# Mortality among U.S. Service Members Deployed to Karshi-Khanabad Air Base, Uzbekistan

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**Abstract**

*Background*: Karshi-Khanabad (K2) Air Base, Uzbekistan was a base utilized by the U.S. Military from late 2001 through 2005 in support of Operation Enduring Freedom in Afghanistan. Several environmental hazards were identified raising concerns about long-term health effects among those who were stationed there. Comparison of the relative all-cause mortality rates of those who deployed to K2 to those Service members who could have deployed, but did not, provides an initial basis to evaluate the plausibility of mortality differences due to deployment to K2.

*Methods*: Service members who were stationed at K2 were identified through personnel lists provided by the Defense Manpower Data Center and the U.S. Central Command. The cohort of Service members who could have deployed to K2 was defined as those serving in the uniformed military at any time from October 2001-December 2005 who were born between 1955 and 1985. Death information was obtained from the National Death Index for all deaths occurring between October 2001 and December 2019. A survival analysis was conducted using Cox proportional hazards regression.

*Results*: There were 3,334,197 individuals who met the inclusion criteria, and 77,282 deaths were reported from 1 October 2001 to 31 December 2019. A total of 14,447 service members deployed to K2. There was no significant association between K2 deployment and increased all-cause mortality risk.

*Conclusions*: Service members deployed to K2 were not associated with increased all-cause mortality risk compared to other service members. This does not exclude a subtle environmental effect but limits the size and severity of any possible effect. Limitations to a mortality design include insensitivity to diagnoses that do not result in death, and the long period of time required to detect mortality differences.

## Introduction

The Karshi-Khanabad (K2) Air Base, Uzbekistan was originally constructed by the former Soviet Union as a refueling base supporting their military operations in Afghanistan. The base was abandoned by the Soviets when they withdrew from Afghanistan. When the U.S. initiated military operations in Afghanistan, they received permission from the government of Uzbekistan to recommission K2 as a staging and support air base. Environmental surveys completed prior to opening K2, as well as subsequent surveys described several environmental hazards requiring remediation. (1) Fuel leaking from an old fuel distribution system installed by the Soviets had contaminated a great deal of the soil in the K2 area. Volatile organic compounds were detected throughout the base. However, the concentration of these substances was below the maximum exposure levels for workers as defined by the Occupational Health and Safety Administration (OSHA). (1) Low levels of radiation were detected in a particular area which was later determined to be the site of a storage facility for Soviet surface to air missiles. Satellite imagery confirmed that the missile storage area had exploded in the late 1990s. The analysis of recovered fragments of radioactive material were consistent with depleted uranium of non-US manufacture. (2,3) The area where the depleted uranium was found was cordoned off and mitigated by covering with fresh fill. The other environmental hazard described in the surveys was particulate matter (dust) which was ubiquitous in the area. Other hazards described in areas not occupied by U.S. forces included asbestos and lead-based paint in certain buildings within the base perimeter. Steps were taken by the Department of Defense (DoD) to inform occupants of K2 about the hazards and mitigate them to the maximum extent practicable. When the base was closed in 2005, a final environmental survey was conducted. (2,3)

A recent series of articles in the lay press called attention to the complaints of former occupants of K2 regarding health concerns these individuals attributed to the environmental conditions at K2. (4,5) These articles sparked a series of Congressional hearings, as well as requests by Congress for material from the DoD related to K2. These hearings culminated in a statutory requirement, contained in the National Defense Authorization Act for Fiscal Year 2021, for the DoD to conduct an epidemiological study of the environmental conditions at K2. (6) This requirement was reinforced by an executive order issued by former President Trump in January 2021. (7)

The first step in establishing if there is a causal link between K2 exposure and adverse health outcomes is to choose the most severe, objectively definable adverse outcome; all-cause mortality. If a mortality difference exists that cannot be explained by other factors, e.g. age, gender, or other risk factor differences, further study is indicated to better describe the exposure-outcome relationship. If no relationship is seen, cause-specific mortality studies are the next most logical step. However, if all-cause mortality is the same, a cause-specific difference implies that other causes of death must be lower in the exposed group. If insufficient time has passed to allow the exposure to result in mortality, examination of morbidity, i.e. specific diagnosis rates, could be considered.

