Changes over time in the Healthy Soldier Effect

Michael Waller, Dr Annabel McGuire
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Summary

Background: Death rates in military populations outside of combat are often lower than those in the general population. The study considers how this 'healthy soldier effect' changes over time.

Methods: Data from two large studies of Australian Veterans of the Korean War (n=17381) and the Vietnam War (n=83908) were analysed to compare changes in death rates relative to the Australian population over time. Separate analyses were conducted for enlisted and National Service personnel.

Results: The healthy soldier effect was most consistently observed in the deaths from circulatory diseases. A large deficit in these deaths in the initial follow-up period (10-20 years) was observed before rates tended back to the level seen in the general population. There was no healthy soldier effect in deaths from external causes in enlisted personnel and these death rates were significantly higher than expected in the initial follow-up period among Korean War Veterans and Regular Army Vietnam Veterans. Those selected for National Service during the Vietnam War exhibited the strongest healthy soldier effect of all cohorts assessed.

Conclusions: Patterns of the healthy soldier effect over time varied markedly by study cohort and by the cause of death studied. In a number of analyses a healthy soldier effect was still apparent after more than 30 years of follow-up.

Executive Summary

Introduction

Workers are known to have lower mortality rates than the general population because they are healthy enough to be selected for, and maintain employment. This is known as the 'healthy worker effect'. Military personnel may also have lower death rates than the general population, because they are subject to health screening prior to entry to the Defence Force and are required to meet and maintain health standards for continuing employment.

Consequently, studies that use the general population as a comparison group may underestimate the risk of an exposure (for example, deploying to Vietnam) on mortality. This study attempted to quantify the healthy soldier effect at different time points and in different military groups.

Research Questions

The aim of this research was to use mortality and cancer incidence data from the DVA studies of Korean War Veterans and Vietnam War Veterans to assess:

- changes in the estimates of the healthy soldier effect over time
- whether the healthy soldier effect tends to unity with increased follow up; that is death rates in these groups becomes similar to death rates in the general population as they get older.
- changes in the healthy soldier effect for different death causes and cancer types – whether 'soldiers' suffer different illnesses or die from different things than the general population.

Methods

Death rates and cancer incidence in the Korean War Veterans and the Vietnam War Veterans were compared to rates in the Australian Population using the Standardised Mortality Ratio (or Standardised Incidence Ratio), which would be expected to be one if there were no differences between the groups. These effects were calculated by follow-up period so that changes in these measures over time could be assessed. The follow-up for this study started from the date an individual returned from deployment (after exposure) until date of death.

Results by study cohort

- The temporal trends in the healthy soldier effect were varied between different military groups. That is outcomes for different deployment groups varied with both group and the amount of time since they returned from deployment.

- There was no evidence of a healthy soldier effect for veterans of the Korean War. They had higher rates of death from external causes (such as accidents and suicides) in the initial period after returning from deployment and this

may be the reason for no difference in mortality rates between them and the general population. .

- The Vietnam War Regular Army Veterans had slightly lower all cause mortality to that of the general population. This small deficit of deaths was steady throughout the follow-up period. However, they did have significantly more deaths from external causes in the first 10 years of follow-up than the Australian population of the same age (SMR 1.27 95% CI (1.13, 1.44)).

- The Vietnam War Regular Navy and Air Force veterans were shown to have a strong healthy soldier effect for all cause mortality in the first 10 years of follow-up (SMR 0.80 95% CI (0.71, 0.89)), before death rates rose back towards the level in the general population.

- There was a clear and strong health soldier effect evident for both groups of National Service Veterans at the time of the Vietnam War. This effect was still evident after more than 30 years of follow-up.

Results by cause of death

- Initially deaths from circulatory diseases were far lower than the rates observed in the general population before death rates gradually rose to a level closer to that observed in the Australian population. The observation was consistent across study cohorts.

- Cancer deaths did not display a clear healthy soldier effect. Cancer mortality was rare in the early part of follow-up because of the age distribution of the study cohorts, in general terms cancer occurs less often in younger people. In each of the enlisted (regular) cohorts there was an excess of cancer deaths between 20 and 40 years follow-up.

- External cause mortality rates (which includes accidents, motor vehicle accidents and suicides) were higher than expected in the initial follow-up period in Korean War Veterans and Regular Army Vietnam Veterans. In contrast, the National Service Veterans conscripted during the Vietnam War had lower death rates than the general population throughout follow-up. As such, no consistent pattern with regard to the existence of a healthy soldier effect in deaths from external causes was observed.

Duration of the Healthy soldier effect

- After between 30 and 40 years follow-up in the respective studies the Healthy Soldier Effect was still present in a number of study cohorts. This was especially true of the Vietnam War National Service Veterans, who were the youngest cohorts studied.

- Having observed an initial deficit, rates of circulatory disease for Korean Army Veterans and Regular Vietnam cohorts may have stabilised at a level

similar to that observed in the general population. The timing of this plateau varied by cohort and was observed between 10 and 25 years follow-up.

Discussion

Trends over time in the healthy soldier effect differed by cause of death. Where present the healthy soldier effect was observed most clearly in all cause death rates and deaths from circulatory diseases.

This finding is consistent with the McMichael's theory that those with heart disease, a chronic and detectable condition, are likely to be screened out in the recruitment of an active workforce(**1**).

There was no clear healthy soldier effect observed in cancer mortality in the enlisted cohorts studied. One reason for this is that factors that will predict eventual death from cancer are less likely to be detected on entry to the workforce(**2**).

The patterns of external cause mortality varied by cohort studied. Both the enlisted Korean Veterans and the Vietnam War Army veterans had significantly higher death rates for these causes than the general population in the first 10 years after deployment. This may suggest that some members of the Defence Force are vulnerable to deaths from causes such as motor vehicle accidents or suicide in the initial period after returning from deployment.

The healthy soldier effect was most clearly observed in the Vietnam National Service Veterans. The selection process of National Service Veterans was comprehensive and many more Australian males were selected by ballot than were actually conscripted. Consequently, only the fittest and healthiest may have been conscripted resulting in a healthy soldier effect stronger than that observed in the selection of the enlisted groups.

Conclusions

These analyses have highlighted the complexity of the healthy soldier effect. This effect was most clearly observed in the deaths from diseases of the circulatory system. The results emphasise that the healthy soldier effect does change over time and does vary markedly between different causes of death and between different subgroups of the Defence Force. In order to avoid bias due to the healthy soldier effect, internal comparison groups (or other employed comparison groups) should be used in studies that aim to assess the effect of a particular exposure in the Defence Force.

Full Report

Introduction

Workers are known to have lower mortality rates than the general population. Good health is necessary to secure and maintain employment whereas the general population includes sick and disabled people who may be at greater risk of mortality. This observation is known as the "healthy worker effect". It is denoted by a Standardised Mortality Ratio (SMR) of less than 1, and has been frequently reported and discussed in occupational epidemiology.(**1-5**)

A similar observation in military populations has been termed the "healthy soldier effect". (**6-8**) Kang and Bullman proposed that military personnel will have lower mortality than the general population because of initial physical screens, a requirement to maintain a certain standard of physical wellbeing and better access to medical care during military service. (**6**) This healthy soldier effect may result in an underestimation of the effect of an exposure in studies which use the general population as the comparison group.

McLaughlin et al. conducted a systematic review of literature and did a meta-analysis to compare mortality rates of military personnel with the general population. (**9**) The results indicated that estimates of the healthy soldier effect were heterogeneous and likely to be strongly dependent on factors such as the type of deployment being studied, the era of the deployment and the baseline general population. Differences in effect sizes are also likely to result from the differences in the follow-up period between studies.

McMichael et al. observed that the healthy worker effect was likely to be larger at ages closest to recruitment years as employers actively reject unhealthy job applicants.(**10**) Further, in an analysis which considered ten occupational cohorts Monson observed a consistent pattern of the healthy worker effect decreasing with increased follow-up until the SMR reached a plateau.(**2**)

Consistent with these observations, in McLaughlin's review the study which showed the greatest reduction in mortality relative to general population was the study of Persian Gulf War veterans by Kang and Bullman which followed a young cohort of military personnel for 2.4 years.(**6**) However, McLaughlin et al observed no consistent pattern of the healthy soldier effect decreasing with time. Indeed studies of Korean War technicians (**11**) and Naval personnel (**12**) with approximately 40 years follow-up also still showed very large mortality reductions.

In order to further understand the how the healthy soldier effect changes over time we used data from the Department of Veterans' Affairs (DVA) Mortality and Cancer Incidence and studies of Australian Veterans of the Vietnam and Korean wars, to study the temporal pattern of the healthy soldier effect in detail. (**13-17**)

The aim of this research was to use mortality and cancer incidence data to assess:

1. changes in the estimates of the healthy soldier effect over time
2. whether the healthy soldier effect tends to unity with increased follow up; that is the SMR approaches 1.
3. changes in the healthy soldier effect for different death causes and cancer types

The Vietnam study data also allows for separate analyses of the trends associated with the healthy soldier effect between enlisted and conscripted personnel.

