Time-varying associations of suicide with deployments, mental health conditions, and stressful life events among current and former US military personnel: a retrospective multivariate analysis

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Summary

Background US military suicides have increased substantially over the past decade and currently account for almost 20% of all military deaths. We investigated the associations of a comprehensive set of time-varying risk factors with suicides among current and former military service members.

Methods We did a retrospective multivariate analysis of all US military personnel between 2001 and 2011 (n=110 035 573 person-quarter-years, representing 3 795 823 service members). Outcome was death by suicide, either during service or post-separation. We used Cox proportional hazard models at the person-quarter level to examine associations of deployment, mental disorders, history of unlawful activity, stressful life events, and other demographic and service factors with death by suicide.

Findings The strongest predictors of death by suicide were current and past diagnoses of self-inflicted injuries, major depression, bipolar disorder, substance use disorder, and other mental health conditions (compared with service members with no history of diagnoses, the hazard ratio [HR] ranged from 1·4 [95% CI 1·14–1·72] to 8·34 [6·71–10·37]). Compared with service members who were never deployed, hazard rates of suicide (which represent the probability of death by suicide in a specific quarter given that the individual was alive in the previous quarter) were lower among the currently deployed (HR 0·50, 95% CI 0·40–0·61) but significantly higher in the quarters following first deployment (HR 1·51 [1·17–1·96] if deployed in the previous three quarters; 1·14 [1·06–1·23] if deployed four or more quarters ago). The hazard rate of suicide increased within the first year of separation from the military (HR 2·49, 95% CI 2·12–2·91), and remained high for those who had separated from the military 6 or more years ago (HR 1·63, 1·45–1·82).

Interpretation The increased hazard rate of death by suicide for military personnel varies by time since exposure to deployment, mental health diagnoses, and other stressful life events. Continued monitoring is especially needed for these high-risk individuals. Additional information should be gathered to address the persistently raised risk of suicide among service members after separation.

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Introduction

Suicide rates among US military personnel have increased substantially since the start of the recent wars in Iraq and Afghanistan in 2001.[1,2] In 2010, suicide became the second highest cause of death after death by combat[3] and the military suicide rate exceeded the rate in the demographically similar civilian population.[4–6]

Although substantial research has been done on the demographic and service profiles of military suicide decedents, most of these studies did not make the comparisons with non-decedents that are necessary for individual-level risk projections;[3,7–9] and many of the studies that made such comparisons focused only on a subset of service members,[4,6,10] or used a non-representative sample of service members.[1,11] Research that has examined risk factors for all military suicides is rare,[2] and so far studies have not examined the role of previous diagnosed mental health disorders in predicting subsequent death by suicide, despite the fact that strong associations of these predictors with death by suicide have been shown in other populations.[6–8,10,12–16] A history of unlawful activity has also been shown to be associated with increased suicide risk in other populations.[17,18] Furthermore, although some previous military studies have implicitly assumed that the association of combat deployment with suicide is the same during and after deployment, other research suggests that this assumption might be inaccurate.[6,12] Finally, many previous research studies in military samples did not consider the possibility that other stressful life events (eg, demotions or divorce) might predict suicides, even though such associations have been shown in previous civilian research.[5,6,12,19]

We addressed the above limitations by undertaking an epidemiological analysis of the associations of a more comprehensive set of potential predictors of death by suicide among current and former service members than previous studies, using quarterly data for all uniformed US

Research in context

Evidence before this study

We did three sets of searches to identify all relevant articles. First, we searched PubMED from Jan 1, 1990, to April 1, 2016, using the keywords "suicide" "risk factors" "military", and "deployment." We also searched EconLit for the same time period using the keywords "deployment" and "suicide or mental". The search yielded 44 articles from PubMED and 2 articles from EconLit. Second, we did an independent search in the Defense Technical Information Center (DTIC) to identify DoD sponsored reports that might not appear in peer-reviewed journal articles (such as reports by Mental Health Advisory Team [MHAT] or the Rand Corporation) using the keywords "military", "suicide", and "MHAT"; this search returned 140 briefs and reports. Last, we searched reports produced by the Department of Defense Suicide Event Report on the their website (http://t2health.dcoe.mil/programs/dodser) which yielded an additional 12 reports.

