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Overall mortality of Canadian Armed Forces personnel enrolled 1976–2012

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Background	Military personnel may be exposed to hazardous substances or environments, making health surveillance critical. However, surveillance is frequently handicapped by long lag times between exposure(s) and outcomes, which often manifest post-military release and are often not recorded.
Aims	To describe the burden of mortality in still serving and released Canadian Armed Forces (CAF) personnel.
Methods	The Canadian Forces Cancer and Mortality Study II (CF CAMS II) is an interdepartmental record linkage study using CAF pay data and Statistics Canada cancer and mortality data. The cohort included all Regular Force and class C Reservist men and women who first enrolled in the CAF between 1976 and 2012, inclusive. The anonymized linked data included death data, including cause and location of death. All-cause mortality (ACM) and International Classification of Disease (ICD)-10 chapter-level mortality (CLM) were quantified using standardized mortality ratios (SMRs), with the Canadian general population (CGP) as the reference population.
Results	Approximately 6870 deaths occurred during over 5 million person-years of observations. For ACM, the CAF risk of death was significantly lower than the CGP for both sexes (females: n = 540, SMR = 0.76 [95% CI 0.69–0.82]; males: n = 6330, SMR = 0.79 [95% CI 0.77–0.81]). In the CLM analysis, SMRs were significantly lower than, or not statistically different from, 1.0 for all ICD chapters.
Conclusions	Military service may have a protective effect that may be partly explained by the healthy soldier effect and the stringent selection process at enrolment.
Key words	Longitudinal studies; military; mortality; occupational health; veterans.

Introduction

One of the responsibilities of a military organization is to protect its personnel from undue harm and to prevent or mitigate exposures that may translate into short- or long-term adverse health outcomes (including death). However, in a military context, deployments can occur in geographic areas where risk assessments are limited by a lack of medical intelligence. This can make it difficult to identify and quantify relevant exposures as they occur.

The military's mandate to protect its own, combined with the possible exposure to hazardous substances and/or environments, make it critical that military health systems incorporate health surveillance to their public health capacity. This can be challenging due to the fact that many of the adverse health outcomes of interest (notably cancer) often have very long lag times, and frequently manifest themselves after a person has been released or retired from the military. In some militaries, as is the case in the Canadian Armed Forces (CAF), the health surveillance capacity only monitors those who are still in uniform. Veterans can be monitored by a Veterans department (in Canada, Veterans Affairs Canada [VAC], or the Veterans Administration in the USA). In other countries, such as the UK, there is no special administration tasked with serving this specific population. The availability of a veterans-specific administration does not ensure population-level service (or surveillance); as is the case in Canada, VAC is only in contact with clients who seek services or assistance from VAC, representing ~8% of its living population [1], making post-release population-level surveillance very difficult. While this reality does not absolve those responsible from protecting their military personnel, including once they leave service, it

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does underscore the challenge faced by organizations in attempting to conduct health surveillance without complete data on their populations.

Cancer and mortality surveillance has been an integral part of the CAF public health portfolio for over 15 years. The CAF's approaches to surveillance, along with the conditions being monitored, have evolved over time. This has been primarily in response to the changing population and military deployments, but also in response to changing surveillance frameworks. In particular, the CAF has become aware that a person's health status and behaviours precede enrolment, and that participation within the military continues to influence health outcomes after release, resulting in a shift towards a life-course perspective on population health and surveillance. This perspective acknowledges the importance of what precedes enrolment in the CAF and ensures that the long-term effects of military service beyond the end of career are not discredited or devolved solely to the civilian sector. More information on this model is available elsewhere [2].