Methods

Data sources

A de-identified version of the data used to conduct the DVA mortality and cancer incidence studies of Korean and Vietnam War Veterans was provided by the Australian Institute of Health and Welfare (AIHW).

For those Australians who deployed to the Korean War mortality records were held for the years 1950-2000 and records of cancer incidence from 1982-1999. For the nominal roll of personnel who deployed to the Vietnam War and those selected for National Service but who did not deploy, mortality and cancer incidence records were available for the periods 1963-2001 and 1982-2000 respectively.

Australian population death rates for the years 1950-2001 (**18**) and cancer incidence between 1982 and 2000(**19**) were compared to the rates in the military cohorts. AIHW publish cancer incidence rates from 1982 and mortality rates from 1907. These population estimates and mortality and incidence counts by cause of death or cancer site were available for each calendar year and by 5 year age-group.

Study cohorts

All people included in the study were male. The Korean War Veterans were analysed as one cohort. The people in the Vietnam War Studies were split into the following groups for analysis:

- Regular Army Veterans
- Regular Navy and Air Force Veterans
- National Service Army Veterans
- National Service Army Comparisons (who did not go to Vietnam)

By splitting the data in this way the different trends of the healthy soldier effect over time in these groups could be assessed. Because the National Service personnel were conscripted for service from the population and went through a series of medical, psychological and educational assessments this group was analysed separately from the Regular Veterans who served in Vietnam.

To summarise the National Service scheme required males aged twenty and normally resident in Australia to register for National Service. A total of 804,286 registered for

National Service and 237,048 were selected by ballot. After exclusions on medical, psychological and education grounds as well as other deferments and exemptions 63,735 were conscripted for National Service and of these approximately 19239 served in Vietnam, and 24729 were passed fit and served in Australia only. (**16**)

Health outcomes

The primary outcome in this study was all cause mortality. The healthy soldier effect was also assessed by common causes of death with available comparison rates for the Australian population with sufficient numbers to be able to assess temporal trends:

- Cancer mortality (ICD9 140-239; ICD10 C00-D48)
- Lung cancer (ICD9 162; ICD10 C33, C34)
- Diseases of the circulatory system (ICD9 390-459; ICD10 I00-I99)
- Diseases of the respiratory system (ICD9 460-519; ICD10 J00-J99)
- Diseases of the digestive system (ICD9 520-579; ICD10 K00-K93)
- External cause mortality (ICD9 E800-999; ICD10 V01-Y98)

Deaths from external causes include accidents, deaths from self harm and assaults. Trends in incidence for all types cancers were also assessed as well as for the most common sites of cancer. The population rates of cancer incidence were available from 1982. The types assessed were:

- Prostate (ICD10 C61; ICD9 185)
- Lung, bronchus and trachea (ICD10 C33-C34; ICD9 162)
- Colorectal (ICD10 C18-C20; ICD9 153, 154.0, 154.1, 154.8)
- Melanoma of skin (ICD10 C43, ICD9 172)

Statistical analysis

All data was analysed using STATA 10.0 (**20**). For the analysis of mortality rates Korean War Veterans were followed up from the date when they returned from Korea until date of death or the end of follow-up (whichever was earliest). Therefore follow-up was over the lifetime of the individual after deployment, and not just the period they served in the Australian Defence Force. Likewise those in the Vietnam group were followed up from the date they return from Vietnam. Since the National Service Comparisons had no date of returning to Australia, follow-up began on the day that they turned 22.

For the cancer incidence analysis persons were followed up from 1st January 1982 until date of diagnosis of the cancer being studied, or alternatively date of death or end of follow-up. This date was used because AIHW publish cancer incidence rates in the population from 1982.

The expected number of events was calculated by multiplying the number of person-years in each 5 year age for each calendar year by the mortality rate (or cancer incidence) in males for that age group and year in the Australian population. The Standardised Mortality ratio (SMR) or Standardised Incidence Ratio (SIR) were used to compare rates in the veteran populations to Australian population norms. This is the ratio of the observed and the expected number of events.

The SMRs are tabulated by follow-up interval to show how the death rates differ from those in the Australian population in each time period. Graphs are also presented to show how the SMRs change by cumulative year of follow-up (that is the overall SMR from the start of follow-up to the year in question). These graphs are presented up to the mean follow-up time for each group. The SIRs of cancer are presented similarly by calendar year, since comparison rates in the population were available from 1982.

The vital status of participants in these datasets had been determined by computerised matching of veterans' records with information in large national databases, such as the AIHW National Death Index (NDI), the electoral roll, DVA databases and other registries. The primary analyses included those persons whose vital status is unknown in the at-risk population, and assumed that they were still alive and residing in Australia. However, the data were also analysed excluding those whose vital status was unknown from the at risk population to assess the effect of this assumption.

Some persons were known to have died but have no cause of death recorded (Korean Veterans n=257, Vietnam Veterans n=162). A program was written to allocate these persons a cause of death based on the distribution of causes in the period they died and their age at death. The random allocation used in this program means that the results presented in these analyses may be marginally different that the results previously published from these studies. (**13-17**)

Ethics approvals

Ethics approval for this study was received from the Department of Veterans' Affairs Ethics Committee, the Australian Institute of Health and Welfare (AIHW) Ethics Committee and the University of Queensland Behavioural & Social Sciences Ethical Review Committee (UQBSSERC).

Results

Demographic characteristics

The Korean War study database contained 17,464 men who had deployed to Korea. Four men with a missing date of birth and 79 men who had died but had no date of death were excluded from the dataset used for analysis, creating a total of 17,381. The average age on returning from service in Korea was 26.0 (standard deviation (SD) 5.4) and the average length of follow-up per person for the mortality study was 41 years. Sixty percent of those deployed were Army members (Table 1).

Table 1: Characteristics of the Korean War Veterans

Characteristics	Frequency (%)
Age*	
15-19	627 (4%)
20-24	8375 (48%)
25-29	5470 (31%)
30-35	1663 (10%)
35+	1246 (7%)
Service	
Navy	5742 (33%)
Army	10482 (60%)
Air Force	1157 (7%)
Total	17381

*Age on return to Australia

There were 59,192 males in the Vietnam War study database of persons who had deployed to Vietnam. This dataset contained 13 people who served in two services. In the analyses these people were only counted once, which gave a total of 59,179 deployed personnel. The mean age on returning to Australia 25 (SD 6.4) and the average length of follow-up accrued was 32 years. Of this total 69% served with the Army (Table 2).

Table 2: Characteristics of the Vietnam War Veterans

	Regular Army Veterans	Regular Navy and Air force Veterans	National Service Army Veterans	Total Vietnam Veterans	National Service comparisons
Characteristics	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Age*					
15-19	1725 (8)	4940 (27)	53 (0.3)	6718 (11)	
20-24	9643 (44)	6585 (36)	18823 (98)	35051 (59)	
25-29	4216 (19)	2928 (16)	363 (2)	7507 (13)	
30-34	2596 (12)	1447 (8)		4043 (7)	
35+	3660 (17)	2200 (12)		5869 (7)	
Service					
Navy		13534 (75)		13534 (23)	
Army	21840 (100)		19239 (100)	41079 (69)	24729 (100)
Air Force		4566 (25)		4566 (8)	
Total	21840	18100	19239	59179	24729

*Age on return to Australia

The personnel who served in Vietnam were made up of 21,840 (37%) Regular Army Vietnam Veterans (RAV), 19,239 (33%) National Service Army Vietnam Veterans (NSV) and 18100 (31%) Navy and Air Force Vietnam Veterans. The Regular Army Veterans (mean age 27.2 (SD 7.4)) were older than the National Service Veterans (22.4 (SD 1.0)) on return from Vietnam.

The Vietnam War study database also contained records for 24,729 National Service Comparisons (NSC) who were selected for National Service with the Army during the Vietnam War but who did not deploy to Vietnam.

Mortality

Korean Veterans

Rates of all cause mortality in the Korean War Veterans were higher than those observed in the general population for the follow-up period 1950 - 2000 (overall SMR 1.11 95% CI (1.08, 1.13)).

The all cause death rates relative to the general population fluctuated during the follow-up period (Figure 1). In the initial 10 years of follow-up there was an excess of deaths from all causes in the Korean War veterans. This was due in part to a statistically significant excess of deaths from external causes (SMR 1.45 95% CI (1.28, 1.64)). Indeed the rates of deaths from external causes were significantly higher than those of the general population over the first 30 years of follow-up (Table

3, Figure 2).

