

## MORTALITY AMONG U.S. VETERANS OF THE PERSIAN GULF WAR

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**ABSTRACT**

**Background** Since the 1990–1991 Persian Gulf War, there has been persistent concern that U.S. war veterans may have had adverse health consequences, including higher-than-normal mortality.

**Methods** We conducted a retrospective cohort study of postwar mortality according to cause among 695,516 Gulf War veterans and 746,291 other veterans. The follow-up continued through September 1993. A stratified, multivariate analysis (with Cox proportional-hazards models) controlled for branch of service, type of unit, age, sex, and race in comparing the two groups. We used standardized mortality ratios to compare the groups of veterans with the general population of the United States.

**Results** Among the Gulf War veterans, there was a small but significant excess of deaths as compared with the veterans who did not serve in the Persian Gulf (adjusted rate ratio, 1.09; 95 percent confidence interval, 1.01 to 1.16). The excess deaths were mainly caused by accidents (1.25; 1.13 to 1.39) rather than disease (0.88; 0.77 to 1.02). The corresponding rate ratios among 49,919 female veterans of the Gulf War were 1.32 (0.95 to 1.83) for death from all causes, 1.83 (1.02 to 3.28) for accidental death, and 0.89 (0.45 to 1.78) for death from disease. In both groups of veterans the mortality rates were significantly lower overall than those in the general population. The adjusted standardized mortality ratios were 0.44 (95 percent confidence interval, 0.42 to 0.47) for Gulf War veterans and 0.38 (0.36 to 0.40) for other veterans.

**Conclusions** Among veterans of the Persian Gulf War, there was a significantly higher mortality rate than among veterans deployed elsewhere, but most of the increase was due to accidents rather than disease, a finding consistent with patterns of postwar mortality among veterans of previous wars. (N Engl J Med 1996;335:1498-504.)

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**T**HERE is persistent concern in the United States that veterans of the Persian Gulf War may have had a higher rate of postwar mortality than other veterans and that certain causes of death may have been especially frequent.<sup>1,2</sup> Excess numbers of deaths from cardiovascular disease and even from malignant neoplasms have been mentioned often in the news media and in one scientific journal.<sup>1</sup>

Some 700,000 U.S. troops were deployed in the Persian Gulf area between August 1990 and the end of Operation Desert Storm in 1991. Among the potential health risks associated with military service during that conflict, infectious diseases, oil-well fires and hazards associated with other petroleum products, insecticides and pesticides, sand particles, the possible use of chemical and biologic warfare agents, anti-nerve gas agents, and multiple vaccinations have often been suggested as putative risk factors.<sup>3,4</sup> Furthermore, the psychological stress involved in deployment to the Persian Gulf and exposure to combat has been well documented.<sup>5-7</sup>

On the basis of previous studies, we expected that veterans of the Gulf War would have increased mortality due to external causes, including motor vehicle accidents and accidents of other types, suicide, and homicide. Among Vietnam veterans, an elevated risk of traumatic deaths, including deaths due to motor vehicle accidents, has been often reported.<sup>8-10</sup>

We conducted a retrospective cohort study of mortality in which we compared the postwar mortality of Gulf War veterans with that of veterans from the era of the Gulf War who did not serve in that conflict. This study complements the study by the Department of Defense of non-battle-related deaths among Gulf War troops who remained on active duty.<sup>11</sup>

**METHODS****Study Subjects**

The study subjects were all 695,516 military personnel who served in the Persian Gulf from August 1990 to April 1991 ("Gulf War veterans"). They were identified from a roster provided by the Defense Manpower Data Center. A control group of 746,291 military personnel consisted of a stratified random sample of approximately half of all personnel on active duty, in the National Guard, and in the military reserves who served from September 1990 to April 1991 but did not go to the Persian Gulf. The number of controls and the number of Gulf War veterans in each type of unit in each branch of the armed forces were approximately equal. In the case of controls serving in reserve and National Guard units, equal numbers were selected from units

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that were activated but sent to places other than the Persian Gulf area and units that were not activated at all. Personnel sent to the Persian Gulf area after the war were not included in the control group.

Available demographic information and data on military service included the veteran's date of birth, race, sex, military rank, branch of service, and deployment date, and the type of unit (active, reserve, or National Guard).