Most of the previously published reports on this topic did not compare people who died by suicide with people who died from other causes, a comparison that is necessary to make individual-level risk projections; additionally, many of the studies that made such comparisons focused only on a subset of service members or used a non-representative sample of service members. Research that examines risk factors for all military suicides is rare, and so far, no studies had examined the role of previous diagnosed mental disorders in predicting subsequent death by suicide, despite the fact that strong associations of these predictors with suicides have been noted in other populations. Furthermore, although some previous military studies have implicitly assumed that the association of combat deployment with death by suicide is the same during and after deployment, other research suggests that this assumption might be inaccurate.

Added value of this study

We addressed the above limitations by using a more comprehensive set of potential predictors of death by suicide among service members than did previous studies. We showed that wide ranges of mental health diagnoses, whether currently diagnosed or diagnosed in the past, are strong predictors of death by suicide. Findings from our study also showed that the risk of death by suicide remained raised long after the occurrence of stressful events, such as after returning from combat deployment, divorce, demotion, and separation from the military.

Implications of all the available evidence

Our findings have two main implications for public health efforts to reduce the incidence of death by suicide. First, clinicians should be aware that deployments might increase the risk of death by suicide independently of underlying mental disorders, and therefore asking patients about deployment history is advisable. Second, our results highlight the importance of using comprehensive data in the development of prediction models that can target the most at-risk service members and veterans for the implementation of preventive interventions. The clinical community is a key component for increased coordination between the DoD and the US Veterans Affairs Administration (VA) to develop exhaustive, integrated data-sharing efforts. Partnerships between DoD, VA, and clinicians can provide effective targeting of high-risk individuals, while coupling with efforts to expand and optimise preventive and clinical interventions based on knowledge of these high-risk targets.

military personnel who were on active duty between 2001 and 2011. We recorded deaths by suicide that occurred either during active duty, while in the reserves, or after separation from service; and we captured all mental health diagnoses from service members' medical records while they were on active duty. We also assessed the joint predictive effects of all variables in our model by calculating the concentration of suicide risk.[20] To our knowledge, this is the most comprehensive study of risk factors for suicide in the US service member population up to now.

Methods

Sample population

Our population was all uniformed service members in the US Army, Navy, Air Force, and Marine Corps between 2001 and 2011 who either served on active duty or were in the reserve component and were activated for 30 or more consecutive days. This population was followed through to the time of their death or Dec 31, 2011, irrespective of whether the individual separated from the military. The population included 3 795 823 unique service members with complete information who were followed up during 110 035 573 person-quarter-years.

Data sources

We obtained quarterly personnel data during years of service from several administrative databases maintained by the US military. The first, the Defense Enrolment Eligibility Reporting System contained data for demographic characteristics (sex, race or ethnic origin, age, marital status, and dependents) and service characteristics (eg, rank, branch, and reserve or active duty status), and data from the second, the Defense Manpower Data Center, contained other service characteristics (occupation, separation date, and for the enlisted population, the Armed Forces Qualification Test [AFQT] score and enlistment waiver status). A third database, the Contingency Tracking System, identified dates and locations deployments under Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Another, TRICARE—the DoD health care system in which all service members are automatically enrolled—provided

clinical diagnoses of mental health conditions from all medical visits during years of service. We obtained data for deaths occurring between 2001 and 2011 from the National Death Index for deaths within the USA and from the Defense Casualty Analysis System for deaths overseas.

Outcome

Our outcome was an indicator of whether an individual died by suicide anytime between 2001 and 2011, as identified by ICD-10 codes.

Potential predictors

Predictors with potentially time-varying effects were grouped as follows: OEF or OIF deployment history; history of mental health diagnosis, which was recorded as ICD-9 codes on medical records (diagnosis of self-inflicted injuries [ICD-9 codes E950-E958], post-traumatic stress disorder [PTSD; ICD-9 code 309.81], major depression [ICD-9 296.2–296.3], substance use disorder [ICD-9 291–292 and 303–305], bipolar [ICD-9 296, except for 296.2–296.3 and 296.9], other psychotic diagnoses [290 293 294, and 296.9–299], anxiety [ICD-9 300], and all other mental health diagnoses [ICD-9 codes 310–319 not covered in previous categories]); other potentially stressful events (demotion and divorce); and military career status (on active duty, in the reserves, separated from service). We explicitly modelled time since exposure with indicators for exposure in either in the current quarter-year or in