In the second 10 years of follow-up (10-19 years) the all cause mortality rate was similar to that of the general population (SMR 0.98 95% CI (0.91, 1.06)) and after 20 years rate of cumulative rates of mortality in the Korean Veterans were approximately equal to those expected in the population. However, after 25 years follow-up all cause rates rose relative to those of the general population for the remainder of the follow-up period (Table 3, Figure 1).

The rises in later periods of follow-up (30-39 and 40-49 years) were characterised by a clear excess in cancer mortality and as well as an excess of deaths due to diseases of the digestive system (Table 3).

Cancer and circulatory disease mortality rates were lower than those expected in the general population in the first twenty years of follow-up before gradually rising (Figures 3 and 4). By the end of the follow-up period the cumulative death rate from cancer was 19% higher than that expected in the general population, whereas the observed rate of deaths from circulatory diseases was approximately equal to the population level.

Vietnam Regular Army Veterans

The all cause mortality in the Regular Army Vietnam Veterans was very similar to that of the Australian population for the duration of follow-up (Figure 5, Table 4).

There was no evidence of a healthy soldier effect in death rates from external causes in this group. In the first 10 years of follow-up there was a clear excess of these deaths. After 10 years of follow-up the deaths rates from external causes dropped to the level observed in the Australian population (Figure 6).

Death rates from cancer were at a similar level to the general population in the first 30 years of follow-up (Figure 7). However, after 30 years rates of cancer mortality were significantly higher than the population level (SMR 95% CI 1.15 (1.02, 1.30), Table 4).

There was a significant deficit of deaths from diseases of the circulatory system. This effect was strongest in the first 10 years and gradually declined with increased follow-up (Figure 8, Table 4).

Vietnam Regular Navy and Air Force Veterans

In the first 20 years of follow-up Regular Navy and Air Force Vietnam Veterans had all cause death rates which were significantly lower than those observed in the general population (Table 5). After 20 years observation the population mortality rates and those observed in this cohort were similar (Figure 9).

There was no evidence of a healthy soldier effect for deaths from external causes in this cohort of Naval and Air Force personnel. Throughout, the death rates from these causes were similar to those of the Australian population (Figure 10).

Cancer mortality rates were similar to those of the general population for the first 20 years of follow-up, before rising to a significant excess between 20 and 30 years (Figure 11, Table 5).

The pattern of deaths from circulatory disease over time was similar to that observed with all cause mortality. A strong healthy soldier effect in the 20 years was followed by a period where mortality rates were close to those observed in the general population (Figure 12, Table 5).

Vietnam National Service Army Veterans

The Vietnam National Service Army Veterans had all cause mortality rates that were significantly lower than those observed in the general population for the first 30 years of follow-up. (Table 6, Figure 13)

This cohort had a significant deficit of deaths from external causes for the first ten years of follow-up (Table 6, Figure 14). After this time rates were still lower than those in the general population but the differences were not statistically significant.

Rates of cancer mortality were no different from those observed in the general population throughout follow-up (Figure 15). In contrast deaths from circulatory diseases were consistently lower than in the general population. This difference was most clearly observed between 10 and 20 years of follow-up (Table 6, Figure 16).

Vietnam National Service Army Comparisons

The Vietnam War National Service Army Comparisons exhibited the strongest healthy soldier effect of all of the cohorts studied. For all cause deaths, there was a clear deficit of mortality in each 10 year follow-up interval (Table 7, Figure 17). The pattern of change in the SMR due to deaths from external causes mirrored that of all-cause mortality (Figure 18). Although the magnitude of the deficit was smaller the effect was still statistically significant.

The National Service Army Comparisons were the only group studied to exhibit a consistent deficit of deaths from cancer mortality (Figure 19). Deaths due to diseases of the circulatory system were also lower than those of the general population. This deficit of circulatory disease deaths gradual declined over time but was still strongly significant at the end of follow-up in 2001 (SMR 0.69 95% CI (0.61, 0.78)).

Adjustment for unknown death status

Excluding those whose death status was unknown from the at risk population resulted in the all cause SMRs associated with the study of Korean War Veterans increasing by between 6 and 12%. The effect of this adjustment in the Vietnam War cohorts was smaller (an increase in SMRs of between 1 and 3%).

Table 3: Changes in Standardised Mortality Ratios (SMR) by period of follow-up for all Korean War veterans

Years of follow-up	*0-9*			*10-19*			*20-29*			*30-39*			*40+*		
	O*	E†	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI
All deaths	383	360.1	1.06 (0.96, 1.18)	674	680.7	0.99 (0.92, 1.07)	1435	1343.3	1.07 (1.01, 1.12)	2590	2168.4	1.19 (1.15, 1.24)	2432	2240.0	1.09 (1.04, 1.13)
Cancer diseases	31	42.0	0.74 (0.52, 1.05)	109	116.4	0.94 (0.78, 1.13)	381	339.1	1.12 (1.02, 1.24)	985	745.1	1.32 (1.24, 1.41)	964	825.8	1.17 (1.10, 1.24)
Lung cancer	2	4.5	0.44 (0.11, 1.77)	24	27.4	0.88 (0.59, 1.31)	152	107.4	1.42 (1.21, 1.66)	317	230.2	1.38 (1.23, 1.54)	303	223.2	1.36 (1.21, 1.52)
Circulatory diseases	62	73.4	0.85 (0.66, 1.09)	256	277.8	0.92 (0.82, 1.04)	669	637.7	1.05 (0.97, 1.13)	1015	942.1	1.08 (1.01, 1.15)	890	880.2	1.01 (0.95, 1.08)
Digestive diseases (from 1968)	0	0	-	25	19.2	1.30 (0.88, 1.93)	84	73.9	1.14 (0.92, 1.41)	131	87.1	1.50 (1.27, 1.78)	71	66.3	1.07 (0.84, 1.35)
Respiratory diseases	1	13.3	0.07 (0.01, 0.53)	27	34.5	0.78 (0.54, 1.14)	58	73.6	0.79 (0.61, 1.02)	208	158.8	1.31 (1.14, 1.50)	280	201.6	1.39 (1.24, 1.56)
External causes	256	176.9	1.45 (1.28, 1.64)	215	166.4	1.29 (1.13, 1.48)	179	135.2	1.32 (1.14, 1.53)	109	96.7	1.13 (0.93, 1.36)	54	57.7	0.94 (0.72, 1.22)

*Observed deaths
†Expected deaths

Figure 1: SMR for all cause mortality in Korean War Veterans by cumulative year of follow-up

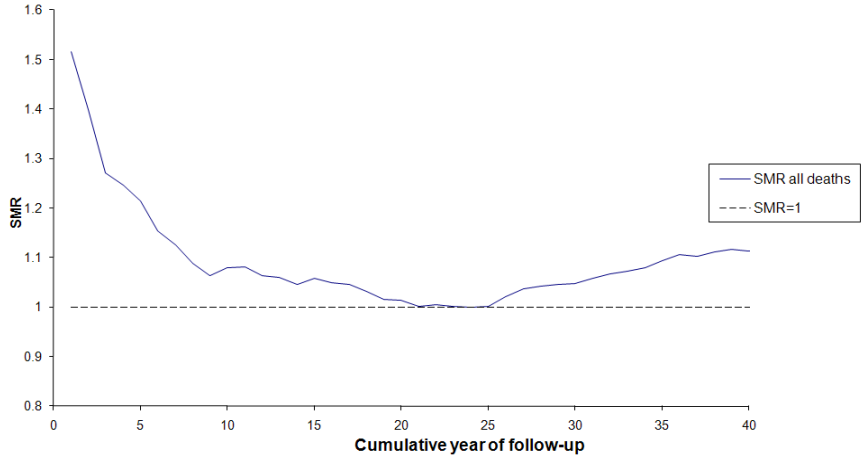


Figure 2: SMR for external cause mortality in Korean Veterans by cumulative year of follow-up

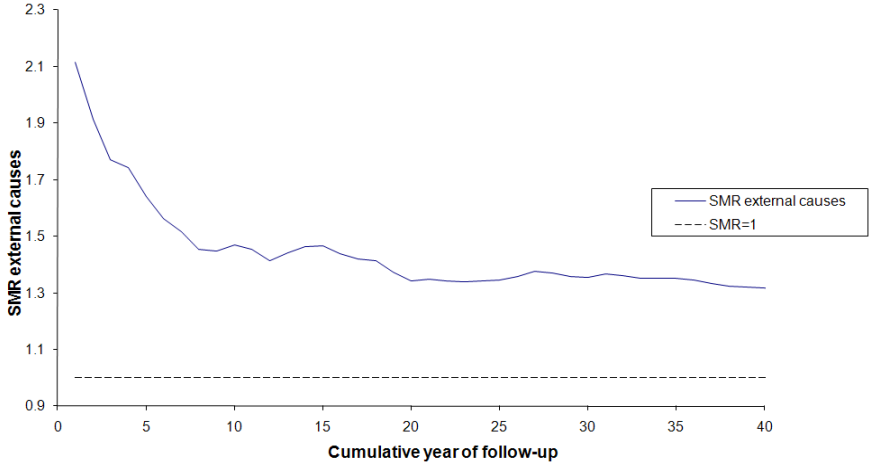


Figure 3: SMR for cancer mortality in Korean War Veterans by cumulative year of follow-up