The previous health surveillance portfolio included the development of indicators to be used in conjunction with data from electronic health records, on-deployment surveillance systems, mortality surveillance capacity and cluster analyses, to name a few approaches and which are described in more detail elsewhere [2]. In response to the paradigm shift in the focus of health surveillance with the CAF, surveillance was broadened to include a record linkage study that looks specifically at all-cause mortality (ACM) and cancer morbidity outcomes in those who are still serving, as well as those who have already released. This is an approach that has been used by other militaries to look at specific deployments (e.g. Korea [3], Vietnam [4], Falklands [5], Gulf War [6–12]), or specific military action (e.g. peacekeeping [13–15]). However, to the best of our knowledge, it is the first time that someone has studied a full military cohort (a census, of sorts) over a long period of time, and across multiple military involvements.

The aim of this study was to describe the ACM of both still serving and released Regular Force (Reg F) and Reserve Force class C (Res C) personnel, stratified by sex, and by International Classification of Disease (ICD) chapter.

Methods

The data described here are part of the Canadian Forces Cancer and Mortality Study II (CF CAMS II), which include cancer morbidity and ACM data. The CF CAMS II is a collaborative study between the Department of National Defence (DND), VAC and Statistics Canada (STC). The study cohort includes all men and women who first enrolled in the CAF as Reg F or Res C personnel between 1976 and 2012, inclusive. Individuals with enrolments prior to this period were excluded. These individuals were identified using the CAF pay system (Central Computerized Pay System [CCPS]), and the records were probabilistically linked by STC to the Canadian Vital Statistics Database (CVSD). The CVSD includes cause of death (COD) information for all Canadian provinces and territories. More information about the CVSD can be found elsewhere [16].

The anonymized linked cohort data (CF CAMS II) includes dates, causes and location of death for all still serving and released CAF personnel who died in Canada until between 1976 and 2012, inclusive. In addition, DND provided STC with additional mortality records for CAF personnel who died out-of-country, including on foreign deployment, for the years 2004 to 2012. For both data sources, each death record includes the underlying COD, as determined by a physician or coroner. All linked data were held in a secure area within STC, and only personnel who were submitted by DND and subsequently vetted by STC could access the data.

Whenever possible, the aggregated COD data were analysed by serving status (still serving versus released) as well as by sex (male versus female). Results were also reported for the full cohort ('total'). Both ACM and chapter-level mortality (CLM) were investigated. Given the long study follow-up period, the CODs were coded in one of three ICD versions, depending on the year of death. As a result, all ICD-8 and ICD-9 codes were mapped to their ICD-10 chapter equivalent, for the purpose of the chapter-level analyses. More details on the study methods are provided elsewhere [17].

To quantify the ACM and CLM burdens, standardized mortality ratios (SMRs) were calculated, using the Canadian general population (CGP) as the reference population. SMRs are a ratio of the observed number of deaths within the cohort, compared with the expected number of deaths given the age and sex distributions of the CGP [18]. SMRs were generated for the full study period (1976–2012), using the equivalent causes of death in the CGP comparator. For example, to generate the SMR for Chapter I (Certain infections and parasitic diseases), the equivalent CGP data (counts of Canadian cases of equivalent ICD codes, for the same time period) were secured. Sex-specific CGP data were secured to conduct the male and female SMR calculations; the total SMRs were an aggregation of both male and female data for both the CAF and the CGP. The CAF denominator for each of these analyses was the total person-year time contributed by the overall cohort. The 95% CIs were calculated using a Poisson distribution when the total number of events was below 100; for 100 or more events, a normal distribution was applied [19]. *P*-values were calculated using chi-squares.

All reported values were rounded to the nearest five observations, in accordance with STC's confidentiality vetting rules on disclosure.

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This research project was submitted for external Institutional Review Board (IRB) approval (QUORUM Review IRB), which it received in April 2016. A consent waiver was requested and approved by the external IRB, allowing the study to be conducted without the individual consent of all participants. This is in accordance with Article 3.7 of the second edition of the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans [20].

Results

During the 37-year follow-up period between 1976 and 2012, ~228 685 males and females joined the CAF for the first time as a Reg F or Res C member (Table 1). During this time period, females represented ~14% of the cohort, but accounted for <8% of all the deaths. In general, deaths of females occurred significantly later than deaths of males ($P < 0.001$).

