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Trends in cardiovascular disease in Scottish military veterans: a retrospective cohort study

Beverly P Bergman, Daniel F Mackay, Jill P Pell

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Institute of Health and Wellbeing, University of Glasgow, Glasgow, UK

Correspondence to
Dr Beverly P Bergman;
Beverly.Bergman@glasgow.ac.uk

ABSTRACT

Objectives To examine the risk of cardiovascular disease (CVD) in Scottish military veterans in comparison with people who had never served in long-term follow-up to 2017, and to compare the findings with our earlier study to 2012 to assess trends.

Design Retrospective cohort study with up to 37 years follow-up.

Setting Pseudo-anonymised extract of computerised Scottish National Health Service records and national vital records.

Participants 78 000 veterans and 253 000 people with no record of service matched for age, sex and area of residence.

Outcome measures Risk of first occurrence of acute myocardial infarction, peripheral arterial disease and stroke in veterans compared with non-veterans, overall and by sex and birth cohort.

Results A first episode of CVD was recorded in 5.7% of veterans and 4.8% of non-veterans overall, Cox proportional HR 1.16, 95% CIs 1.12 to 1.20, p=0.001. The difference was only significant for men, and for veterans born before 1960, and was highest in veterans with the shortest service. In all categories, the difference in risk was less than at the end of 2012.

Conclusions The excess burden of CVD in veterans which was evident at the end of 2012 has reduced in the following 5 years from 23% to 16% overall. The increased risk continues to affect only those veterans born prior to 1960, suggesting that improvements in military health promotion since 1978, when veterans born from 1960 joined the armed forces, have had an important and ongoing beneficial effect on the long-term health of veterans.

Strengths and limitations of this study

- This is a large retrospective study comparing long-term outcomes in veterans in Scotland with matched non-veterans.
- The results were able to be compared with an earlier study to explore trends.
- The health outcome data were derived from computerised National Health Service and national vital records, thus reducing the risk of recall bias.
- Primary care data were not available, therefore the results represent only the more severe end of the cardiovascular disease spectrum, resulting in either hospitalisation or death.
- No information was available of personal lifestyle factors such as smoking which could have influenced cardiovascular risk, nor on occupational factors other than veteran/non-veteran status.

INTRODUCTION

Despite major advances in prevention, diagnosis and treatment in recent decades, cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide.[1] Known modifiable risk factors include smoking, obesity, hypertension and diabetes.[2] We have previously reported that a cohort of 57 000 veterans in Scotland who were born between 1945 and 1985, followed up for over 30 years to 2012, were at increased risk of acute myocardial infarction in comparison with 173 000 age-matched, sex-matched and geographically matched non-veterans.[3] We also found that the same cohort was at increased risk of peripheral arterial disease,[4] smoking-related cancers[5] and chronic obstructive pulmonary disease.[6] We suggested that this was likely to be due to the well-documented higher rates of smoking which have been reported in serving military personnel over many years.[7–9]

The cohort has now been refreshed; the birth cohort has been extended to 1995 and follow-up extended to the end of 2017. In a follow-up study on the refreshed cohort, now encompassing 78 000 veterans and 253 000 non-veterans, we report on trends in CVD in military veterans in Scotland, examining inter alia the possible long-term impact of the workplace health promotion initiatives which have been implemented in the armed forces as a driver for change.

METHODS

Study population

Trends in Scottish Veterans' Health is a retrospective cohort study of all 78 385 military veterans resident in Scotland who were born between 1 January 1945 and 31 December 1995, and a matched comparison group of 252 637 individuals with no record of service. Veterans were eligible for inclusion if they were registered with National Health Service (NHS) Scotland both pre-service and post-service. The selection of the comparison group was carried out by NHS Scotland and involved running a process script on the NHS Scotland central database to select four people with no record of service for every veteran, matched on postcode sector of residence (mean population 5000), year of birth and sex. This generated some duplicates among the non-veterans; elimination of the duplicates resulted in the required output file of approximately 3:1 non-veterans:veterans. As there were fewer women than men to be matched, less duplicates arose and therefore fewer female records required removal. This gave rise to ratios of 3.17:1 for men and 3.83:1 for women; it is unlikely that this slight oversampling of matched non-veteran women has introduced any appreciable selection bias.