	Person-quarter-years	Deaths by suicide	Rate of deaths by suicide per 100 000 person-quarter years*	Fully regression-adjusted hazard ratio (95% CI) of deaths by suicide†	p value
All personnel (n=3 795 823)	110 035 573	4492	4·08	..	..
OEF or OIF deployment status					
Not deployed	69 590 523	2760	3·97	1·00	
Deployed during the current quarter	8 970 422	110	1·23	0·50 (0·41–0·61)‡	<0·0001
Deployed in the previous three quarters	1 781 499	62	3·48	1·51 (1·17–1·96)‡	0·002
Deployed four or more quarters ago	29 693 129	1560	5·25	1·14 (1·06–1·23)‡	0·001
Self-inflicted injuries					
Never diagnosed	109 718 289	4275	3·90	1·00	
Diagnosed during the current quarter	81 014	104	128·37	8·34 (6·71–10·37)	<0·0001
Diagnosed in the previous three quarters	130 066	70	53·82	2·77 (2·15–3·57)	<0·0001
Diagnosed four or more quarters ago	106 204	43	40·49	3·12 (2·28–4·28)	<0·0001
Post-traumatic stress disorder					
Never diagnosed	108 126 634	4258	3·94	1·00	
Diagnosed during the current quarter	204 686	21	10·26	0·82 (0·53–1·28)	0·385
Diagnosed in the previous three quarters	660 480	105	15·90	0·81 (0·65–1·00)	0·045
Diagnosed four or more quarters ago	1 043 773	108	10·35	0·63 (0·51–0·78)	<0·0001
Major depression					
Never diagnosed	107 978 303	4139	3·83	1·00	
Diagnosed during the current quarter	253 485	67	26·43	2·10 (1·61–2·73)	<0·0001
Diagnosed in the previous three quarters	730 041	151	20·68	1·76 (1·46–2·11)	<0·0001
Diagnosed four or more quarters ago	1 073 744	135	12·57	1·65 (1·36–2·00)	<0·0001
Substance use disorder					
Never diagnosed	109 063 734	4236	3·88	1·00	
Diagnosed during the current quarter	152 727	36	23·57	1·27 (0·90–1·80)	0·169
Diagnosed in the previous three quarters	391 620	119	30·39	1·74 (1·42–2·13)	<0·0001
Diagnosed four or more quarters ago	427 492	101	23·63	2·19 (1·77–2·71)	<0·0001
Bipolar disorder					
Never diagnosed	109 336 460	4328	3·96	1·00	
Diagnosed during the current quarter	34 067	15	44·03	2·44 (1·42–4·20)	0·001
Diagnosed in the previous three quarters	99 366	39	39·25	2·08 (1·47–2·94)	<0·0001
Diagnosed four or more quarters ago	565 680	110	19·45	1·40 (1·14–1·72)	0·002
Other psychotic disorders					
Never diagnosed	108 680 682	4219	3·88	1·00	
Diagnosed during the current quarter	77 796	19	24·42	1·68 (1·03–2·73)	0·038
Diagnosed in the previous three quarters	218 423	66	30·22	1·94 (1·47–2·56)	<0·0001
Diagnosed four or more quarters ago	1 058 672	188	17·76	1·51 (1·28–1·78)	<0·0001

(Table 1 continues on next page)