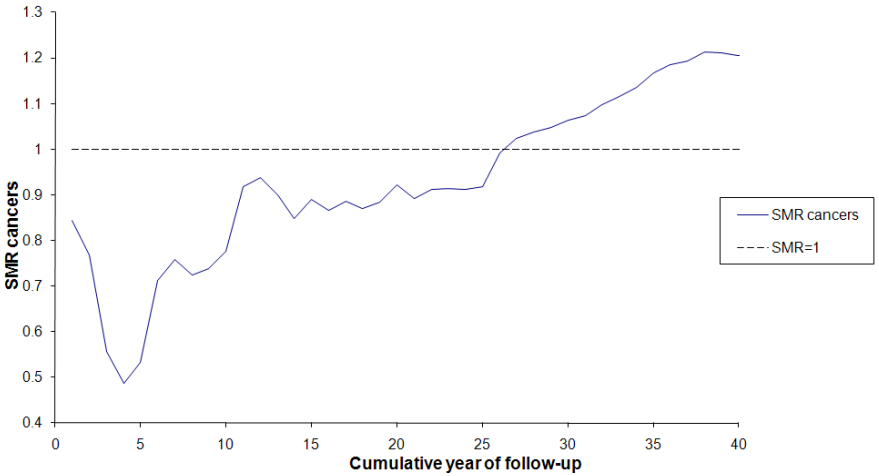


Figure 4: SMR for circulatory disease mortality in Korean War Veterans by cumulative year of follow-up

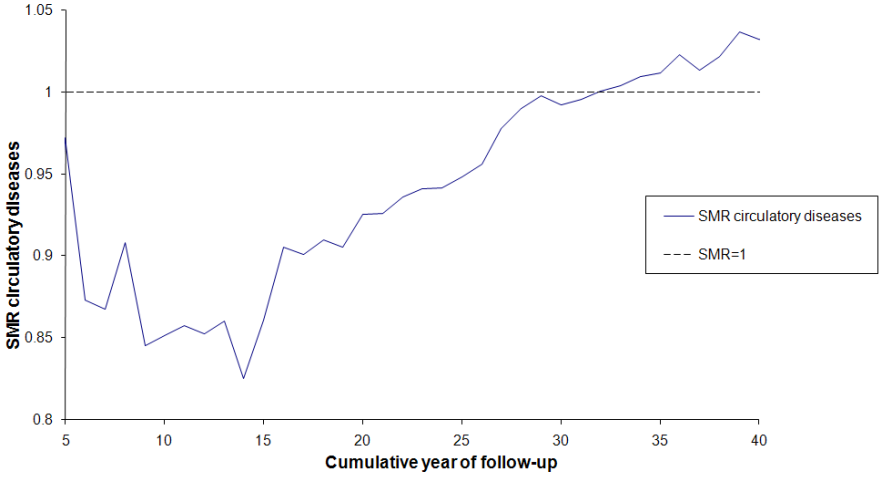


Table 4: Changes in Standardised Mortality Ratios (SMR) by period of follow-up for all Vietnam War Regular Army Veterans

Follow-up	*0-9 years*			*10-19 years*			*20-29 years*			*30+ years*		
	O*	E†	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI
All deaths	464	485.6	0.96 (0.87, 1.05)	702	749.4	0.94 (0.87, 1.01)	1256	1309.9	0.96 (0.91, 1.01)	571	561.6	1.02 (0.94, 1.10)
Cancer diseases	71	73.2	0.97 (0.77, 1.22)	208	201.6	1.03 (0.90, 1.18)	491	476.1	1.03 (0.94, 1.13)	261	226.3	1.15 (1.02, 1.30)
Lung cancer	10	14.0	0.71 (0.38, 1.33)	52	53.3	0.98 (0.74, 1.28)	135	124.8	1.08 (0.91, 1.28)	73	56.8	1.28(1.02, 1.62)
Circulatory diseases	83	125.6	0.66 (0.53, 0.82)	253	275.1	0.92 (0.81, 1.04)	408	464.5	0.88 (0.80, 0.97)	176	188.9	0.93 (0.80, 1.08)
Digestive diseases (from 1968)	20	18.4	1.09 (0.70, 1.69)	35	39.8	0.88 (0.63, 1.23)	61	55.7	1.10 (0.85, 1.41)	24	20.7	1.16 (0.78, 1.73)
Respiratory diseases	3	18.2	0.17 (0.05, 0.51)	28	33.6	0.83 (0.58, 1.21)	76	77.7	0.98 (0.78, 1.22)	40	39.1	1.02 (0.75, 1.40)
External causes	268	210.3	1.27 (1.13, 1.44)	147	145.9	1.01 (0.86, 1.18)	127	116.4	1.09 (0.92, 1.30)	28	29.8	0.94 (0.65, 1.36)

*Observed deaths
†Expected deaths

Figure 5: SMR for all cause mortality in Vietnam War Regular Army Veterans by cumulative year of follow-up

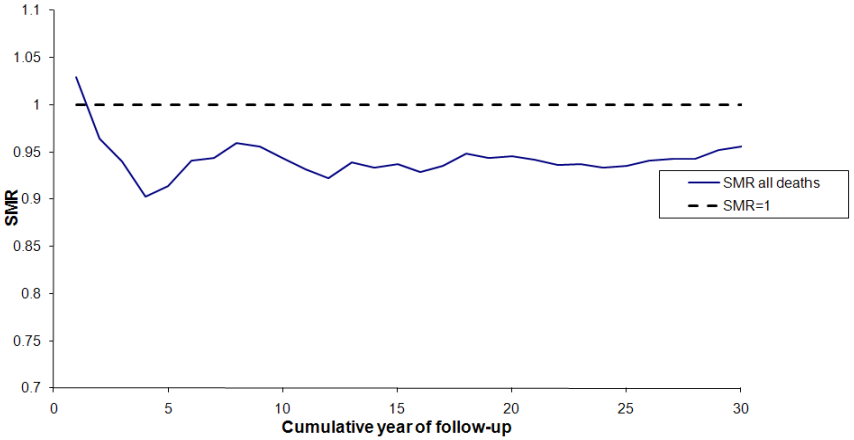


Figure 6: SMR for external cause mortality in Vietnam War Regular Army Veterans by cumulative year of follow-up

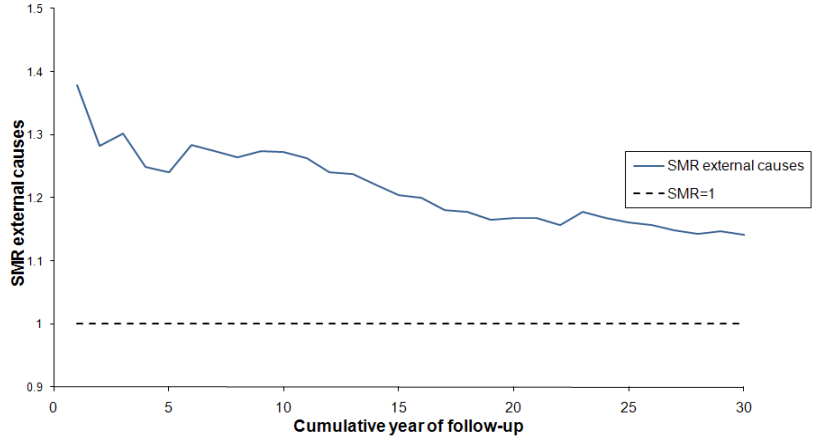


Figure 7: SMRs for cancer mortality in Vietnam War Regular Army Veterans by cumulative year of follow-up

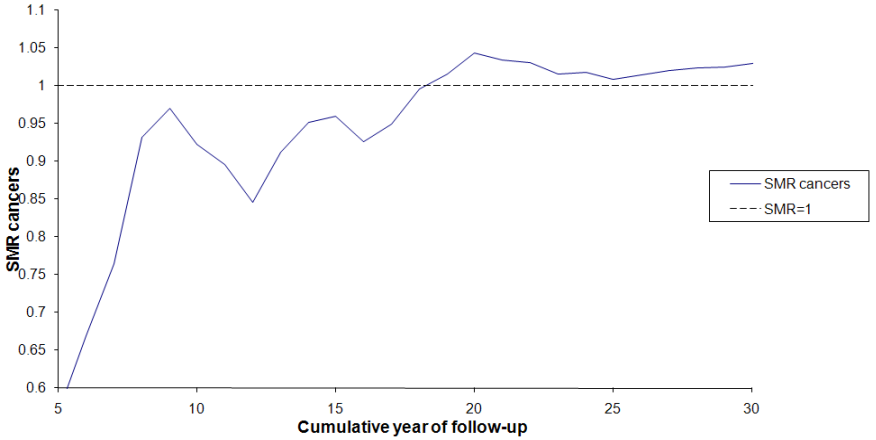


Figure 8: SMRs for circulatory disease mortality in Vietnam War Regular Army Veterans by cumulative year of follow-up