Exposure data at the individual level is critical to establishing causality, i.e. what particular environmental exposure, for how long, and what quantity. While being stationed at K2 may imply a general level of elevated exposure to all known and unknown environmental hazards, applying a uniform exposure level to all K2 veterans may obscure subtle findings.

The Secretary of Defense must submit a report on the results of the study no later than 180 days after the enactment of this act. A separate Executive Order, published by former President Trump on January 19, 2021, also requires a study of this same topic. This proposed study, using mortality as an outcome, is intended to provide an initial response within the timeframe allowed by

Congress. Once complete, it will be used to inform a more in-depth study using other outcomes (specific diagnoses or diagnosis clusters vs. mortality).

## Methods

*Data source*

This study used the Defense Manpower Data Center (DMDC) to identify the study cohort and ascertain casualty of service members in the cohort. The DMDC is an electronic database that is used to collate personnel, manpower, training, financial, and other data for the DoD. This information is used for DoD public health surveillance efforts and to support epidemiological research designed to improve force readiness. The National Death Index (NDI) was also utilized to ascertain death information including cause of death and death date for the study cohort. The Defense Medical Surveillance System (DMSS) was used to identify deployment information and demographics information for the study cohort. Army Public Health Command (APHC) service member records were used to supplement deployment data. The DMSS is the central repository of medical surveillance data for the U.S. Armed Forces and contains current and historic data on diseases and medical events such as hospitalizations, ambulatory visits, reportable medical events, etc. Longitudinal data on personnel and deployments is also included in DMSS.

*Study population*

This retrospective cohort study included 3,339,337 service members who were active, reserve, or guard component in the Army, Air Force, Navy, and Marine Corps. Service members who deployed to K2 and were included if born between 1955 and 1985 to capture the largest number of those who deployed to K2. Service members who deployed to K2 but born before 1955 or after 1985 were excluded because they were too few in number to impact the outcome of the analysis and would introduce more variance in mortality estimates. A list of 15,033 service members identified by the United States Central Command (CENTCOM) and a June 30, 2021, DMDC file were also included in the study population as part of the exposed group. The final study population was 3,334,197 after excluding service members in the exposure group who were not within the birth cohort, and service members with death records prior to the beginning of follow-up (01OCT2001) (Figure 1).