The study follows on from the Scottish Veterans Health Study, using similar methodology which is fully described elsewhere.[3] The veterans, who were all volunteers, served in the armed forces between 1 January 1960 and 31 December 2017; enlistment in this period excluded all veterans of post-Second World War compulsory conscription (National Service). All veterans and non-veterans from the original cohort were included. The additional veterans comprised people who left the armed forces between 1 January 2013 and 31 December 2017 and met the inclusion criteria, and those who were newly identified by a targeted campaign to encourage veterans to report their status to their healthcare provider. New non-veterans were selected to match all newly added veterans, using the same criteria as previously.

Demographic data obtained from electronic NHS registration records were linked at an individual level to routine hospital admissions data (Scottish Morbidity Record SMR01) and death certificates to provide information on first recorded diagnosis of acute myocardial infarction, stroke and peripheral arterial disease. Data on comorbid conditions were also obtained from SMR04 (psychiatric hospital admissions), SMR06 (cancer registrations) and disease registers. Dates of entering and leaving the service, for veterans, were obtained from the Scottish NHS registration record. The maximum period of follow-up was from 1 January 1981 (or date of leaving the armed forces, for veterans, if later) to 31 December 2017. The data extract was pseudo-anonymised and approval for the study was granted by the Public Benefit and Privacy Panel of the Information Services Division of NHS Scotland approval number 1718-0133. Individual consent was not required.

Patient and public involvement

As this was a pseudo-anonymised secondary data study, there was no direct patient or public involvement.

Socioeconomic status

Area socioeconomic status (SES) was measured using the Scottish Index of Multiple Deprivation (SIMD), which is calculated for each of the 6505 datazones of residence (mean population 800) from data on income, employment, health, education (including skills and training), housing, crime and access to services. The SIMD is categorised into quintiles of SES for the Scottish population; ranging from 1 (most deprived) to 5 (least deprived).[10] Postcode of residence was used to categorise cohort participants according to these quintiles.

Statistical methods

For the purposes of the study, acute myocardial infarction was defined as any occurrence in the clinical record of ICD-10 code I21 or ICD-9 code 410, stroke was defined as any occurrence of ICD-10 codes I60–I64 or ICD-9 codes 430–432, 436 and 436 and peripheral arterial disease was defined as any occurrence of ICD-10 codes I702 or I73–I79, or ICD-9 443.9 or 440.2, including subcodes where appropriate. CVD was defined as the first occurrence of any of these codes. A diagnosis of diabetes was defined as ICD-10 E10–E14 or ICD-9 250 at any position in the SMR record, or an entry in the Scottish Diabetes Register. For Scottish Diabetes Register entries, we restricted the analysis to type 2 diabetes. For SMR01 records, where type of diabetes was unknown, we restricted the analysis to cases first diagnosed at age 30 years or later to maximise the likelihood of capturing type 2 disease.

Cox proportional hazard models were used to examine the association between veteran status and cumulative risk of CVD, overall and by specific condition, using age as the time dependent variable, age at first record of CVD as the failure time and death (if no CVD) as the censor time. We also examined comorbidity with mental health and other specific diagnoses where this was recorded, and in particular with severe stress or post-traumatic stress disorder (ICD-10 F43 or ICD-9 308 or 309). HRs and p values were calculated and the a priori rejection level was set at 0.05. Proportionality was tested using methodology based on Schoenfeld residuals.[11] The models were run univariably and then repeated adjusting for the potential confounding effect of SES. The analyses were repeated stratifying by year of birth in 5-year bands to examine birth cohort effects, and stratifying by length of service grouped into common lengths of military engagement. All analyses were performed using Stata V.16.

RESULTS

The cohort comprised 78 395 veterans and 252 637 people with no record of military service. After data cleansing to remove veterans with invalid dates of service, 78 157 (99.7%) were included in the analysis. No non-veterans were excluded as a result of data cleansing. There were 7573 women among the veterans (9.7%), reflecting the gender balance of the armed forces. Table 1 summarises the demographic characteristics of the cohort.