#### Determination of Vital Status and Collection of Death Certificates

We determined the vital status of each Gulf War veteran from the date the veteran left the Persian Gulf area. The follow-up of controls began on May 1, 1991. The follow-up period ended either on the veteran's date of death or on September 30, 1993, whichever came first. (The reporting of vital status after that date was expected to be incomplete in the national data bases available for matching in May 1994.) Vital status was determined with a data base of the Department of Veterans Affairs known as the Beneficiary Identification and Records Locator Subsystem (BIRLS). Veterans were also matched against a file of deaths reported to the Social Security Administration. In a recent study of 4300 deaths of veterans ascertained independently from states, the Veterans Affairs BIRLS data base, used in conjunction with the Social Security Administration file, reported 97 percent of deaths of Vietnam-era veterans.<sup>12</sup>

Death certificates were requested first from the Veterans Affairs regional offices and the Federal Records Centers identified in the BIRLS data base. Death certificates not found at these locations were requested from state vital-statistics offices. Causes of death were coded by a qualified nosologist who used the *International Classification of Diseases, 9th Revision* (ICD-9), without knowing the subject's deployment status.<sup>13</sup>

The degree of completeness of the combined data sources (the BIRLS data base and the files of the Social Security Administration) used in the determination of vital status was evaluated by matching a random sample of 15,000 Gulf War veterans and 15,000 other veterans with the National Death Index, which includes all deaths reported to the National Center for Health Statistics by state vital-statistics offices, beginning in 1979.

#### Statistical Analysis

The data were analyzed in three stages. In stage 1, for each Gulf War veteran the number of person-years at risk of dying were counted from the date the veteran left the Persian Gulf area to the veteran's date of death or September 30, 1993. For the controls, this period at risk began on May 1, 1991. The relative frequency of death overall, as well as death due to specific causes, was compared between the Gulf War veterans and the controls on the basis of the number of person-years at risk. Unadjusted rate ratios were calculated from the crude death rates.

In stage 2, the Cox proportional-hazards model was used to account for possible confounding and the effect of selected covariates on the risk of a veteran's dying from a specific cause, according to the time since that veteran's entry into the cohort.<sup>14</sup> The covariates considered in the model included age at the start of follow-up, race, sex, service branch, and type of unit.

In stage 3, the cause-specific mortality of Gulf War veterans and other veterans was compared with the number of deaths expected in the overall U.S. population after adjustment for age, sex, race, and year of death. The results were expressed as standardized mortality ratios<sup>15</sup> expressing the ratio of observed deaths among veterans to the expected number of deaths in the general population.

## RESULTS

#### Characteristics of the Two Groups

The demographic and military characteristics of the Gulf War veterans were similar to those of the

controls with the exception of the year of birth, sex, and type of unit (Table 1). The Gulf War veterans were slightly younger than the controls (age in May 1991, 28.4 vs. 30.2 years), included more troops serving in active units, and included fewer women (7.2 percent vs. 13.3 percent). Among reservists and members of the National Guard who did not take part in the Gulf War, the characteristics of 106,840 veterans who were mobilized and 115,478 veterans who were not were similar.

Among the 695,516 Gulf War veterans, 1765 died, and death certificates were located for 1654 (93.7 percent). Among the 746,291 controls, 1729 died, and death certificates were located for 1615 (93.4 percent). In a random sample of 30,000 veterans (15,000 Gulf War veterans and 15,000 controls), 71 were identified from the National Death Index as having died during follow-up. Sixty-three of these deaths had been identified earlier through the use of the BIRLS data base and the Social Security Administration files, for an estimated reporting rate of 89 percent (95 percent confidence interval, 83 to 97 percent). Of the eight veterans whose deaths were identified only from the index, four were Gulf War veterans and four were controls. Whether a veteran had served in the Gulf War bore no signif-

TABLE 1. DEMOGRAPHIC AND MILITARY CHARACTERISTICS OF THE STUDY SUBJECTS.