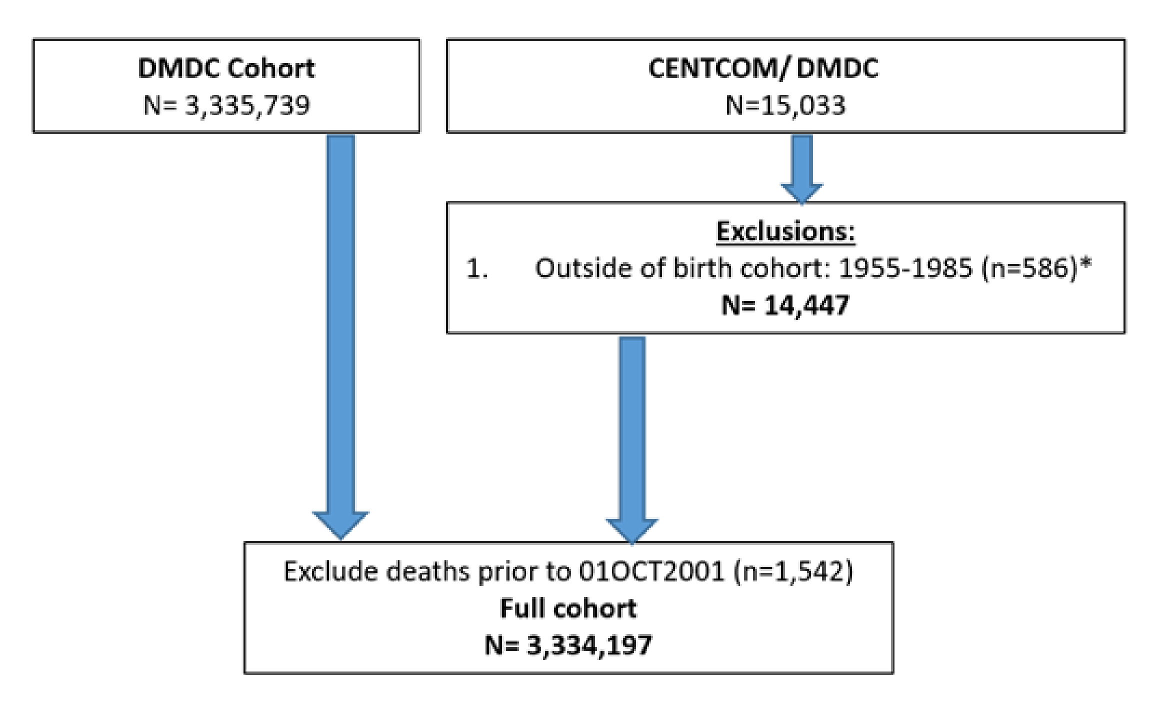


**Figure 1: Inclusion/exclusion Criteria for DoD Analysis of survival analysis and mortality risk**

* 51 of the 586 service members outside of the birth cohort for this study had no demographic information at AFHSD or DMDC hence their date of birth could not be ascertained.

*Exposure definition*

A service member who was deployed to K2 between October 1, 2001, and December 31, 2005 and was validated by DMDC or CENTCOM was considered an exposed individual. (1, 2)

*Statistical analysis*

An all-cause mortality survival analysis, using Cox proportional hazards was conducted. The outcomes of interest were all-cause mortality, and the independent variable was service members' deployment to K2. Covariates of interest in this study were, sex, birth cohort, branch of service, component, and time of deployment (in days). Birth cohort was stratified into 6 groups by 5-year increments from 1955 to 1985 and military component was grouped into active, reserve, and national guard. Deployment to K2 was based on DMDC or CENTCOM verification of deployment to the region. Among service members only identified through CENTCOM, APHC records of length of deployment obtained from Defense Occupational and Environmental Health Readiness System were used. Deployment to K2 was dichotomized (K2 service/ No K2 service). Length of deployment to K2 was used as a proxy for exposure to toxic substances at K2 and it was stratified into 4 categories based on number of days deployed (1-30, 31-90, 91-180, 180+). Race/ethnic group was stratified into non-Hispanic Whites, non-Hispanic Black, Hispanic, Asian/Pacific Islander, and other. The distribution of covariates was determined across deployment to K2. Almost all demographic variables (95%) were based on service members' records within the potential exposure period of 1 October 2001 – 31 December 2005.

Kaplan Meier estimates, and survival curves were constructed using PROC LIFE tests with a Logrank test to test for proportional hazards assumption, statistical comparison of survival curves, using statistical analysis software (SAS). Length of follow-up in years was defined as the time from date of potential deployment to K2 that occurs from 1 October 2001- 31 December 2005, or the first month of service, whichever is later or to the date of being loss to follow-up defined as leaving military service or the end of the surveillance period on 31 December 2019. The survival analysis was censored at death, loss to follow up or at the end of the study period (31 December 2019). Survival curves were also stratified by key covariates of interest to check if survival varied by demographic variables.

Univariate and bivariate analytical methods were employed to determine the association of death with factors such as birth cohort, race, sex, branch of service, and military component. Appropriate parametric (Pearson chi-square) tests were used to evaluate bivariate relationships. In all multivariable models, statistical evaluation of covariates, as well as *apriori* knowledge was used to determine inclusion of covariates in the final models. Multivariable cox proportional hazards models were used to assess the association between exposure (deployment to K2) and all-cause mortality. All analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC). The Defense Health Agency at the Office of Human Research Protections approved the study and determined it to be "not research" under the public health exemption (DHQ-21-2008).