In total, 6870 deaths occurred (rounded to the nearest five observations) during over 5 million person-years of observations. The observed number of deaths was 540 (SMR: 0.76 [95% CI 0.69–0.82]) for females and 6330 (SMR: 0.79 [95% CI 0.77–0.81]) for males (Table 2). For both sexes, the number of deaths was significantly lower than expected, compared to the CGP.

Table 1. Demographics of still serving and released CAF Regular and Reserve C Force personnel, by sex, 1976–2012

	Male, *n* (%)	Female, *n* (%)	*P*-value
Age at 31 December 2012 (still alive)			
<25 years	14 050 (7)	1715 (5)	<0.001
25–39	52 595 (28)	8745 (28)	
40–59	121 190 (64)	20 450 (65)	
60+	2405 (1)	665 (2)	
Age at death			
<25 years	850 (13)	40 (8)	<0.001
25–39	2185 (35)	160 (30)	
40–59	2825 (45)	320 (59)	
60+	470 (7)	20 (4)	
Last documented rank			
Junior NCM	132 720 (68)	20 750 (65)	<0.001
Senior NCM	26 255 (14)	3750 (12)	
Officer	36 035 (19)	7345 (23)	
Component			
Reg Force only	147 795 (75)	22 755 (71)	<0.001
Res C Force only	15 740 (8)	3030 (9)	
Both Reg and Res C Force	33 040 (17)	6330 (20)	
Military status			
Still serving	69 890 (36)	11 675 (36)	<0.01
Released	126 685 (64)	20 440 (63)	
Era of first enrolment			
1976–87	98 295 (50)	14 815 (46)	<0.001
1988–99	44 845 (23)	8255 (26)	
2000–12	53 435 (27)	9040 (28)	

All numbers are rounded to the nearest five observations; totals may not equal 100% due to rounding.

NCM, non-commissioned member.

A number of ICD chapters had fewer than five reported deaths, resulting in the SMRs for these chapters being censored. These are noted in Table 2 with an 'X'. In addition, a number of chapters had no reported deaths, including diseases of the blood (Chapter III) and diseases of the skin and subcutaneous tissue (Chapter XII) among women, as well as diseases of the eye and adnexa (Chapter VII) and diseases of the ear and mastoid process (Chapter VIII) among both men and women.

With the exception of diseases of the musculoskeletal system and connective tissue (Chapter XIII) and diseases of the genitourinary system (Chapter XIV), the incidence of mortality for males was significantly lower than in the CGP for all remaining ICD chapters for which an SMR was reported. For females, the only chapter with an SMR that was higher than in the CGP was the chapter on external causes of morbidity and mortality (Chapter XX), which includes deaths due to both accidental and intentional injuries; however, this value was non-significant.

In males, the lowest SMRs were reported for deaths related to a congenital malformation, deformation or chromosomal abnormality (Chapter XVII) (SMR: 0.22 [95% CI 0.12–0.39]) and deaths due to diseases of the respiratory system (Chapter X) (SMR: 0.51 [95% CI 0.41–0.60]). In women, deaths resulting from symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (Chapter XVIII) (SMR: 0.30 [95% CI 0.10–0.70]) and deaths due to diseases of the nervous system (Chapter VI) (SMR: 0.32 [95% CI 0.13–0.66]) had the lowest significant SMRs. The SMRs for neoplasms (Chapter II) for both sexes were also significantly below 1.0, as well as being close to the ACM rates for the respective sexes. None of the cause-specific SMRs were significantly above 1.0.

Discussion

This study found that ACM in still serving and released CAF personnel was significantly lower compared with the CGP which is consistent with findings reported as part of CF CAMS I [21]. The CF CAMS I SMRs were lower for both sexes than those reported here, but both sets of SMRs suggested that military service may be protective. The differences between the two studies may be attributable to different time frames, subpopulations and more complete data in this cohort.