CHARACTERISTIC	GULF WAR VETERANS (N=695,516)	OTHER VETERANS (N=746,291)
	percent	
Race		
White	67.6	69.6
Black	22.6	21.5
Other	9.8	8.9
Sex		
Male	92.8	86.7
Female	7.2	13.3
Year of birth		
≤1961	33.7	42.7
1962–1967	31.9	28.5
≥1968	34.3	28.6
Rank		
Enlisted person	89.1	84.8
Officer	9.6	13.9
Warrant officer	1.3	1.2
Service branch		
Army	50.5	55.7
Navy	22.7	17.7
Air Force	11.9	11.3
Marine Corps	14.9	15.2
Type of unit		
Active	83.3	70.2
Reserve		
Activated	10.4	9.7
Not activated	—	9.6
National Guard		
Activated	6.3	4.7
Not activated	—	5.8

icant relation to the rate of ascertainment of vital status.

**Cause-Specific Mortality**

As Table 2 shows, after we controlled for potential confounders (age, sex, race, and military variables), the Gulf War veterans had significantly higher mortality from all causes than the other veterans. The excess deaths were entirely attributable to external causes (rate ratio, 1.17; 1317 deaths observed vs. 1126 expected), including all types of accidents and motor vehicle accidents specifically. There was no observed excess of suicides, homicides, or deaths from disease-related causes. The risk of death from infectious and parasitic diseases was significantly lower among the Gulf War veterans than among the other veterans.

Relative-risk estimates derived from the Cox proportional-hazards model are shown in Table 3 for 1,000,996 male troops (both Gulf War veterans and other veterans) who served in active units. Overall mortality and mortality from all external causes (rate

ratio, 1.17; 1110 deaths observed vs. 949 expected), including accidents of all types and motor vehicle accidents, continued to be significantly elevated among the Gulf War veterans as compared with the controls. In men, the risk of disease-related mortality was lower among Gulf War veterans than among controls.

We also compared mortality rates among 49,919 women deployed in the Persian Gulf area with those among 84,517 women deployed elsewhere at the time of the Persian Gulf War (Table 3). Like their male counterparts, the women sent to the Persian Gulf had a significant excess of deaths from all external causes, including accidental deaths. Mortality due to motor vehicle accidents, suicides, and homicides was elevated, but the excess was not statistically significant. The adjusted rate ratio for deaths from external causes was higher among female than among male veterans (1.78 vs. 1.17). In contrast, the rate ratio for deaths from disease-related causes was almost the same among female veterans as among male veterans (0.89 vs. 0.87).

**TABLE 2. DEATHS, MORTALITY RATES, AND MORTALITY-RATE RATIOS AMONG THE STUDY SUBJECTS, 1991 THROUGH 1993, ACCORDING TO THE CAUSE OF DEATH SHOWN ON THE DEATH CERTIFICATE.**

CAUSE OF DEATH (ICD-9 CODE)*	GULF WAR VETERANS (N=695,516)		OTHER VETERANS (N=746,291)		MORTALITY-RATE RATIOS	
	NO. OF DEATHS	MORTALITY RATE†	NO. OF DEATHS	MORTALITY RATE†	CRUDE	ADJUSTED (95% CI)‡
All causes	1765	10.4	1729	9.6	1.08	1.09 (1.01–1.16)
Disease-related causes (001–799)	337	2.0	534	2.96	0.68	0.88 (0.77–1.02)
Infectious and parasitic disease (001–139)	10	0.06	49	0.27	0.22	0.21 (0.11–0.43)
All cancers (140–208)	119	0.70	216	1.20	0.58	0.83 (0.66–1.05)
Disease of circulatory system (390–459)	149	0.88	184	1.02	0.86	1.12 (0.90–1.40)
Disease of respiratory system (460–519)	14	0.08	14	0.08	1.07	1.27 (0.60–2.70)
Disease of digestive system (520–579)	12	0.07	21	0.12	0.58	0.79 (0.37–1.69)
All external causes (E800–E999)	1317	7.74	1081	6.0	1.29	1.17 (1.08–1.27)
All accidents (E800–E929)	812	4.77	619	3.44	1.39	1.25 (1.13–1.39)
Motor vehicle accidents (E810–E825)	549	3.23	398	2.21	1.46	1.31 (1.14–1.49)
Suicide (E950–E959)	261	1.53	277	1.54	0.99	0.94 (0.79–1.12)
Homicide (E960–E969)	145	0.85	159	0.88	0.97	0.85 (0.67–1.08)
No death certificate	111	—	114	—	—	—

\*ICD-9 denotes *International Classification of Diseases, 9th Revision*.<sup>13</sup> Only major causes of death are shown.