**Results**

There were 3,334,197 service members included in the study with a total of 14,447 deployments to K2. Of the 14,447 service members deployed to K2, a total of 174 service members were missing length of deployment. After 19 years of follow up, the average age was slightly higher among those who deployed to K2 compared to those who did not; 39.1 years versus 34.4 years. A total of 77,282 deaths were reported in this study group from 1 October 2001 to 31 December 2019 of which 99.6 % (n = 76,972) were among service members with no service to K2 (Table 1). Among those deployed to K2, there were 310 deaths (2.1%) (Table 1). Over 60% (n = 46,727) of the deaths occurred between 2011 and 2019 and 26.6% (n = 20,542) of deaths were of service members born in 1981-1985. Overall, the cohort was predominantly active duty, army, white, male, and married (Table 1). Detailed distribution of all demographic variables by K2 deployment are shown in Table 1.

Figure 2 shows the survival curves for service members stratified by birth cohort. Overall the probability of survival in this study group was relatively high; over 80%. The probability of survival did however show decreasing trend with increasing age such that those born in 1971-1985 had over 98% probability of surviving 19 years whilst those born in 1955-1960 had an 81% probability of surviving 19 years (Figure 2).

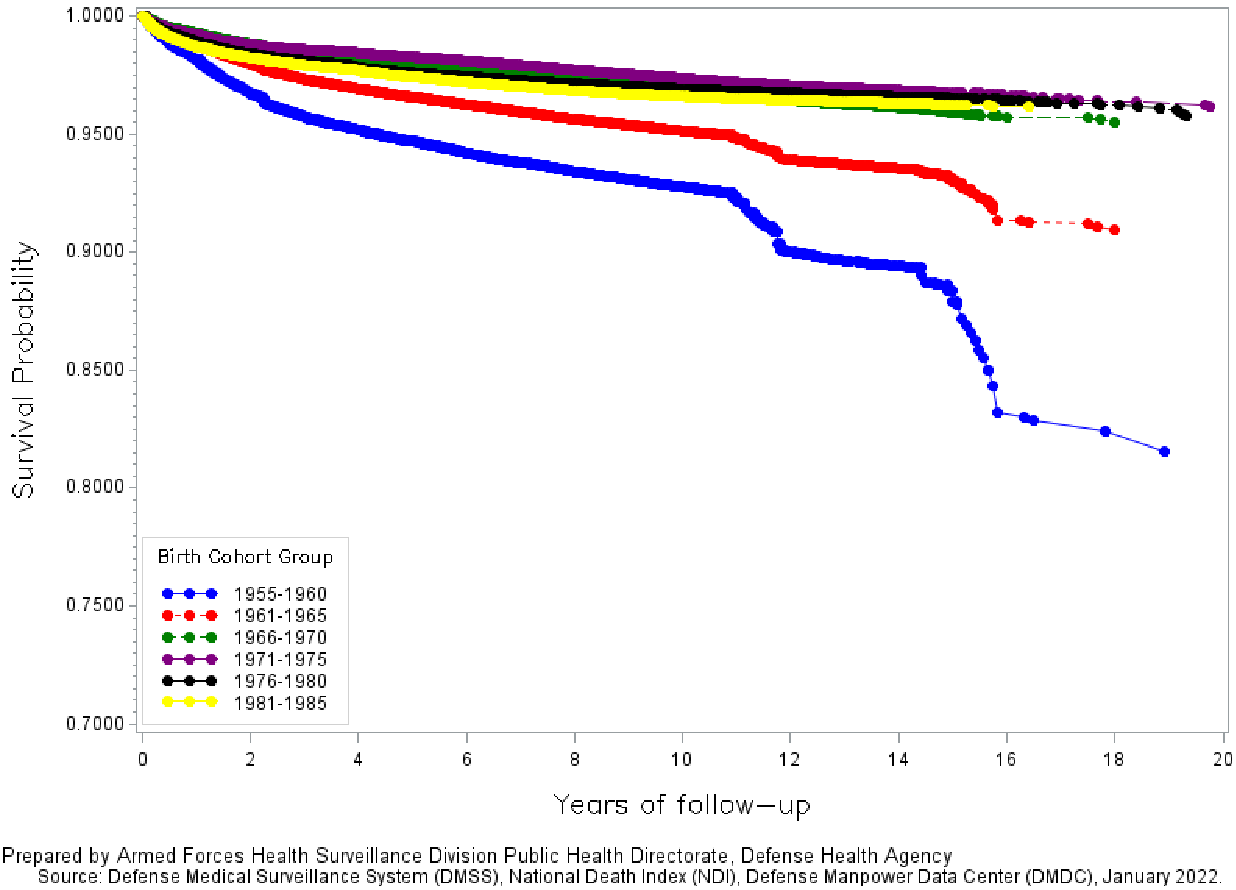


Figure 2 Survival curves of service members stratified by birth cohort

### Table 1: Military Service to Karshi-Khanabad (K2) Air Base by covariates, 2001-2005

| Variable | K2 Service, N (%) | No K2 Service, N (%) | Total |
|---|---|---|---|
| **Overall** | 14,447 (0.43) | 3,319,750 (99.57) | 3,334,197 |
| Sex | | | |
| Male | 13,096 (0.47) | 2,769,258 (99.53) | 2,782,354 |
| Female | 1,351 (0.24) | 550,469 (99.76) | 551,820 |