The use of CAF pay records to build this cohort contributed greatly to its completeness and accuracy, and to our ability to draw conclusions about CAF's mortality burden. The long follow-up study period was also very important, as it allowed for sufficient lead up time, especially for CODs with long lag times.

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Table 2. SMRs comparing ICD CLM rates in still serving and released CAF Regular and Reserve C Force personnel to equivalent rates in the CGP, by sex, 1976–2012

ICD-10 equivalent chapter	SMR (95% CI)		
	Males	Females	Combined male and female (total)
ACM	0.79 (0.77–0.81)*	0.76 (0.69–0.82)*	0.79 (0.77–0.81)*
I—Certain infections and parasitic diseases	0.68 (0.58–0.77)*	0.40 (0.13–0.93)*	0.67 (0.58–0.76)*
II—Neoplasms	0.77 (0.73–0.82)*	0.78 (0.68–0.88)*	0.77 (0.73–0.81)*
III—Diseases of blood	0.75 (0.42–1.23)	0 (0.0)	N/A
IV—Endocrine, nutritional and metabolic diseases	0.58 (0.47–0.68)*	0.53 (0.26–0.98)*	0.57 (0.47–0.68)*
V—Mental and behavioural disorders	0.53 (0.40–0.68)*	X	0.52 (0.40–0.67)*
VI—Diseases of the nervous system	0.62 (0.51–0.74)*	0.32 (0.13–0.66)*	0.59 (0.48–0.70)*
VII—Diseases of the eye and adnexa	0 (0.0)	0 (0.0)	0 (0.0)
VIII—Diseases of the ear and mastoid process	0 (0.0)	0 (0.0)	0 (0.0)
IX—Diseases of the circulatory system	0.61 (0.57–0.64)*	0.60 (0.46–0.77)*	0.61 (0.57–0.64)*
X—Diseases of the respiratory system	0.51 (0.41–0.60)*	0.55 (0.29–0.94)*	0.51 (0.42–0.60)*
XI—Diseases of the digestive system	0.53 (0.45–0.60)*	0.57 (0.33–0.92)*	0.53 (0.45–0.61)*
XII—Diseases of the skin and subcutaneous tissue	X	0 (0.0)	N/A
XIII—Diseases of the musculoskeletal system and connective tissue	0.61 (0.29–1.11)	X	0.50 (0.25–0.89)*
XIV—Diseases of the genitourinary system	0.24 (0.11–0.44)	X	0.25 (0.13–0.44)*
XV—Pregnancy, childbirth and the puerperium	Females only	X	N/A
XVII—Congenital malformations, deformations and chromosomal abnormalities	0.22 (0.12–0.39)*	X	0.23 (0.13–0.39)*
XVIII—Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	0.86 (0.74–0.98)*	0.30 (0.10–0.70)*	1.05 (0.91–1.20)
XX—External causes of morbidity and mortality	0.98 (0.95–1.02)	1.14 (0.98–1.32)	0.99 (0.96–1.02)

X, SMR suppressed as based on $n < 5$.

*$P < 0.05$.

Ideally, the cohort would have also included those with Reserve Force Class A and/or B (Res A/B) service only, so as to more optimally quantify total service time. We were unable to do so due to severe data quality issues with Res A/B data, resulting in a small underestimation of cumulative service time for the cohort, particularly for those already in the cohort but with unaccounted Res A/B service time. Foreign deaths were also not systematically captured by STC/DND. As a consequence of these two limitations, both person-time and mortality counts may have been underestimated. It is unlikely that the inclusion of these missing data would have appreciably changed our results, as Reg/Res C members are the only full-time members of the CAF (and therefore contribute the largest proportion of person-time), and the findings described here were fairly consistent with findings reported elsewhere [21].

Generally, the finding that military service may be a protective factor for premature mortality is in keeping with the limited existing body of evidence. Specific to peacekeeping, Laukkala *et al.* [13] found that a history of peacekeeping service resulted in low general mortality. Strand *et al.* [15] also found that peacekeeping service conferred a protective effect; however, an exception was made for neoplasms, whereby the protective effect dissipated within 5 years. In this cohort, a direct relationship was also noted between combat exposure and increased mortality from all external sources, motor vehicle accidents and suicides within 5 years of release from the military [15].