†Crude rates shown are per 10,000 person-years.

‡Adjusted rate ratios (and 95 percent confidence intervals [CI]) were derived from the Cox proportional-hazards model after adjustment for age, race, sex, branch of service, and type of unit.

**Cause-Specific Mortality According to the Time of Deployment to the Persian Gulf**

Troops sent to the Persian Gulf before March 1, 1991, would have been subjected to most of the potential risk factors previously described. Troops deployed after the war ended (that is, after March 1, 1991) would not have taken anti-nerve gas agents (pyridostigmine bromide) or received vaccinations against anthrax and botulinum toxins. Nor would they have been subjected to the threats of Scud missile attacks, chemical and biologic warfare, or combat-induced stress. There was no significant difference among Gulf War veterans in the risk of death from any of the underlying causes studied according to period of deployment.

**Effect of Mobilization**

We studied the effect of being mobilized without being actually sent to the Persian Gulf area in 222,318 veterans assigned to units in the reserves and the National Guard. Mobilization without subsequent deployment to the Persian Gulf did not appear to affect the overall mortality or the risk of death from external causes, even after adjustment for the type of unit (reserve or National Guard), age, sex, race, and branch of service.

**Comparison with the General Population**

As compared with the general population of the United States, the Gulf War veterans and the non-Gulf War veterans both had significantly lower

**TABLE 3. DEATHS, MORTALITY RATES, AND MORTALITY-RATE RATIOS AMONG THE STUDY SUBJECTS ACCORDING TO CAUSE OF DEATH AND SEX.\***

CAUSE OF DEATH†	GULF WAR VETERANS		OTHER VETERANS		MORTALITY-RATE RATIOS	
	NO. OF DEATHS	MORTALITY RATE‡	NO. OF DEATHS	MORTALITY RATE‡	CRUDE	ADJUSTED (95% CI)§
All causes						
Men	1437	10.7	1084	9.8	1.10	1.09 (1.01–1.18)
Women	70	5.8	84	4.1	1.41	1.32 (0.95–1.83)
Disease-related causes						
Men	238	1.8	286	2.6	0.69	0.87 (0.73–1.04)
Women	14	1.2	26	1.3	0.92	0.89 (0.45–1.78)
All external causes						
Men	1110	8.3	732	6.6	1.26	1.17 (1.07–1.29)
Women	47	3.9	41	2.0	1.95	1.78 (1.16–2.73)
All accidents						
Men	689	5.1	422	3.8	1.34	1.26 (1.11–1.42)
Women	25	2.1	22	1.1	1.91	1.83 (1.02–3.28)
Motor vehicle accidents						
Men	457	3.4	269	2.4	1.42	1.27 (1.09–1.48)
Women	21	1.7	19	0.9	1.89	1.81 (0.96–3.41)
Suicide						
Men	211	1.6	191	1.7	0.94	0.88 (0.72–1.08)
Women	11	0.9	12	0.6	1.50	1.47 (0.63–3.43)
Homicide						
Men	116	0.9	101	0.9	1.00	0.80 (0.61–1.05)
Women	11	0.9	6	0.3	3.00	2.66 (0.96–7.36)

\*Data for men are based on 544,270 Gulf War veterans and 456,726 controls assigned to active units. Data for women are based on 49,919 Gulf War veterans and 84,517 controls assigned to active duty.

†The ICD-9 codes corresponding to the various causes of death are shown in Table 2.

‡Crude rates shown are per 10,000 person-years.

§Adjusted rate ratios (and 95 percent confidence intervals [CI]) were derived from the Cox proportional-hazards model after adjustment for age, race, branch of service, and type of unit.

cause-specific standardized mortality ratios (Table 4). Deaths among both groups of veterans occurred at a rate no more than half that expected in the U.S. population after adjustment for age, sex, race, and year of death.

#### Effect of the War on Female Veterans

Being mobilized without actually serving in the Persian Gulf area appears to have affected the mortality rates of women more than those of men. Among 31,814 female study subjects who served in the reserves or the National Guard and who did not serve in the Gulf War, 17,270 were mobilized and deployed somewhere (for example, in Germany), and 14,544 were not mobilized at all. Women who were deployed somewhere had a higher, but not a significantly higher, rate of death from all causes than non-mobilized women (rate ratio, 1.94; 95 percent confidence interval, 0.92 to 4.07), a higher rate of death from external causes (1.81; 0.73 to 4.5), and a higher rate of death from accidents (3.0; 0.6 to 15) after adjustment for the type of unit, age, race, and branch of service.