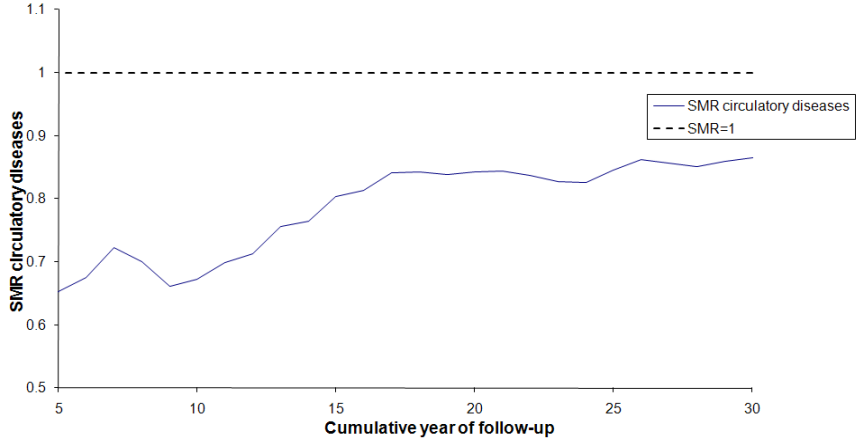


Table 5: Changes in Standardised Mortality Ratios (SMR) by period of follow-up for Vietnam War Regular Navy and Air Force veterans

Follow-up	*0-9 years*			*10-19 years*			*20-29 years*			*30+ years*		
	O*	E†	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI
All deaths	291	364.8	0.80 (0.71, 0.89)	456	521.5	0.87 (0.80, 0.96)	922	893.9	1.03 (0.97, 1.10)	452	451.1	1.00 (0.91, 1.10)
Cancer diseases	44	49.0	0.90 (0.67, 1.21)	129	131.1	0.98 (0.83, 1.17)	385	314.5	1.22 (1.11, 1.35)	185	181.1	1.02 (0.88, 1.18)
Lung cancer	9	8.3	1.09 (0.57, 2.09)	44	32.7	1.35 (1.00, 1.81)	51	45.0	1.13 (0.86, 1.49)	211	166.0	1.27 (1.11, 1.45)
Circulatory diseases	44	77.9	0.57 (0.42, 0.76)	144	177.3	0.81 (0.69, 0.96)	298	307.6	0.97 (0.86, 1.09)	144	149.1	0.97 (0.82, 1.14)
Digestive diseases (from 1968)	10	11.5	0.87 (0.47, 1.62)	22	27.1	0.81 (0.53, 1.23)	39	39.7	0.98 (0.72, 1.35)	24	17.8	1.35 (0.90, 2.01)
Respiratory diseases	4	12.7	0.32 (0.12, 0.84)	9	21.8	0.41 (0.21, 0.79)	34	48.9	0.70 (0.50, 0.97)	31	28.7	1.08 (0.76, 1.54)
External causes	180	183.5	0.98 (0.85, 1.13)	130	124.3	1.05 (0.88, 1.24)	102	98.2	1.04 (0.86, 1.26)	28	29.1	0.96 (0.66, 1.39)

*Observed deaths
†Expected deaths

Figure 9: SMR for all cause mortality in Vietnam War Navy and Air Force Veterans by cumulative year of follow-up

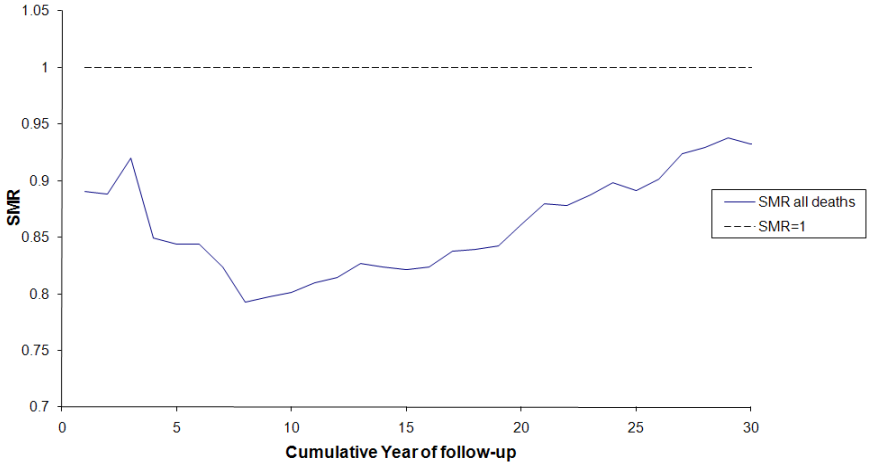


Figure 10: SMR for external cause mortality in Vietnam War Navy and Air Force Veterans by cumulative year of follow-up

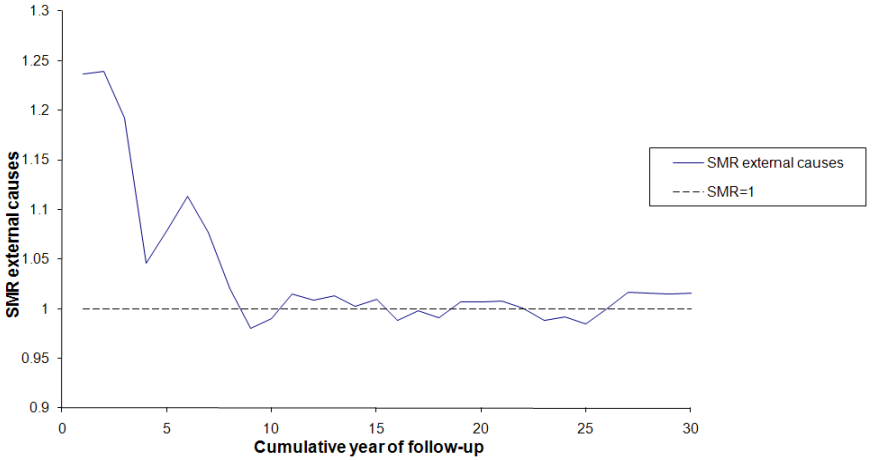


Figure 11: SMR for cancer mortality in Vietnam War Navy and Air Force Veterans by cumulative year of follow-up

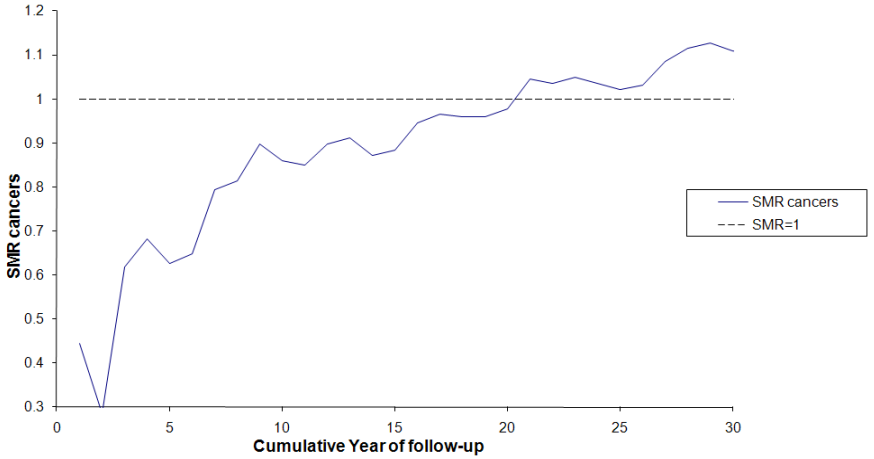


Figure 12: SMR for circulatory disease mortality in Vietnam War Navy and Air Force Veterans by cumulative year of follow-up

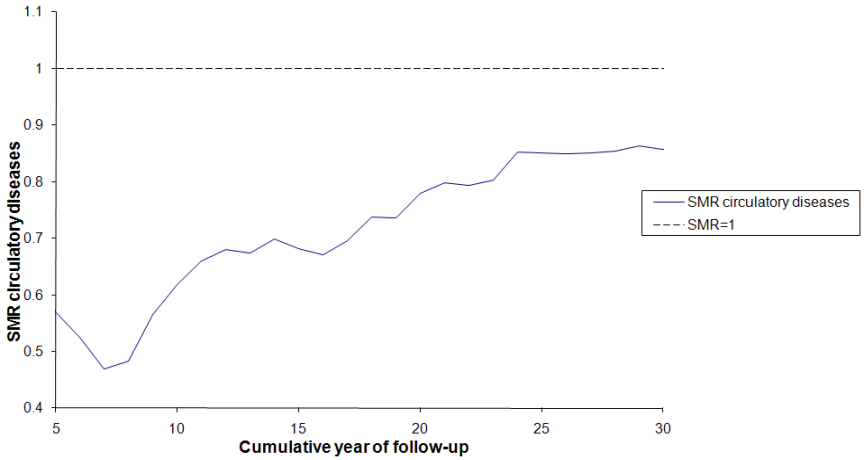


Table 6: Changes in Standardised Mortality Ratios (SMR) by period of follow-up for Vietnam War National Service Army veterans