| *Missing (n=23)* | | | |
| Birth Cohort | | | |
| 1955 - 1960 | 1,110 (0.46) | 240,534 (99.54) | 241,644 |
| 1961 - 1965 | 2,061 (0.54) | 382,843 (99.46) | 384,904 |
| 1966 - 1970 | 2,480 (0.60) | 409,836 (99.40) | 412,316 |
| 1971 - 1975 | 2,920 (0.58) | 504,026 (99.42) | 506,946 |
| 1976 - 1980 | 3,759 (0.45) | 834,029 (99.55) | 837,788 |
| 1981 - 1985 | 2,117 (0.22) | 948,482 (99.78) | 950,599 |
| Race/Ethnic group | | | |
| Non-Hispanic White | 10,508 (0.51) | 2,068,247 (99.49) | 2,078,755 |
| Non-Hispanic Black | 1,917 (0.35) | 551,894 (99.65) | 553,811 |
| Hispanic | 954 (0.30) | 312,055 (99.70) | 313,009 |
| Asian/Pacific Islander | 241 (0.24) | 99,830 (99.76) | 100,071 |
| Other | 827 (0.29) | 287,724 (99.71) | 288,551 |
| Component | | | |
| Active | 10,071 (0.48) | 2,080,675 (99.52) | 2,090,746 |
| Reserve | 1,368 (0.22) | 613,983 (99.78) | 615,351 |
| National Guard | 2,984 (0.49) | 606,605 (99.51) | 609,589 |
| Unknown | 24 (0.13) | 18,487 (99.87) | 18,511 |
| Service | | | |
| Army | 5,376 (0.35) | 1,529,415 (99.65) | 1,534,791 |
| Navy | 44 (0.01) | 659,224 (99.99) | 659,268 |
| Air Force | 8,753 (1.25) | 693,225 (98.75) | 701,978 |
| Marines | 247 (0.07) | 356,720 (99.93) | 356,967 |
| Coast Guard | 3 (0.00) | 62,679 (100.00) | 62,682 |
| *Missing (n= 18,511)* | | | |
| Length of K2 Service (days) | | | |
| 01-30 | 1,611 | | |
| 31-90 | 4,360 | | |
| 91-180 | 6,098 | | |
| 181+ | 2,204 | | |
| *Missing (n= 174)* | | | |
| Death | | | |
| No | 14,137 (0.43) | 3,242,778 (99.57) | 3,256,915 |
| Yes | 310 (0.40) | 76,972 (99.60) | 77,282 |

Prepared by Armed Forces Health Surveillance Division
Public Health Directorate, Defense Health Agency
Source: Defense Medical Surveillance System (DMSS), National Death Index (NDI), Defense Manpower Data Center (DMDC), January 2022.

