Vietnam veterans in our study. No association between soft tissue sarcoma and military service in Vietnam was found by Greenwald et al<sup>22</sup> in a case control study of 281 men with soft tissue sarcoma from New York State, nor was any association found between military service in Vietnam and 234 cases of soft tissue sarcoma occurring among Vietnam-era veterans admitted to Veterans Administration hospitals,<sup>23</sup> or 217 soft tissue sarcoma cases referred to the Armed Forces Institute of Pathology.<sup>24</sup>

The veterans who served in the Marine Corps in Vietnam were seen to have a statistically significant ( $P < .025$ ) excess of non-Hodgkin's lymphoma when compared with Marines who did not serve in Vietnam. West Virginia veterans with service in Vietnam had a statistically significant excess of Hodgkin's disease when compared with other Vietnam-era veterans.<sup>2</sup> None of the other state studies indicated any excess of lymphomas among veterans with service in Vietnam.<sup>1,2,4</sup>

Non-Hodgkin's lymphoma has been associated with exposure to phenoxy herbicides,<sup>8,9</sup> arsenicals,<sup>25</sup> dapsone,<sup>26</sup> and certain viruses.<sup>27</sup> The men who served in Vietnam had the potential for exposure to all of these agents. Agent Blue, a herbicide used in Vietnam, was an organic arsenical compound and dapsone, a sulfone, was used as an antimalarial drug by some of the troops in Vietnam. Dapsone<sup>26</sup> has been shown to cause lymphomas in laboratory animals. Dapsone was given mainly to troops stationed in I Corps and the central highland areas of Vietnam where falciparum malaria was prevalent. Most of the Marines in Vietnam served in I Corps. It will be interesting to see whether the Army troops who were stationed in I Corps also exhibit an excess of lymphomas. The data necessary for this analysis are now being collected.

Lung cancer was significantly elevated ( $PMR, 1.58$ ;  $P < .025$ ) among Marines who served in Vietnam relative to Marines who did not serve in Vietnam. The veterans from New York<sup>2</sup> with service in Vietnam also had relatively more lung cancer than other Vietnam-era veterans but the excess was not statistically significant.

Although tobacco is the etiologic agent most commonly associated with lung cancer, this disease has also been associated with exposure to other substances such as arsenic<sup>28</sup> and phenoxy herbicides.<sup>20,29</sup> A survey of more than 29,000 Vietnam-era veterans in Wisconsin indicated that they were nearly twice as likely to be cigarette smokers as were men in the general population.<sup>1</sup> There are no smoking histories available for the Marines in this study. If the lung cancer deaths in this study are associated with an increased use of tobacco by the men who served in Vietnam, lung cancer deaths should also be increased among Army troops in Vietnam. They were not.

The present study has certain inherent limitations that make it difficult to draw firm conclusions. First,



risk estimates obtained from PMR analyses can approximate the results from studies of cause-specific mortality rates or the standardized mortality ratio (SMR).<sup>30</sup> However, PMRs may be inflated for certain causes when the overall mortality rate of the study group is lower than that of the comparison population. This would have been the case if the US general population had been chosen for the comparison population in this study. It was shown that the selection process for military service exerted a profound effect on the mortality of veterans after separation from service. The number of deaths among the World War II male Army veterans was only 83.5% of the expected number at concurrent death rates for US white men.<sup>31</sup> A recent study published by the CDC showed that the mortality among the Vietnam veteran study population was 17% higher than the rate among the non-Vietnam veteran comparison populations.<sup>5</sup> These suggested that SPMRs for lung cancer and non-Hodgkin's lymphoma reported in this study could have been biased toward underestimating the risks.

Second, it is possible that, with so many comparisons being made, the few significant elevations observed could be interpreted as chance findings. Findings from this study need to be replicated by other Vietnam veteran studies.

Third, no exposure data on individual veterans were available so as to evaluate the possible etiologic factors of the malignancies which appeared to be elevated among Marine Vietnam veterans. Additional work needs to be done to find characteristics that may point to possible etiologic factors.

Fourth, the observation period in this study, a maximum of 17 years, may have been still insufficient to observe the risk of dying from diseases with a long latency period. A periodic monitoring of Vietnam veteran mortality patterns is warranted.

Despite the limitations described above, the present study is the largest mortality study of Vietnam veterans reported to date encompassing approximately one third of all deaths which have occurred among the US Army and Marine veterans who served in Vietnam. Having an equally large number of non-Vietnam veterans whose characteristics are well-defined and are similar to the study population except for service in Vietnam should be considered a major strength. Furthermore, unlike other PMR studies of Vietnam veterans, in this study military personnel records for almost all (98.6%) potential study subjects were retrieved and reviewed to determine eligibility of the veteran. Therefore, the chance of misclassification of the most important study variable, namely service in Vietnam, is minimal.

In summary, the study shows no significant differences in the major cause of death between Vietnam veterans and non-Vietnam veterans with a few exceptions. Accidental and drug-related deaths were relatively more frequent among Army Vietnam veterans. Suicides were less frequent among Vietnam veterans. Vietnam veterans who served in the Marine Corps were seen to have statistically significant excess of lung cancer and non-Hodgkin's lymphoma.

## Acknowledgments

The Veterans Administration wishes to acknowledge the assistance and support received from many individuals and agencies without which the VA mortality study could not have been successfully completed. We are grateful to Gilbert Beebe, PhD (NIH), Chin Long Chiang, PhD (UC Berkeley), Joseph Fleiss, PhD (Columbia University), the late Bernard Greenberg, PhD (University of North Carolina), the late Abraham Lillienfeld, MD (Johns Hopkins University), and Richard Monson, MD (Harvard University) for their reviews of the study protocol and the many suggestions and recommendations made on the conduct of the study. We also would like to acknowledge the contributions of David Peterson and Carolyn Brooks of the National Archives Records Administration; Paul Gray, National Personnel Records Center; Richard Christian, US Army and Joint Services Environmental Support Group; Robert Bilgrad, National Center for Health Statistics, National Death Index; and the Social Security Administration; the National Institute for Occupational Safety and Health; and the Internal Revenue Service. John Ward of Westat and Elaine Kokiko of Moshman Associates assisted us in the collection of military service data and death certificates, respectively. The guidance provided by William Page, PhD (National Academy of Sciences) and Alvin Young, PhD (White House Office of Science and Technology Policy) in planning for the study is greatly appreciated.

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