Follow-up	*0-9 years*			*10-19 years*			*20-29 years*			*30+ years*		
	O*	E†	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI
All deaths	206	274.0	0.75 (0.66, 0.86)	236	298.1	0.79 (0.70, 0.90)	436	540.9	0.81 (0.73, 0.88)	174	184.9	0.94 (0.81, 1.09)
Cancer diseases	22	26.4	0.83 (0.55, 1.27)	56	56.0	1.00 (0.77, 1.30)	146	171.1	0.85 (0.73, 1.00)	74	75.4	0.98 (0.78, 1.23)
Lung cancer	1	0.9	1.12 (0.16, 7.97)	9	6.3	1.42 (0.74, 2.74)	35	34.6	1.01 (0.73, 1.41)	22	16.6	1.33 (0.87, 2.02)
Circulatory diseases	15	20.0	0.75 (0.45, 1.24)	38	63.3	0.60 (0.44, 0.82)	116	152.6	0.76 (0.63, 0.91)	44	53.0	0.83 (0.62, 1.12)
Digestive diseases (from 1968)	5	4.8	1.04 (0.43, 2.49)	11	14.7	0.75 (0.41, 1.35)	33	29.8	1.11 (0.79, 1.56)	10	9.2	1.08 (0.58, 2.01)
Respiratory diseases	0	7.0	0 -	4	8.7	0.46 (0.17, 1.22)	9	15.5	0.58 (0.30, 1.12)	5	6.5	0.77 (0.32, 1.86)
External causes	161	192.4	0.84 (0.72, 0.98)	114	125.3	0.91 (0.76, 1.09)	89	104.5	0.85 (0.69, 1.05)	21	21.6	0.97 (0.63, 1.49)

*Observed deaths
†Expected deaths

Figure 13: SMR for all cause mortality in Vietnam War National Service Army Veterans by cumulative year of follow-up

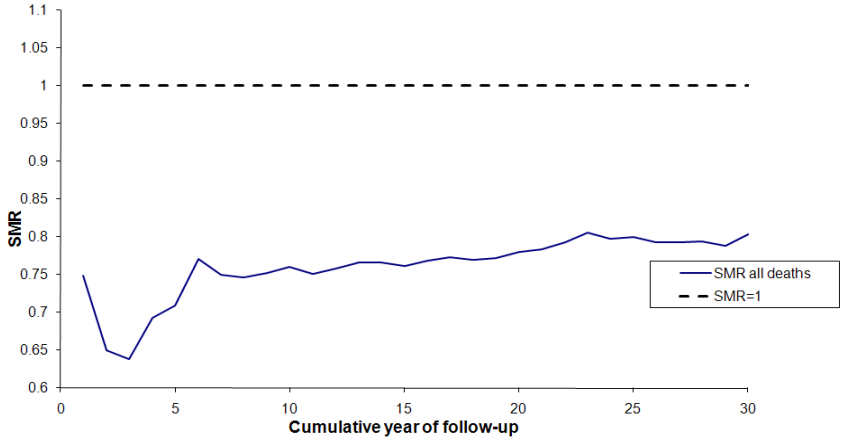


Figure 14: SMR for external cause mortality in Vietnam War National Service Army Veterans by cumulative year of follow-up

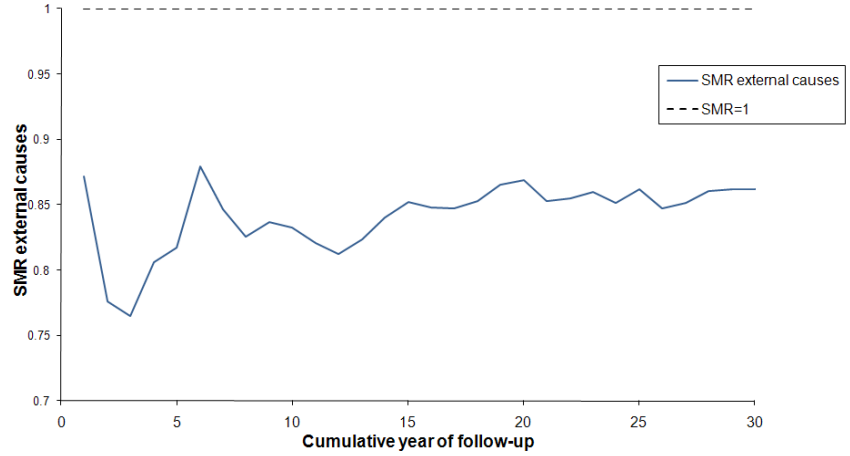


Figure 15: SMRs for cancer mortality in Vietnam War National Service Army Veterans by cumulative year of follow-up

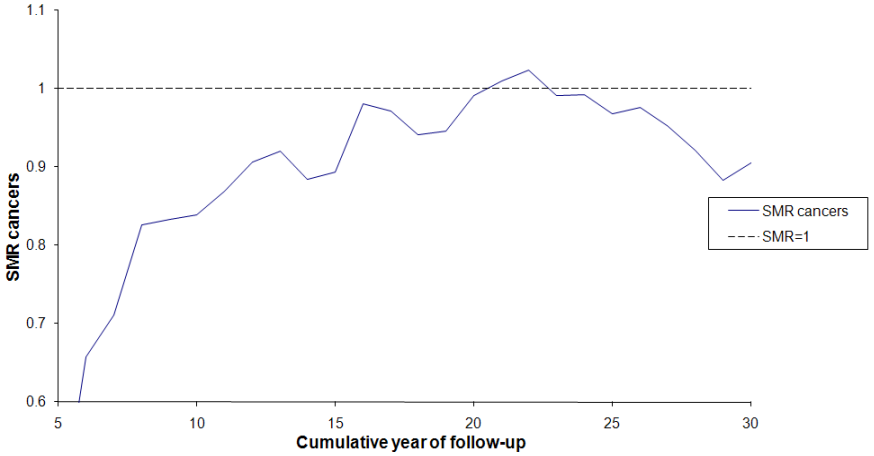


Figure 16: SMRs for circulatory disease mortality in Vietnam War National Service Army Veterans by cumulative year of follow-up

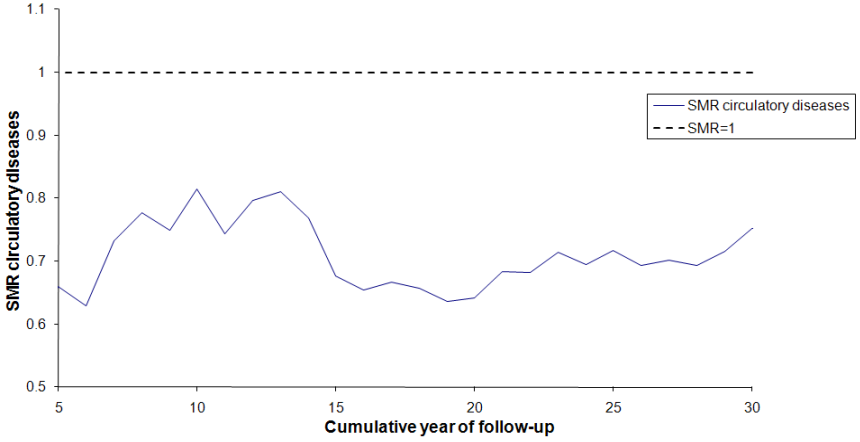


Table 7: Changes in Standardised Mortality Ratios (SMR) by period of follow-up for Vietnam War National Service Army Comparisons