Female Gulf War veterans had a higher (but not significantly higher) risk of death from external causes, including accidents, than their female peers in the general U.S. population (Table 4). The rate of death due to motor vehicle accidents among the female Gulf War veterans was 43 percent higher than expected, whereas among other female veterans the risk was 31 percent lower than expected.

#### DISCUSSION

The purpose of this study was to assess the effect of service in the Persian Gulf War on mortality among veterans of U.S. military service. Gulf War

veterans have had a significantly higher mortality than other veterans who served during the same period. Accidental deaths accounted for most of this increase. Neither the suicide rate nor the homicide rate was elevated among Gulf War veterans. Mortality due to illness was not higher in Gulf War veterans than in other veterans. Of the 10 deaths attributed to infectious or parasitic disease, none were reported as due to leishmaniasis or other infectious diseases endemic to the Middle East, or as due to the effects of biologic warfare agents. If there are excess illnesses due to Persian Gulf service, they do not appear to have been life-threatening.

The significant excess mortality from external causes among Gulf War veterans as compared with controls is similar to what has been observed in studies of veterans of other wars. Studies of Vietnam veterans repeatedly found an increased risk of traumatic deaths, mainly from accidents.<sup>8-10</sup> The Department of Defense study of Gulf War veterans who remained on active duty found 225 non-battle-related deaths, including 183 deaths from injuries, through July 1991 (five months after the war began), whereas 202.7 and 118.6 deaths, respectively, were expected on the basis of the rates among other veterans serving at the same time.<sup>11</sup>

The underlying reasons for the excess of deaths due to external causes among war veterans are not well understood. One may speculate that survivors of war perceive the degree of risk in any given situation differently from others and may therefore engage in more risk-taking behavior. Another possibility is that those in combat may be at increased risk for post-traumatic stress disorder or other depressive disorders, which in turn contribute to the excess number of deaths due to trauma.<sup>5,7,16-18</sup>

**TABLE 4.** STANDARDIZED MORTALITY RATIOS (AND 95 PERCENT CONFIDENCE INTERVALS) FOR THE STUDY SUBJECTS, ACCORDING TO CAUSE OF DEATH, AS COMPARED WITH THE U.S. POPULATION.\*

CAUSE OF DEATH†	GULF WAR VETERANS		OTHER VETERANS	
	MEN AND WOMEN (N=695,516)	WOMEN ONLY (N=49,919)	MEN AND WOMEN (N=746,291)	WOMEN ONLY (N=99,061)
All causes	0.44 (0.42-0.47)	0.56 (0.44-0.71)	0.38 (0.36-0.40)	0.37 (0.30-0.45)
Infectious and parasitic disease	0.03 (0.02-0.06)	0.14 (0.00-0.80)	0.14 (0.11-0.19)	0.15 (0.02-0.54)
All cancers	0.32 (0.27-0.38)	0.28 (0.11-0.57)	0.38 (0.33-0.44)	0.27 (0.15-0.44)
Disease of circulatory system	0.28 (0.24-0.33)	0.21 (0.06-0.54)	0.23 (0.20-0.27)	0.12 (0.04-0.29)
Disease of respiratory system	0.14 (0.07-0.23)	—	0.11 (0.06-0.18)	—
Disease of digestive system	0.08 (0.04-0.14)	—	0.10 (0.06-0.16)	—
All external causes	0.64 (0.61-0.68)	1.14 (0.84-1.52)	0.55 (0.51-0.58)	0.60 (0.45-0.80)
All accidents	0.76 (0.71-0.82)	1.17 (0.76-1.73)	0.60 (0.55-0.65)	0.50 (0.37-0.85)
Motor vehicle accidents	0.82 (0.75-0.89)	1.43 (0.88-2.18)	0.62 (0.56-0.69)	0.69 (0.42-1.07)
Suicide	0.69 (0.61-0.77)	1.81 (0.90-3.24)	0.73 (0.65-0.82)	1.22 (0.68-2.00)

\*Standardized mortality ratios were calculated by dividing the number of observed deaths by the number of expected deaths in the U.S. population for each cause shown, after standardization for age, sex, race, and calendar year of death.