Table 1 Cohort description, Trends in Scottish Veterans Health, veterans and non-veterans

	Veterans, n=78 157	Non-veterans, n=252 637	
	n (%)	n (%)	P value
Sex			
Men	70 581 (90.3)	223 654 (88.5)	<0.001
Women	7573 (9.7)	28 983 (11.5)	
Vital status			
Alive	72 298 (92.5)	232 963 (92.2)	0.008
Dead	5859 (7.5)	19 674 (7.8)	
Birth year			
1945–1949	8510 (10.9)	25 982 (10.3)	<0.001
1950–1954	10 673 (13.7)	30 392 (12.0)	
1955–1959	12 400 (15.9)	35 141 (13.9)	
1960–1964	11 539 (14.8)	35 803 (14.2)	
1965–1969	10 645 (13.6)	34 361 (13.6)	
1970–1974	9017 (11.5)	31 877 (12.6)	
1975–1979	4839 (6.2)	18 797 (7.4)	
1980–1984	5786 (7.4)	21 888 (8.7)	
1985–1989	2997 (3.8)	11 096 (4.4)	
1990–1995	1751 (2.2)	7300 (2.9)	
SES (SIMD)			
1 (most deprived)	15 786 (20.2)	50 729 (20.1)	<0.001
2	16 783 (21.5)	52 281 (20.7)	
3	16 766 (21.5)	53 410 (21.1)	
4	16 335 (20.9)	52 421 (20.7)	
5 (least deprived)	12 309 (15.7)	42 564 (16.8)	
Not recorded	178 (0.2)	1232 (0.5)	
Region			
Central Belt (south)	34 342 (43.9)	111 065 (44.0)	<0.001
Central Belt (north)	20 914 (26.8)	75 023 (29.7)	
Highlands, Islands and rural	22 693 (29.0)	66 432 (26.3)	
Length of service			
Basic training (<20 weeks)	6113 (7.82)	N/A	
Early service leaver (<3 years)	21 115 (27.02)	N/A	
4–6 years	15 171 (19.41)	N/A	
7–9 years	9905 (12.67)	N/A	
10–12 years	7218 (9.24)	N/A	
13–16 years	5571 (7.13)	N/A	
17–22 years	6102 (7.81)	N/A	
Over 23 years	6962 (8.91)	N/A	

Length of service: intervals reflect common lengths of UK military engagement.
Early service leaver: left prior to completion of minimum military engagement.
Central Belt (south): Ayrshire and Arran, Glasgow, Lanarkshire, Lothian.
Central Belt (north): Argyll and Clyde, Fife, Tayside, Forth Valley
Highland, Islands and Rural: Grampian, Highland, Western Isles, Orkney, Shetland, Borders, Dumfries & Galloway.
p value, chi-squared; SES, socioeconomic status; SIMD, Scottish Index of Multiple Deprivation.

The mean period of follow-up was 32.5 years, and there was a total of 10.6 million person years of follow-up among veterans and non-veterans combined. By the end of follow-up, 4471 (5.7%) veterans and 12 010 (4.8%) non-veterans had a record of a first episode of CVD. The veterans were at significantly higher risk overall than non-veterans, unadjusted Cox proportional HR 1.16, 95% CI: 1.12 to 1.20, p<0.001, although the excess risk was lower than at the end of 2012 when the HR was 1.23, 95% CI: 1.18 to 1.29, p<0.001. The higher risk was only apparent in men. There were 4336 (6.14%) cases in male veterans compared with 11 398 (5.10%) cases in male non-veterans (HR 1.16, 95% CI: 1.12 to 1.20, p<0.001), and 133 (1.75%) in veteran women compared with 612 (2.11%) in non-veteran women (HR 0.87, 95% CI: 0.72 to 1.05, p=0.157). Data for individual diagnoses, with a comparison between 2012 and 2017 HRs, are shown at table 2.

The higher risk was confined to veterans born prior to 1960, HR 1.23, 95% CI: 1.18 to 1.28, p<0.001; those born from 1960 onwards were at non-significantly lower risk, HR 0.93, 95% CI: 0.86 to 1.01, p=0.083. Adjusting for SES made little difference to the HRs. Analysis by 5-year birth cohort demonstrates the higher risk among veterans in the three oldest birth cohorts (1945–1959), with a non-significantly lower risk among veterans in all subsequent birth cohorts. The overall pattern is similar for the 2012 and 2017 studies, although the values for the HRs are slightly lower in the more recent dataset (figure 1). The neutral point has remained the 1960–1964 birth cohort in both the 2012 and 2017 datasets, despite ageing of the cohort by 5 years.