	Person-quarter-years	Deaths by suicide	Rate of deaths by suicide per 100 000 person-quarter years*	Fully regression-adjusted hazard ratio (95% CI) of deaths by suicide†	p value
(Continued from previous page)					
Anxiety disorder					
Never diagnosed	108 581 727	4211	3·88	1·00	
Diagnosed during the current quarter	83 633	23	27·50	1·46 (0·93–2·29)	0·103
Diagnosed in the previous three quarters	233 685	66	28·24	1·34 (1·01–1·77)	0·043
Diagnosed four or more quarters ago	1 136 528	192	16·89	1·01 (0·85–1·19)	0·932
Other mental health diagnoses					
Never diagnosed	98 855 501	3192	3·23	1·00	
Diagnosed during the current quarter	560 032	72	12·86	2·34 (1·81–3·04)	<0·0001
Diagnosed in the previous three quarters	1 607 874	240	14·93	3·43 (2·94–4·01)	<0·0001
Diagnosed four or more quarters ago	9 012 166	988	10·96	2·10 (1·92–2·30)	<0·0001
Enlistment waivers					
No waiver	98 225 938	3781	3·85	1·00	
Minor non-drug-related offence	570 906	42	7·36	1·46 (1·07–1·98)	0·016
Major non-drug-related offence	3 412 507	279	8·18	1·53 (1·35–1·73)	<0·0001
Drug-related waiver	955 266	86	9·00	1·28 (1·03–1·59)	0·026
Other type of waiver	6 870 956	304	4·42	0·98 (0·87–1·11)	0·771
Divorce status					
Not divorced	101 777 439	4132	4·06	1·00	
Divorced during the current quarter	727 729	32	4·40	1·27 (0·90–1·81)	0·173
Divorced in the previous three quarters	1 794 328	82	4·57	1·48 (1·18–1·86)	0·001
Divorced four or more quarters ago	5 736 077	246	4·29	1·33 (1·14–1·55)	<0·0001
Demotion status					
Not demoted	104 331 475	4006	3·84	1·00	
Demoted during the current quarter	1 673 687	173	10·34	1·49 (1·27–1·76)	<0·0001
Demoted in the previous three quarters	1 315 952	116	8·81	1·35 (1·12–1·63)	0·002
Demoted four or more quarters ago	2 714 459	197	7·26	1·13 (0·97–1·31)	0·112
Career status					
On active duty	59 141 217	1771	2·99	1·00	
In the reserve component	4 498 195	109	2·42	0·60 (0·50–0·74)	<0·0001
Left service (time since separation)					
During the current quarter	2 200 215	176	8·00	2·49 (2·12–2·91)	<0·0001
In the previous three quarters	6 281 817	424	6·75	2·64 (2·37–2·95)	<0·0001
Between 1 and 3 years ago	14 473 331	923	6·38	2·48 (2·27–2·71)	<0·0001
Between 4 and 5 years ago	11 156 160	572	5·13	1·88 (1·70–2·09)	<0·0001
6 or more years ago	12 284 638	517	4·21	1·63 (1·45–1·82)	<0·0001
Time in service at the time of separation					
More than two quarters of service	109 830 396	4375	3·98	1·00	
One or two quarters of service	205 177	117	57·02	1·70 (1·39–2·08)	<0·0001
Enlisted	94 457 652	4233	4·48	1·00	
Officer	15 577 921	259	1·66	0·82 (0·63–1·07)	0·143
Military branch					
Army	46 383 748	2087	4·50	1·00	
Marine Corps	16 678 619	841	5·04	1·03 (0·94–1·12)	0·543
Navy	21 807 297	747	3·43	0·58 (0·53–0·64)	<0·0001
Air Force	25 165 909	817	3·25	0·94 (0·86–1·02)	0·146

Data are overall and divided by select categories. OEF=Operation Enduring Freedom. OIF=Operation Iraqi Freedom. ··=not applicable. *Crude suicide rate per 100 000 person-quarter years was calculated as the number of suicide deaths per quarter divided by the total person-quarter years × 100 000. †The regression adjustment was done via a Cox proportional hazard model which included all variables presented in this table and the following additional variables: sex, race, age, marital status, dependent quantity, rank, Armed Forces Qualifying Test percentile, and military occupational specialty. Summary statistics of these additional variables and the complete survival analysis results are in the appendix.