Follow-up	*0-9 years*			*10-19 years*			*20-29 years*			*30+ years*		
	O*	E†	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI	O	E	SMR 95% CI
All deaths	204	351.9	0.58 (0.51, 0.67)	240	385.1	0.62 (0.55, 0.71)	484	688.6	0.70 (0.64, 0.77)	161	238.0	0.68 (0.58, 0.79)
Cancer diseases	28	33.6	0.83 (0.58, 1.21)	49	72.3	0.68 (0.51, 0.90)	171	217.2	0.79 (0.68, 0.91)	72	97.5	0.74 (0.59, 0.93)
Lung cancer	1	1.5	-	3	8.1	-	31	43.8	0.71 (0.50, 1.01)	13	21.7	0.60 (0.35, 1.03)
Circulatory diseases	8	25.7	0.31 (0.16, 0.62)	51	81.1	0.63 (0.48, 0.83)	148	194.1	0.76 (0.65, 0.90)	47	68.3	0.69 (0.52, 0.92)
Digestive diseases (from 1968)	0	6.2	0 -	6	18.9	0.32 (0.14, 0.71)	21	37.9	0.55 (0.36, 0.85)	6	11.9	0.50 (0.23, 1.12)
Respiratory diseases	1	8.9	-	4	11.2	0.36 (0.13, 0.95)	10	19.6	0.51 (0.27, 0.95)	5	8.5	0.59 (0.25, 1.42)
External causes	159	247.6	0.64 (0.55, 0.75)	117	161.8	0.72 (0.60, 0.87)	90	133.8	0.67 (0.55, 0.83)	16	27.3	0.59 (0.36, 0.96)

*Observed deaths
†Expected deaths

Figure 17: SMR for all cause mortality Vietnam National Service Comparisons by cumulative year of follow-up

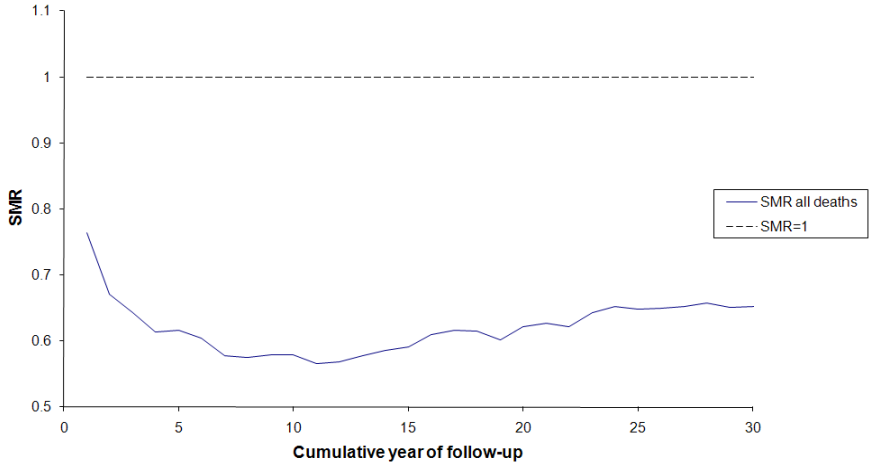


Figure 18: SMR for all cause mortality Vietnam National Service Comparisons by cumulative year of follow-up

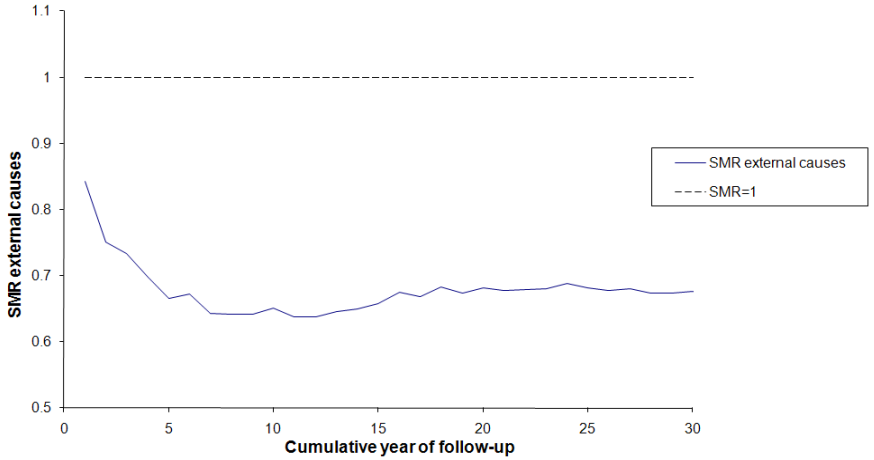


Figure 19: SMR for cancer mortality Vietnam National Service Comparisons by cumulative year of follow-up

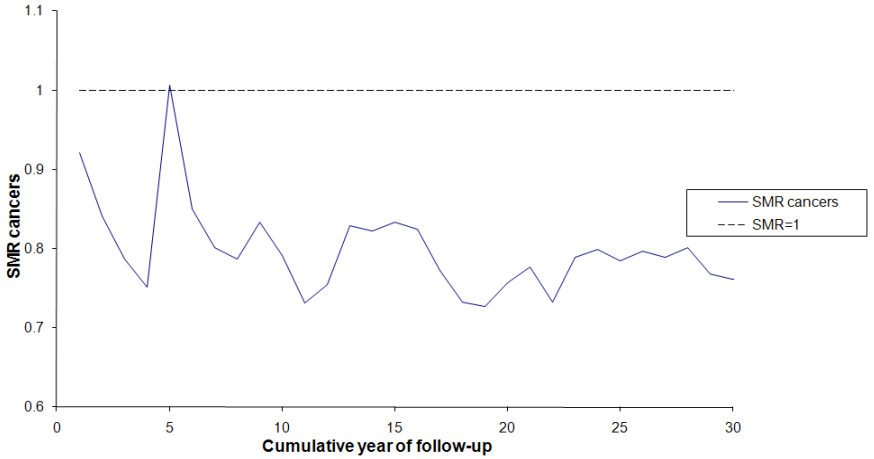
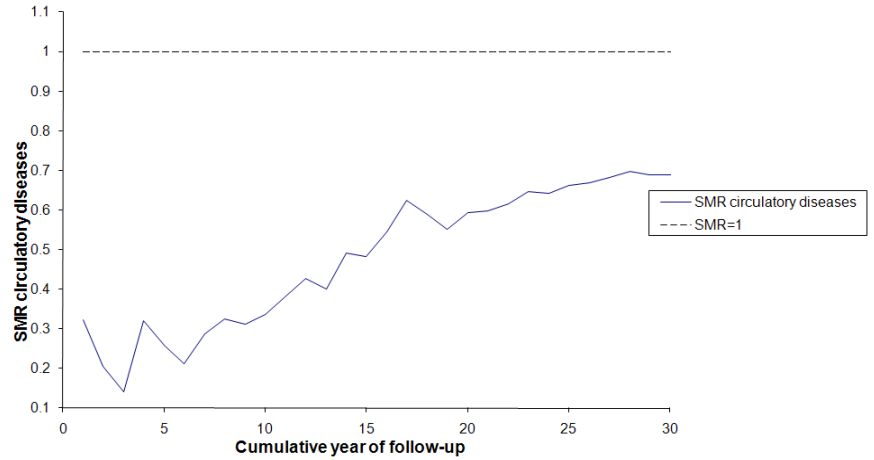


Figure 20: SMR for circulatory disease mortality Vietnam National Service Comparisons by cumulative year of follow-up



Cancer Incidence

Korean Veterans

The Korean Veterans had cancer incidence 7% higher than that of the general population for the years 1982-1999. There were significant increases in total cancer incidence and lung cancers. In both cases the SIRs were almost identical for the periods 1982-1989 and 1990-1999. For the other cancer types assessed the SIRs indicated that rates in each period were not significantly different from the Australian population (Table 8).

Vietnam Regular Army Veterans

The cancer incidence rate in the Vietnam War Regular Army Veterans was 11% higher than the expected rate in the Australian population for the period 1982-2000. This increase was observed in lung cancers, skin cancers and prostate cancers (but not colorectal cancers). For each of these sites the excess of cancers was highest in the period 1990-2000 (Table 9).

Vietnam National Service Army Veterans

There were no clear differences between cancer incidence rates the National Service Army Veterans and the Australian general population (Table 10). The fact that the age cohort was younger in this group meant the number of observed and expected cancers was small.