In both studies there was a clear relationship with length of service, with the highest risk in those with the shortest service although the gap has narrowed. In the 2012 dataset, the highest risk was in early service leavers

Table 2 Cox proportional hazard model of the association between veteran status and cardiovascular cases by diagnosis, 2012 and 2017

	Veterans, n=78157	Non-veterans, n=252637	2012			2017		
	Cases, n (%)	Cases, n (%)	HR	95% CI	P value	HR	95% CI	P value
All CVD	4469 (5.71)	12010 (4.75)	1.23	1.18 to 1.29	<0.001	1.16	1.12 to 1.20	<0.001
Sex								
Men	4336 (6.14)	11398 (5.10)	1.23	1.17 to 1.28	<0.001	1.16	1.12 to 1.20	<0.001
Women	133 (1.75)	612 (2.11)	0.89	0.70 to 1.14	0.365	0.87	0.72 to 1.05	0.157
Diagnosis								
AMI	3113 (3.98)	8362 (3.31)	1.22	1.16 to 1.29	<0.001	1.15	1.10 to 1.20	<0.001
PAD	1051 (1.34)	2467 (0.98)	1.46	1.33 to 1.60	<0.001	1.29	1.20 to 1.39	<0.001
Stroke	742 (0.94)	2109 (0.86)	1.21	1.09 to 1.29	0.001	1.16	1.06 to 1.28	0.001

Cohort size and cases as at 2017.
Stroke—landmark age 40 years.
AMI, acute myocardial infarction; CVD, cardiovascular disease; PAD, peripheral arterial disease.

born prior to 1960 who left prior to completion of training (HR 1.52, 95% CI: 1.36 to 1.68, p<0.001), while in the 2017 dataset the HR for the same subgroup has narrowed to 1.37, 95% CI: 1.23 to 1.53, p<0.001. Veterans with more than 16 years service showed either no difference in risk compared with non-veterans, or reduced risk, in both datasets.

We performed a sensitivity analysis to examine the notional HRs if the comparison between veterans and non-veterans had been undertaken at earlier points in time. This demonstrated an initial small increase in risk with wide CIs (HR 1.17, 95% CI: 0.64 to 1.93) in 1983, when the dataset was smaller, the oldest study subjects were 38 years of age, and CVD was infrequent, rising to a peak of 1.61 (95% CI: 1.32 to 1.97) in 1989–1991 when the oldest were around 45 years of age, followed by a steady fall to 1.16 (95% CI: 1.12 to 1.20) by the end of 2017, the CIs narrowing as the cohort increased in size and more cases were recorded (figure 2).

Analysis of comorbidities showed that veterans with mental health disorders were at higher risk of comorbid CVD than non-veterans with mental health diagnoses. Veterans with a cardiovascular diagnosis also had a higher risk of type 2 diabetes, cancer overall and lung cancer specifically. Cardiovascular risk was no higher than in non-veterans for dementia or lower limb amputation (table 3).

DISCUSSION

During the 1970s, there was widespread concern about an apparent increase in mortality from coronary heart disease in young, otherwise fit serving personnel, which was confirmed by a study published in 1981 by Lynch and Oelman.[12] They tentatively attributed the risk to smoking and socioeconomic factors, the former being known to be higher among military personnel, although the cardiovascular 'epidemic' has never been fully explained.[8 13] Our earlier study[3] demonstrated that the increased risk persisted into post-service life. In this follow-up study, in which we have looked at all CVD, although it is acute myocardial infarction which predominates, we have

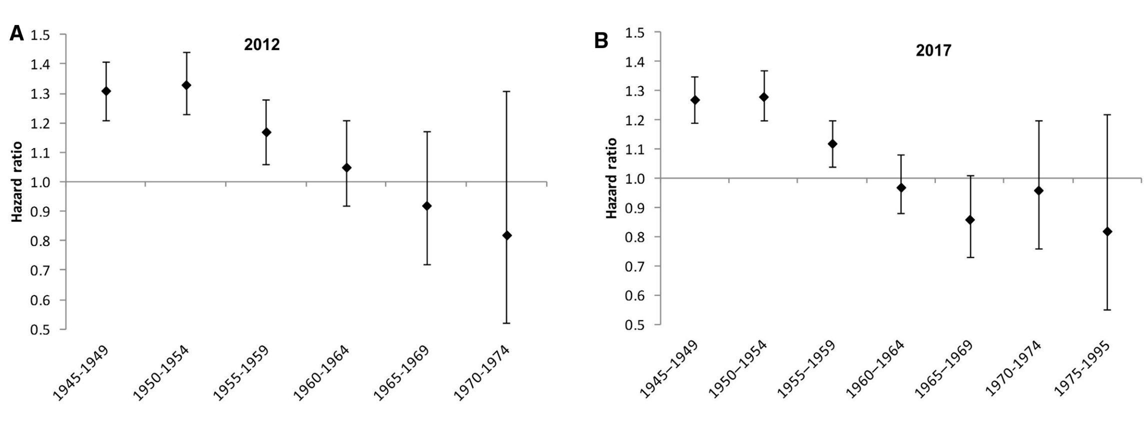

Figure 1 HRs for cardiovascular disease by birth cohort, veterans referent to non-veterans, (A) 2012 and (B) 2017.