Table 1: **Suicide counts, rates, and regression-adjusted hazard ratios among military personnel**

	Whole sample	Army	Marines	Navy	Air Force
Number of person-quarter years	110 035 573	46 383 748	16 678 619	21 807 297	25 165 909
Number of service members	3 795 823	1 648 313	605 211	739 647	802 716
Deaths by suicide categorised by OEF or OIF deployment status					
Not deployed	1·00	1·00	1·00	1·00	1·00
Deployed during the current quarter	0·51 (0·41–0·62); p<0·0001	0·40 (0·30–0·53); p<0·0001	0·36 (0·21–0·64); p<0·0001	1·35 (0·86–2·11); p=0·187	0·50 (0·30–0·82); p=0·006
Deployed in the previous three quarters	1·54 (1·19–2·00); p=0·001	1·68 (1·05–2·70); p=0·030	1·62 (0·87–3·00); p=0·127	0·98 (0·52–1·86); p=0·960	2·19 (1·42–3·40); p<0·0001
Deployed in the previous four to seven quarters	1·44 (1·26–1·65); p<0·0001	1·56 (1·30–1·87); p<0·0001	1·36 (0·98–1·88); p=0·062	1·11 (0·73–1·70); p=0·626	1·10 (0·76–1·59); p=0·603
Deployed in the previous eight to 11 quarters	1·18 (1·03–1·36); p=0·021	1·14 (0·93–1·40); p=0·206	1·12 (0·81–1·57); p=0·486	1·24 (0·85–1·79); p=0·261	0·94 (0·65–1·38); p=0·767
Deployed in the previous 12 to 15 quarters	1·20 (1·05–1·38); p=0·009	1·04 (0·85–1·28); p=0·686	1·29 (0·95–1·76); p=0·108	1·46 (1·05–2·02); p=0·025	1·02 (0·70–1·47); p=0·928
Deployed in the previous 16 or more quarters	1·03 (0·93–1·12); p=0·596	0·89 (0·78–1·03); p=0·128	1·03 (0·82–1·29); p=0·804	1·14 (0·93–1·39); p=0·203	0·99 (0·80–1·23); p=0·946

Data for deaths by suicide are hazard ratios (95% CIs) overall and divided by service branch. OEF=Operation Enduring Freedom. OIF=Operation Iraqi Freedom. The rest of the model specifications are identical to those reported in table 1.

Table 2: **Association of past deployments with death by suicide**

various groups of quarter-years in the past (eg, the previous three quarters, or four or more quarters ago).

Other predictors were grouped into the following categories: type of waiver required for enlistment upon failure to meet a given recruitment standard[21] (waiver for drug use, minor non-drug related offence, major non-drug-related offence, or for failure to meet physical standards [eg, being above the maximum age, being overweight, or having physical ailments]); demographic characteristics (age, sex, race or ethnic origin, marital status, and number of dependents); and service variables (branch, rank, AFQT score, and five broad categories of occupations: combat arms, combat service, service support, medical, or aviation). We created five categories of AFQT scores by percentile (0–30, 31–49, 50–64, 65–92, and 93–100), and one category for the 18% of enlisted individuals with a missing AFQT score. Finally, we included an indicator for personnel who had separated from the military within 6 months of joining, a population known to have high risk of suicide.[2,22]

Statistical analysis

Following the published literature,[1,2] we estimated the hazard rate of suicide (which represents the probability of death by suicide in a specific quarter given that the individual was alive in the previous quarter) using the Cox proportional hazard model. We used the person-quarter-year as the unit of analysis and included all risk factors described earlier.[23] Individuals entered the risk window in either the first quarter of 2001 or the quarter they joined the military. Individuals left the risk window when they died (up to Dec 31, 2011). Individuals were censored either at the end of 2011 or at the quarter that they died in by means other than suicide.

All time-invariant exposure variables (sex, race, waiver status, and AFQT score) did not fail tests of the proportional hazard assumption[24] except for AFQT. Our results are robust to either allowing the association between AFQT and death by suicide to vary over time or excluding AFQT from the model; results are also robust to using multiple imputation[25] for the 18% of the enlisted population with missing AFQT scores. We did all analyses using STATA version 14.