When looking at deployment-specific results, different patterns to those we identified may emerge. For example, a 13-year follow-up of US Gulf War veterans (GWV) found that male GWV had a significantly lower mortality rate relative to non-GWV, but that the inverse was true in females [22]. When looking specifically at suicide, GWV females had a 60% higher risk compared to the US general population, while this relative risk was significantly lower for GWV males. This was a change from prior data that showed no statistically significant difference in cause-specific mortality among GWV [7]. These findings suggest that the chapter-level trends described here may be more complex once multivariate analyses are conducted.

In this cohort, the ACM SMRs appreciably below 1.0 may partially be attributable to the 'healthy soldier' effect (HSE). A systematic literature review estimated the HSE between 10 to 25%, but that this estimate may not be applicable to all deployment health studies [23]. Military service as a protective mechanism

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should therefore not be discounted outright, but should be evaluated with the understanding that leaving service may erode the HSE [24] and that its influence varies markedly by COD [23,25]. With these caveats in mind, it is expected that the HSE contributed somewhat to the protective SMRs related here, but we were unable to quantify its importance. It is probable that stringent recruitment criteria also contributed to these SMRs being below 1.0 [24].

Related to the concept of the HSE is the more general notion that gainful employment (of any type) translates into income which, in turn, means better health outcomes [26]. In our cohort, the relationship between income and health was likely confounded by military service itself, and by the fact that Canada provides socialized healthcare to all civilian citizens. Also, generalizations about income and health status can be difficult to make on a heterogeneous cohort like this one. For example, in those who were released, VAC research found that post-release income dropped and took 8 years to reach pre-release levels. These income declines were most acute in those who were medically released [27].

Within this cohort, a better explanation than income may be social capital (volunteering, trusting others) [28]. The military is a 'critical social institution that can reshape educational, occupational, income, marital/family, health, and other life course trajectories and outcomes' [29]. It is possible that those who have served may benefit from more social capital than those who have not, although its effect may be differential across cohort subgroups.

Despite similar ACM SMRs for both sexes, the SMRs with the lowest values were different. This may have been partially due to the smaller female cohort (i.e. more variability). It is also possible that underlying military career motivations were different between sexes and that this was somehow related to mortality; or that differences (particularly historical) in male and female military professions, exposures and deployments [6] may have resulted in different mortality profiles.

Our findings were a first attempt at describing mortality in the CAF. Over the tenure of this cohort, changes in military activity type [29]; geographic locations; and recruitment, retention and release policies were common. The possible effect of these factors was not explored in this paper, but future research will include multivariate analyses to evaluate predictors for a number of specific CODs (including suicide) and to identify possible at-risk subgroups.

Despite the public perception that military service is a cause of premature death, the findings here suggest that military service may have a protective effective that may be, at least in part, explained by the HSE. These, and future findings, will be used to ensure that care and supportive policies within by DND/CAF and VAC are based on relevant evidence generated by this study.

Key points

- Previous research has shown that military personnel tend to be at lower risk of mortality than their civilian counterparts, partly because military personnel are relatively healthy as a result of full employment (healthy soldier effect), but also because of the stringent selection process at enrolment.
- This study found that, based on nearly 40 years of cohort data, Canadian military personnel were at lower risk for all-cause mortality, as well as mortality for most reported International Classification of Disease chapters, when compared to the Canadian general population.
- This study represents a first step in examining the risk of mortality in the Canadian Armed Forces; follow-up research based on these findings will endeavour to identify Canadian Armed Forces subgroups at increased risk of mortality so that any related occupational risks can be identified, resulting in the prevention of further/future exposure and the provision of treatment and/or support to groups who may have already been exposed.

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Conflicts of interest

None declared.

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