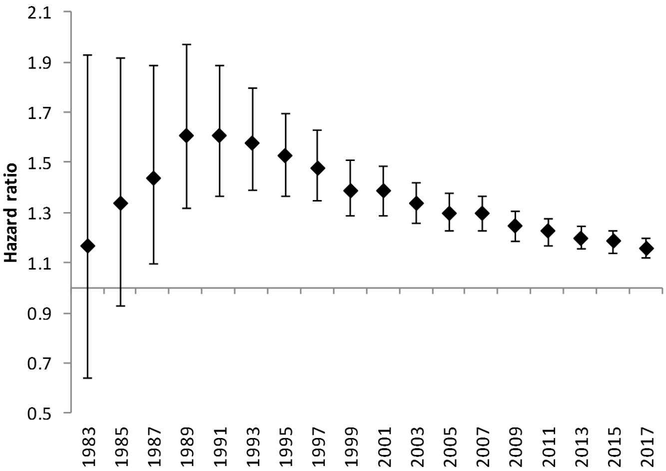

Figure 2 Notional HRs for risk of cardiovascular disease at 2-year intervals 1983–2017, veterans referent to non-veterans.

demonstrated that the increased risk in comparison with non-veterans has gradually attenuated over time. By looking back at notional earlier end-points, we have demonstrated an initial steeply increasing relative risk among the veterans, followed by a gradual reduction since the early 1990s, mirroring the cardiovascular 'epidemic' in serving personnel.

The increased risk is only experienced by veterans born prior to 1960, who would have generally begun their service prior to 1978, when aged 18 years. Veterans born after 1960 were at no higher risk, and some subgroups were at lower risk. We have shown that this 'neutral point' is not an age effect; it has not changed between the 2012 and 2017 datasets. Therefore, it implies a genuine change in risk profile for these more recently born veterans, the oldest of whom are now in their late 50s and hence any increase in risk would be expected to have become manifest.

A new Defence Health Strategy began to be implemented in 1978, taking the form of weight management, health education (including smoking cessation) and mandatory tests of cardiovascular fitness, as well as changes in the delivery of military public health and occupational health services.[14 15] Its impact would have been greatest in those who joined from that year onwards and were therefore exposed to enhanced health promotion throughout their service. Those born in earlier years, who had joined prior to 1978 and were still serving, would have only experienced the programme in the latter years of their service, and would therefore be expected to demonstrate proportionately less benefit to their health. That is supported by figure 1, which demonstrates a baseline risk in the pre-1955 birth cohorts (the majority of whom would have left service by 1978) with a modest fall in the 1955–1959 cohort. Although almost all who joined in 1978 have now become veterans, there is sufficient legacy risk in the pool of older veterans to result in a continuing overall increase in risk, although that is now reducing. Defence health promotion initiatives would also be expected to have had the greatest beneficial impact on those who served for longest, who had a greater period of exposure to these workplace health promotion initiatives; this is also supported by our findings. The poorer long-term outcome of the early service leavers is in part likely to reflect that their period of service was too short for them to have been influenced by military health promotion. However the 'healthy worker effect' is also likely to have contributed to explaining the better outcomes in longer-serving veterans; we have shown elsewhere that this is an important factor in veterans.[16]

The association with lung cancer is unsurprising in view of the shared risk factor of smoking, and the increased risk with comorbid mental health conditions is also consistent with known associations between smoking and mental ill-health.[17–19] A longitudinal cohort study of

Table 3 Cox proportional hazard model of risk of comorbidities with cardiovascular disease in veterans compared with non-veterans

	Veterans with CVD, n=4469	Non-veterans with CVD, n=12010	Univariable		
	Cases, n (%)	Cases, n (%)	HR	95% CI	P value
Mood disorder	303 (6.8)	687 (5.7)	1.21	1.05 to 1.38	0.007
Anxiety	295 (6.6)	612 (5.1)	1.21	1.05 to 1.39	0.007
PTSD	116 (2.6)	160 (1.3)	1.20	1.02 to 1.65	0.032
Type 2 diabetes	1032 (23.1)	2528 (21.0)	1.15	1.07 to 1.24	<0.001
Any cancer	682 (15.3)	1793 (14.9)	1.24	1.14 to 1.36	<0.001
Lung cancer	152 (3.4)	310 (2.6)	1.25	1.03 to 1.51	0.025
Dementia	40 (0.9)	100 (0.8)	1.15	0.79 to 1.38	0.454
Lower limb amputation	100 (2.2)	321 (2.7)	0.95	0.76 to 1.19	0.646

*Cohort size and cases as at 2017.
PTSD, post-traumatic stress disorder.