Role of the funding source

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Between 2001 and 2011, we noted 4492 suicides occurred in our analysis population, a crude suicide rate of 16·33 per 100 000 person-years (table 1, appendix). The overall crude suicide rate in the adult US population (aged 18 years and older, including military) was 14·71 per 100 000 person-years.[26]

See Online for appendix

Conditional on other risk factors, deployments in support of OEF or OIF were associated with a reduced

	Never deployed	Ever deployed
Number of person-quarter years	55 568 783	54 466 790
Number of service members	2 053 250	1 742 465
OEF or OIF deployment status		
Deployed during the current quarter	..	1·00
Deployed in the previous three quarters	..	8·25 (5·96–11·42); p<0·0001
Deployed four or more quarters ago	..	8·39 (6·65–10·58); p<0·0001
Self-inflicted injuries		
Diagnosed during the current quarter	4·69 (3·49–6·30); p<0·0001	26·25 (18·83–36·61); p<0·0001
Diagnosed in the previous three quarters	2·31 (1·68–3·17); p<0·0001	3·78 (2·48–5·76); p<0·0001
Diagnosed four or more quarters ago	2·86 (1·81–4·53); p<0·0001	3·65 (2·36–5·63); p<0·0001
Post-traumatic stress disorder		
Diagnosed during the current quarter	0·77 (0·36–1·63); p=0·487	0·66 (0·37–1·18); p=0·162
Diagnosed in the previous three quarters	0·76 (0·51–1·12); p=0·165	0·91 (0·69–1·19); p=0·481
Diagnosed four or more quarters ago	0·67 (0·45–0·99); p=0·047	0·68 (0·52–0·88); p=0·004
Major depression		
Diagnosed during the current quarter	2·23 (1·62–3·06); p<0·0001	1·65 (1·02–2·65); p=0·041
Diagnosed in the previous three quarters	1·89 (1·52–2·36); p<0·0001	1·38 (1·00–1·90); p=0·047
Diagnosed four or more quarters ago	1·69 (1·31–2·18); p<0·0001	1·56 (1·17–2·08); p=0·002
Substance use disorder		
Diagnosed during the current quarter	1·42 (0·93–2·16); p=0·101	0·83 (0·46–1·53); p=0·557
Diagnosed in the previous three quarters	1·69 (1·30–2·20); p<0·0001	1·66 (1·21–2·27); p=0·002
Diagnosed four or more quarters ago	2·09 (1·53–2·85); p<0·0001	2·20 (1·64–2·97); p<0·0001

(Table 3 continues in next column)

(Continued from previous column)

	Never deployed	Ever deployed
Bipolar disorder		
Diagnosed during the current quarter	2·29 (1·09–4·81); p=0·029	2·44 (1·10–5·41); p=0·028
Diagnosed in the previous three quarters	1·54 (0·95–2·52); p=0·08	2·79 (1·70–4·57); p<0·0001
Diagnosed four or more quarters ago	1·36 (1·06–1·74); p=0·017	1·39 (0·96–2·01); p=0·084
Other psychotic disorders		
Diagnosed during the current quarter	1·19 (0·54–2·62); p=0·660	1·74 (0·93–3·26); p=0·081
Diagnosed in the previous three quarters	1·99 (1·36–2·91); p<0·0001	1·66 (1·10–2·49); p=0·016
Diagnosed four or more quarters ago	1·64 (1·34–2·02); p<0·0001	1·28 (0·97–1·68); p=0·080
Anxiety disorder		
Diagnosed during the current quarter	1·50 (0·78–2·86); p=0·221	1·19 (0·64–2·24); p=0·581
Diagnosed in the previous three quarters	1·12 (0·75–1·67); p=0·574	1·46 (0·99–2·17); p=0·058
Diagnosed four or more quarters ago	1·17 (0·95–1·43); p=0·147	0·79 (0·59–1·06); p=0·113
Other mental health diagnoses		
Diagnosed during the current quarter	1·59 (1·11–2·27); p=0·011	3·55 (2·42–5·20); p<0·0001
Diagnosed in the previous three quarters	3·84 (3·16–4·65); p<0·0001	2·41 (1·87–3·11); p<0·0001
Diagnosed four or more quarters ago	1·99 (1·77–2·22); p<0·0001	2·05 (1·78–2·37); p<0·0001
Enlistment waivers		
Minor non-drug-related offence waiver	1·38 (0·92–2·06); p=0·122	1·57 (0·99–2·51); p=0·057
Major non-drug-related offence waiver	1·62 (1·37–1·90); p<0·0001	1·39 (1·15–1·69); p=0·001
Drug-related waiver	1·32 (1·01–1·74); p=0·046	1·16 (0·81–1·66); p=0·409
Other type of waiver	0·95 (0·82–1·11); p=0·541	1·00 (0·83–1·20); p=0·961