Crude associations between each covariate and mortality are shown in Table 2. Being deployed to K2 was associated with a 30% decrease in all–cause mortality risk compared having no K2 service [HR = 0.70 (95% CI 0.62, 0.78)]. Compared to active component, Reserve and National Guard were associated with increased risk of all-cause mortality [HR = 1.05 (95% CI 1.03, 1.07)] and HR = 1.19 (95% CI 1.17, 1.21)]. Being born in 1955-1960 was associated with a more than two-fold increase in mortality risk [HR = 2.27 (95% CI 2.21, 2.32)] and being born in 1961-1965 was also associated with increased risk of mortality [HR = 1.42 (95% CI 1.39, 1.45)] compared to being born in 1981-1985. Moreover, being any other service had a protective effect compared to being in the Army. The mortality risk increased with increasing number of days in K2, however, this was not statistically significant (Table 2).

In fully adjusted models (adjusted for sex, birth cohort, race, component of military service, branch of service, and K2 length of service), there was no significant association between K2 service and all-cause mortality [HR =0.84 (95% CI 0.61, 1.15)] (Table 3).

**Table 2: Association of Military Service to Karshi-Khanabad (K2) Air Base and All-cause Mortality, 2001- 2019.**

| Variable | Crude Mortality Ratio | 95 % CI | |
|---|---|---|---|
| **K2 Service** | | | |
| No K2 Service | Reference | | |
| K2 Service | 0.70 | 0.62 | 0.78 |
| **Sex** | | | |
| Male | Reference | | |
| Female | 0.59 | 0.58 | 0.61 |
| **Birth Cohort** | | | |
| 1955 - 1960 | 2.27 | 2.21 | 2.32 |
| 1961 - 1965 | 1.42 | 1.39 | 1.45 |
| 1966 - 1970 | 0.86 | 0.83 | 0.88 |
| 1971 - 1975 | 0.75 | 0.73 | 0.77 |
| 1976 - 1980 | 0.90 | 0.88 | 0.92 |
| 1981 - 1985 | Reference | | |
| **Race/Ethnic group** | | | |
| Non-Hispanic White | Reference | | |
| Non-Hispanic Black | 0.99 | 0.97 | 1.01 |
| Hispanic | 0.69 | 0.67 | 0.71 |
| Asian/Pacific Islander | 0.69 | 0.66 | 0.73 |
| Other | 1.51 | 1.47 | 1.55 |
| **Component** | | | |
| Active | Reference | | |
| Reserve | 1.05 | 1.03 | 1.07 |
| National Guard | 1.19 | 1.17 | 1.21 |
| Unknown | 0.02 | N/A | N/A |
| **Service** | | | |
| Army | Reference | | |
| Navy | 0.83 | 0.82 | 0.85 |
| Air Force | 0.57 | 0.56 | 0.58 |
| Marines | 0.98 | 0.95 | 1.00 |
| Coast Guard | 0.58 | 0.55 | 0.61 |
| **K2 Length of service (days)** | | | |
| 001-030 | Reference | | |
| 031-090 | 0.90 | 0.62 | 1.31 |
| 091-180 | 0.92 | 0.64 | 1.33 |
| 181+ | 1.03 | 0.68 | 1.57 |

Prepared by Armed Forces Health Surveillance Division
Public Health Directorate, Defense Health Agency
Source: Defense Medical Surveillance System (DMSS), National Death Index (NDI), Defense Manpower Data Center (DMDC), January 2022.