Table 8: Changes in Standardised Incidence Ratios (SIR) by calendar years for all Korean War veterans

Period	*1982-1989*			*1990-1999*			*Total*		
	O*	E†	SIR 95% CI	O	E	SIR 95% CI	O	E	SIR 95% CI
All cancers	1017	939.8	1.08 (1.02, 1.15)	2176	2039.8	1.07 (1.02, 1.11)	3193	2979.7	1.07 (1.04, 1.11)
Lung cancers	241	190.0	1.27 (1.12, 1.44)	428	331.5	1.29 (1.17, 1.42)	669	521.5	1.28 (1.19, 1.38)
Skin cancers	87	79.2	1.10 (0.89, 1.35)	164	157.6	1.04 (0.89, 1.21)	251	236.9	1.06 (0.94, 1.20)
Colorectal cancers	163	154.4	1.06 (0.91, 1.23)	336	319.9	1.05 (0.94, 1.17)	499	474.3	1.05 (0.96, 1.15)
Prostate cancers	99	96.0	1.03 (0.85, 1.26)	628	583.4	1.08 (1.00, 1.16)	727	678.4	1.07 (1.00, 1.15)

*Observed cancers
†Expected cancers

Table 9: Changes in Standardised Incidence Ratios (SIR) by calendar years for Vietnam War Regular Army Veterans

Period	*1982-1989*			*1990-2000*			*Total*		
	O*	E†	SIR 95% CI	O	E	SIR 95% CI	O	E	SIR 95% CI
All cancers	458	436.1	1.05 (0.96, 1.15)	1570	1392.1	1.13 (1.07, 1.18)	2028	1828.2	1.11 (1.06, 1.16)
Lung cancers	70	64.6	1.08 (0.86, 1.37)	222	185.2	1.20 (1.05, 1.37)	292	249.8	1.17 (1.04, 1.31)
Skin cancers	79	67.0	1.18 (0.95, 1.47)	224	169.6	1.32 (1.16, 1.51)	303	236.6	1.28 (1.14, 1.43)
Colorectal cancers	66	63.8	1.03 (0.81, 1.32)	220	218.9	1.00 (0.88, 1.15)	286	282.7	1.01 (0.90, 1.14)
Prostate cancers	26	22.6	1.15 (0.78, 1.69)	359	284.8	1.26 (1.14, 1.40)	385	307.4	1.25 (1.13, 1.38)

*Observed cancers
†Expected cancers

Table 10: Changes in Standardised Incidence Ratios (SIR) by calendar years for Vietnam War National Service Army Veterans

Period	*1982-1989*			*1990-2000*			*Total*		
	O*	E†	SIR 95% CI	O	E	SIR 95% CI	O	E	SIR 95% CI
All cancers	163	168.6	0.97 (0.83, 1.13)	620	622.3	1.00 (0.92, 1.08)	783	791.0	0.99 (0.92, 1.06)
Lung cancers	13	8.7	1.49 (0.87, 2.57)	63	56.0	1.12 (0.88, 1.44)	76	64.7	1.17 (0.94, 1.47)
Skin cancers	56	46.4	1.21 (0.93, 1.57)	144	120.0	1.20 (1.02, 1.41)	200	166.4	1.20 (1.05, 1.38)
Colorectal cancers	13	16.1	0.81 (0.47, 1.39)	82	87.3	0.94 (0.76, 1.17)	95	103.4	0.92 (0.75, 1.12)
Prostate cancers	0	0.7	0 -	64	53.9	1.19 (0.93, 1.52)	64	54.6	1.17 (0.92, 1.50)

*Observed cancers
†Expected cancers

Discussion

The estimates of the 'healthy soldier effect' were markedly different between the cohorts studied in these analyses. Among Korean War Veterans there was no evidence of a healthy soldier effect for total deaths. In the Vietnam War Veterans a clear healthy soldier effect for all cause mortality was observed in the National Service groups and among the Navy and Air Force personnel. Such an effect was not observed in the Vietnam Regular Army cohort.

Temporal trends in the healthy soldier effect were shown to vary by cause of death. Where present, the healthy soldier effect was observed most clearly in all cause death rates and deaths from circulatory diseases. Indeed a consistent observation was an initial deficit in deaths from circulatory diseases which declined with increasing follow-up.

This finding is consistent with the McMichael's theory that those with heart disease, a chronic and detectable condition, are likely to be screened out in the recruitment of an active workforce(**1**). It follows that this healthy soldier effect is greatest in the time interval closest to a person's date of entry into the military.

Healthy soldier effects on cancer mortality were not clearly observed in these analyses. These trends were difficult to assess in the initial follow-up period because most cancer types are more common at older ages. Nevertheless, it has been hypothesised that a healthy soldier effect on cancer mortality is less likely to be observed in occupational cohorts, because the factors that will predict eventual death from cancer cannot be easily detected on entry to the workforce (**2**).

In each of the enlisted (regular) cohorts there was an excess of cancer deaths between 20 and 40 years follow-up. It has been hypothesised that this observed increase in cancer incidence and mortality may be due in part to smoking patterns or chemical exposures experienced in the respective deployments to Korea and Vietnam (**14, 15**). This increase in deaths from cancer was not observed among National Service personnel. Given that the National Service cohorts were the youngest of those studied, it will be interesting to observe future changes in cancer mortality rates in these groups to determine if any cancers are associated with deployment to Vietnam and whether cancer mortality rises to a level similar to or above that observed in the population. Trends of cancer incidence were limited by the fact that population rates were not routinely available before 1982. However, it was noted that the SIRs were broadly consistent in magnitude and direction with the ratios produced for cancer mortality for the same time periods.

There was no evidence of a healthy soldier effect for deaths due to external causes, except in the Vietnam War National Service Veterans and Comparisons. In both the Korean War Veterans and the Vietnam Regular Army Veterans there were clear excesses of deaths due to external causes in the initial period of follow-up, which may have cancelled out the expected healthy soldier effect in all cause mortality in the initial follow-up period in these cohorts. This may indicate that some members of the Defence Force are vulnerable to deaths from external causes in the period after

returning from deployment. Common causes within this external cause deaths chapter were suicides and deaths from other accidental causes, such as motor vehicle accidents. It has been hypothesised that an excess in deaths from accidental causes may be due in part to 'risk takers' attraction to a military career (**21**). This may help explain why no excess in deaths from external causes was present in the National Service cohorts.

Previous research has shown the duration of the healthy worker effect to vary between 5 and 25 years (**2, 3**), after such time the effect has been shown to plateau, but not necessarily at the population level (**22**). Circulatory disease death rates in Korean Army Veterans followed this pattern, and in the interval 20-29 years of follow-up the previous deficit of circulatory disease deaths had turned into a slight excess. The regular (enlisted) Vietnam cohorts could also be said to have followed this pattern with a plateau of circulatory disease deaths below the level in the Australian population occurring between 10 years (Regular Army) and 20-25 years (Regular Navy and Air Force).

After a strong initial deficit of mortality in the Vietnam study National Service cohorts, no plateau of the healthy soldier effect was observed. However, these were the youngest of all of the cohorts studied (the majority were under 56 years old at the end of follow-up) and therefore further follow-up of this group may be necessary to observe the point where the healthy soldier effect is no longer present.

The reduced mortality in National Service Veterans was observed in both the group who deployed to Vietnam and the group who did not. The National Service program allowed the Australian Defence Force to select from the population more educated and skilled personnel than it had been attracting at that time(**16**). In addition the selection process of National Service Veterans was comprehensive and consequently the criteria used to select these personnel may have resulted in a healthy soldier effect stronger than that observed in the selection of the enlisted groups.

The Korean War Veterans' cohort were distinctive in that they had an excess of all cause mortality at the end of follow-up. The initial excess in all cause mortality in the Korean Veterans had disappeared by 20-25 years follow-up, after which all cause mortality rates increased. At least 30% of the Korean War Veterans served in World War II and involvement in more than one conflict may have contributed to this observed increase in mortality (**14**).

The increased level of mortality in Korean War Veterans relative to the general population may also be due in part to the characteristics of the Australian population used a comparison group. Net migration to Australia was high in the period after World WarII and immigration rates were relatively high through the 1950s and 1960s(**23**). Throughout this period the Australian population would have been refreshed by new migrants who passed the necessary health screens to enter Australia and who were a similar age to the Korean Veterans. Therefore the excess of deaths observed in the Korean veterans may have been higher than if the comparison group were required to have been living in Australia at the time of the Korean War. Even so, a study which used a comparison group made up of people who were resident in Australia at the time of the Korean War did indicate that Korean War Veterans had a

low perception of their quality of life and that this was associated with the severity of combat experienced during the conflict (**24**).

A question of interest which this study has been unable to answer is how the mortality experience of a military population changes when personnel leave the Defence Force. In a study of Royal Naval personnel Inskip et al. observed that mortality rates of those who left the military were closer to that of the general population. (**25**) This finding is intuitive in that personnel may leave the Defence because of ill health, and ex-serving personnel may no longer be required to maintain a minimum standard of health in their new employment. An analysis of these temporal trends of current and ex-serving personnel would be valuable to further understand this interaction.

These analyses have highlighted the complexity of the healthy soldier effect. This effect was most clearly observed in deaths from diseases of the circulatory system. The results emphasise that the healthy soldier effect does change over time and does vary markedly between different causes of death and between different subgroups of the Defence Force. As such, crude adjustments to adjust for the 'healthy soldier effect' in studies of military personnel which use the general population as a comparison group are unlikely to be adequate, even after accounting for the length of follow-up. Where possible, internal comparison groups (i.e. from a Defence population) should be used in studies that aim to assess the effect of a particular exposure on Defence Force members. In some instances a comparison of Defence Force personnel with an alternative employed group may be of use to ensure that the comparison is between two cohorts healthy enough to maintain employment. Nevertheless, a comparison with the general population may still be of interest to observe which exposure group outcomes are closest to those of the general population.

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