UK military personnel spanning the period 2004–2009 demonstrated a fall in overall smoking prevalence from 25% to 21%, and of those who initiated smoking during the study period, there was an association with both new-onset psychological distress and remission of symptoms, and also with having been deployed.[20] A freedom of information (FOI) request in 2013 to the Ministry of Defence showed an increase in smoking prevalence between 2010 and 2013, with the highest rate for the army at 33%.[21] However a follow-up FOI request has demonstrated a subsequent fall to 2020, down to a tri-service rate of 18% (19% men, 12% women), with the highest rates in the army (23% men and overall, 15% women) although this remains higher than the overall rate in the UK population.[22 23] With the prevalence of smoking in the community continuing to fall, especially among young people, and an increase in those who have quit,[23] it seems likely that the excess burden of smoking-related disease among veterans will continue to reduce.

The finding that veterans who have experienced post-service lower limb amputation have no higher risk of CVD than their non-veteran counterparts is reassuring as other studies have demonstrated an increased risk of CVD in young traumatic military amputees[24] although whether this is in excess of the risk in non-military amputees is disputed.[25] In a recent study of the long-term impact of lower limb amputation in the same cohort, we found that the risk of mortality in post-service lower limb amputees did not differ from non-veteran amputees (HR 0.98, 95% CI: 0.96 to 1.01, p=0.646), but that the predominant cause of death for both was ischaemic heart disease or acute myocardial infarction.[26]

The major strength of this study is that it was based on a large cohort of over 78 000 Scottish veterans, over a period of up to 37 years follow-up. Health outcome data were obtained from computerised health records, so were not dependent on personal recall and therefore less prone to bias. NHS registration in Scotland is reasonably complete, even among disadvantaged and hard-to-reach groups.

Limitations of the study include possible loss to follow-up of subjects due to migration away from Scotland, for which no data are available, and the lack of any follow-up data prior to 1 January 1981. Cardiovascular disorders diagnosed and treated solely in primary care could not be identified; therefore, our data reflect the more severe end of the spectrum. We have made the assumption that there is no difference in baseline cardiovascular risk at enlistment between those who join the armed forces and those who remain civilians, as the number who are rejected for pre-existing CVD as teenagers is likely to be very small. We had no personal lifestyle information and therefore had to infer smoking prevalence from other published work. Residual confounding of which we had no visibility may still be present. We had no information on the service to which a veteran had belonged (army, Royal Navy or Royal Air Force), and smoking rates are known to be higher in army personnel than the other two services. Non-veterans matching the 0.3% of veterans excluded on data cleansing could not be separately identified and therefore remained in the analysis.

CONCLUSION

In summary, the excess incidence of CVD in veterans which was evident at the end of 2012 has reduced in the following 5 years from 23% to 16% overall. The increased risk continues to affect only those veterans born prior to 1960, adding further weight to our hypothesis that improvements in military health promotion since 1978 have had an important and ongoing beneficial impact on the long-term health of veterans, and thereby demonstrating that a workplace health promotion initiative can achieve long-term benefit.

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Contributors BPB conceived the idea and designed the study, with advice from JPP and DM. BPB carried out the data analysis, which was overseen by DM, and interpreted the findings. BPB wrote the first draft of the report, which was critically reviewed and edited by all authors. BPB revised the draft following peer review. All authors approved the final article.

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Competing interests BPB is a military veteran and is Honorary Civilian Consultant Advisor (Army) in Veterans' Health and Epidemiology, an unfunded role. Neither the Army nor the Ministry of Defence had any input to this paper, and the views and opinions expressed are solely those of the authors. The authors declare no other competing interests.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval Approval for the study was granted by the Public Benefit and Privacy Panel of the Information Services Division of NHS Scotland approval number 1718-0133. As a pseudo-anonymised secondary data study, individual consent was not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement The study remains in progress and the data are not currently available for sharing.

ORCID iD

Beverly P Bergman http://orcid.org/0000-0003-4596-3399

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