**Table 3: Crude and adjusted All- cause mortality risk of Karshi-Khanabad (K2) Exposure, 2001- 2019**

| | Mortality Ratio | 95%CI | |
|---|---|---|---|
| Crude | 0.70 | 0.62 | 0.78 |
| Fully Adjusted Model 1[1] | 0.84 | 0.61 | 1.15 |

1. Adjusted for sex, Birth cohort, race/ethnic group, Military component, branch of service, length of K2 service.

Prepared by Armed Forces Health Surveillance Division
Public Health Directorate, Defense Health Agency
Source: Defense Medical Surveillance System (DMSS), National Death Index (NDI), Defense Manpower Data Center (DMDC), January 2022.

**Discussion**

This mortality analysis of over 3 million service members with 14,447 service members having deployment to K2 failed to demonstrate an association between K2 service and death after 19 years of follow-up. There was also no significant correlation observed with increasing length of K2 service and all-cause mortality. While our finding does not exclude a subtle association from K2 environmental exposures and adverse health outcomes, the results are similar to other studies of military populations. An all-cause mortality study of veterans of the Persian Gulf war with a 13-year follow –up showed similar results; compared to non-Golf War veterans, Gulf war veterans had a lower risk of all-cause mortality [aRR = 0.98(95%CI: 0.96 – 1.01)]. (8)

Age is a contributing factor for mortality in the study, older birth cohorts had a lower survival probability compared to younger birth cohorts (Figure 2). In crude models using being born in 1980- 1985 as the reference, being born after 1966 had a protective all-cause mortality effect whilst being born in 1955-1965 had an increased all-cause mortality risk (Table 2). Being born 1955-1960 was significantly associated with 2.3 times increased in all-cause mortality risk and being born in 1961-1965 was significantly associated with 1.4 times increased in all-cause mortality (Table 2). Even though there is no increased risk of mortality among service members who deployed to K2, it is important to note that being older was associated with increased all-cause mortality, which could be attributed to other comorbidities that tend to present with an increase in age. A cause-specific mortality survival analysis would help delineate the age effect on mortality in this study. However, a recent study of cause-specific mortality among Operation Enduring Freedom, Operation Iraqi Freedom, and Operation New Dawn Veterans did not observe an increase in mortality in these Veterans when compared to the general US population. (9)

Another factor to consider is the overall health status of the military population in relation to healthy worker effect. In order to enter military service, one must undergo a rigorous screening process that eliminates most known serious pre-existing conditions and Military members also undergo annual health screening, as well as health screening before deployment. They are also generally required to maintain a high level of fitness, as well as maintain a body weight within prescribed standards. The healthy soldier effect likely explains the lower overall mortality in our study. In a systemic review to quantify the impact of the healthy soldier effect, the meta-standardized mortality ratios (SMRs) for all-cause mortality for deployed and non-deployed veterans were 0.76 and 0.78, respectively compared to the US general population. This was evident in numerous studies in this meta-analysis ranging from 10-25 % protective effect in military populations compared to the general US population. (10)

*Strengths*

This large, population-based study with a 19-year follow-up period is able to detect small differences in mortality rates over time. Given the long follow-up period and large cohort size, any significant mortality resulting from deployment to K2 should have been detected. This study used a CENTCOM validated list of service members who deployed to K2 and it excluded non-military service members who might have been deployed to K2 and may not have been subject to exposure that military personnel were potentially exposed to.

*Limitations*

Mortality studies may be insensitive to subtle adverse health outcomes that do not result in death. However, the environmental exposures documented at K2 would have been expected to result in diagnoses associated with a shortened lifespan if the levels of exposure were significant. The inability to more accurately classify exposure on an individual level is problematic. Unfortunately, data describing specific exposure to particular environmental threats was not available. This lack of specificity in exposure definition limits the ability of any study to detect a difference. The exposures documented at K2 were all within the limits set by regulatory agencies or what might be commonly encountered in everyday life.

**Conclusions**

Service at K2 is not associated with excess mortality. A subtle association between adverse health outcomes not associated with death cannot be excluded. Follow-on morbidity studies would be necessary to address these issues. In addition to the challenges of defining specific exposures, morbidity studies will face additional challenges of defining specific outcomes, and obtaining necessary health records for review.

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