†The ICD-9 codes corresponding to the various causes of death are shown in Table 2.

That there were fewer deaths among veterans than were expected from mortality rates in the U.S. population is consistent with the findings of studies of many other military populations. This "healthy-soldier effect" is similar to a healthy-worker effect. Because of the initial physical screening for military service, requirements to maintain a certain standard of physical well-being, and better access to medical care during and after military service, a military cohort almost always has better survival rates than a comparable segment of the general population. A recent study of all soldiers in the U.S. Army who were on active duty in 1986 found that the mortality of soldiers was only half that of their civilian counterparts.<sup>19</sup>

Serious flaws in the design and execution of the study are an unlikely explanation for our findings. To minimize statistical variation due to sampling, the study included all Gulf War veterans and almost half of all military personnel who were not sent to the Persian Gulf. Given the large sample and the 2.4-year period of follow-up, the statistical power of the study would be about 80 percent to detect a 10 percent increase in overall mortality and almost 100 percent to detect a 20 percent increase (by a two-tailed test with a type I error of 0.05).<sup>20</sup> In the analysis of deaths from all external causes combined, the power would be about 60 percent to detect a 10 percent increase, but 99 percent to detect a 20 percent increase. For accidental deaths, the statistical power would be about 90 percent to detect a 20 percent increase, and almost 100 percent to detect a 50 percent increase.

Because of the healthy-soldier effect, a moderate increase in the risk of death would not have been detected in a population of recent veterans, had we compared our findings only with the U.S. population. The results would be unlikely to change substantially if data from missing death certificates were added. Vital status was ascertained at an estimated rate of 89 percent (95 percent confidence interval, 83 to 97 percent) in relation to the National Death Index, with no significant difference between Gulf War veterans and other veterans in the proportion whose vital status was unknown. Among veterans who died, the cause of death was known for 93.7 percent of those who served in the Gulf War and 93.4 percent of those who did not.

The interpretation of the study findings is somewhat confounded by the possibility that military personnel who were seriously ill or recovering from major surgery would not have been deployed to the Persian Gulf area. How much this potential selection bias has contributed to the favorable outcomes with regard to mortality from disease-related causes in veterans of the Gulf War is unknown.

Another limitation of the study is our reliance on death certificates rather than medical records for in-

formation on causes of death. Death certificates dependably establish the fact of a person's death, but their accuracy in recording the cause is variable.<sup>21</sup> However, in reporting external causes of death the agreement between medical records and death certificates has been reported to be good.<sup>8</sup> A further possible limitation is the lack of data on potential risk factors, such as a history of smoking, a history of drinking, and preexisting mental disorders. Any such factors may have been present in equal degrees in the two groups, because the men and women were all accepted into the military before the war and in almost all instances deployment to the Persian Gulf was not voluntary.

The effect of the Gulf War on postwar mortality appears to be greater among female veterans. Both male and female veterans of the conflict had higher rates of mortality from external causes than the controls, but the increase was greater among women. In contrast, there was no excess of deaths from disease among either male or female Gulf War veterans. Mobilization without actual service in the Persian Gulf area had no substantial effect on the mortality of Gulf War veterans as a group. Among women, however, those who were mobilized had a higher risk of death from each category of external causes than those who were not mobilized, although the risk was not significantly higher.

More of the troops deployed to the Persian Gulf War were women (7 percent) than in any previous war. By contrast, women made up less than 0.5 percent of Vietnam veterans.<sup>10</sup> The increase in the number of women in the military and their expanding role in combat-related activities mean that their health must be monitored carefully. Furthermore, a substantial portion of the women sent to the Persian Gulf area (45 percent) were married at the time, and some of them left small children at home to be cared for by others. The effect of this added psychological stress associated with deployment and redeployment warrants further study.

In summary, as compared with non-Gulf War veterans, veterans of the conflict in the Persian Gulf had significant excesses of death from external causes (mainly accidents) but not from disease-related causes. Their risk of death remained less than half that expected in their civilian counterparts. Our findings are consistent with the postwar mortality observed in veterans of previous wars.

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