(Table 3 continues in next column)

hazard rate of suicide during the quarter of deployment (HR 0·50, 95% CI 0·40–0·61) but an increased hazard rate in the quarters after deployment (HR 1·51 if deployed in the previous three quarters, 95% CI 1·17–1·96; HR 1·14 if deployed four or more quarters ago, 1·06–1·23). Consistent with findings from two previous studies,[1,2] when we used only an indicator for whether a person was ever deployed we noted no significant association between deployment and suicide (HR 1·06, 95% CI 0·98–1·14, appendix). Additional analyses showed that the positive relationship between deployment and the risk of suicide dissipates by 16 quarters after deployment (table 2). Although less precisely estimated, this decreasing trend was observed across all branches except for the Navy, where the HR increased over time.

By far the strongest predictors were diagnoses of self-inflicted injury: during the quarter in which an individual was diagnosed, the hazard rate of death by suicide was 8·34 times higher than in those with no history of self-inflicted injuries (95% CI 6·71–10·37). The hazard rate remained substantially increased in all subsequent quarters (eg, HR 3·12, 95% CI 2·28–4·28 if diagnosed four or more quarters ago).

Current and past diagnoses of all other mental health diagnoses except for PTSD were also strongly associated with an increased risk of death by suicide. For example, the hazard rate of death by suicide from major depression ranged from 2·1 (95% CI 1·61–2·73) during the quarter an individual was diagnosed to

	Never deployed	Ever deployed
(Continued from previous column)		
Divorce status		
Divorced during the current quarter	1·24 (0·77–2·00); p=0·379	1·33 (0·80–2·21); p<0·0001
Divorced in the previous three quarters	1·29 (0·92–1·81); p=0·134	1·60 (1·16–2·19); p=0·004
Divorced four or more quarters ago	1·41 (1·12–1·76); p=0·003	1·19 (0·96–1·48); p<0·0001
Demotion		
Demoted during the current quarter	1·53 (1·25–1·86); p<0·0001	1·29 (0·95–1·75); p=0·106
Demoted in the previous three quarters	1·13 (0·87–1·47); p=0·369	1·56 (1·18–2·08); p=0·002
Demoted four or more quarters ago	1·07 (0·86–1·34); p=0·549	1·14 (0·93–1·39); p=0·203
On active duty	..	1·00
In the reserve component	0·54 (0·42–0·69); p<0·0001	0·71 (0·51–0·98); p=0·039
Left service (time since separation)		
Separated during the current quarter	1·83 (1·49–2·26); p<0·0001	2·06 (1·63–2·62); p<0·0001
Separated in the previous three quarters	2·42 (2·10–2·79); p<0·0001	1·62 (1·36–1·94); p<0·0001
Separated between 1 and 3 years ago	2·28 (2·04–2·55); p<0·0001	1·54 (1·34–1·77); p<0·0001
Separated between 4 and 5 years ago	1·67 (1·46–1·91); p<0·0001	1·29 (1·09–1·53); p=0·002
Separated 6 or more years ago	1·42 (1·23–1·63); p<0·0001	1·26 (1·03–1·53); p=0·025

Data are hazard ratios (95% CIs) for death by suicide (complete survival analysis results in the appendix). Model specifications are the same as table 1, except for the omission of deployment variables for the never-deployed sample. Mental health diagnoses were recorded as ICD-9 codes on medical records. OEF=Operation Enduring Freedom. OIF=Operation Iraqi Freedom. ..=not applicable.

***Table 3*: Hazard ratios of suicide, categorised by deployment history**

	Suicide deaths (hazard ratio [95% CI])	p value
OEF or OIF deployment status		
Never deployed	1·00	
Deployed in the previous 3 quarters	0·66 (0·27–1·59)	0·351
Deployed 4 or more quarters ago	1·09 (0·99–1·20)	0·096
Mental health diagnoses while in service		
Ever diagnosed with self-inflicted injuries	2·31 (1·84–2·89)	<0·0001
Ever diagnosed with Post Traumatic Stress Disorder (PTSD)	0·70 (0·57–0·86)	0·001
Ever diagnosed with major depression	1·71 (1·45–2·01)	<0·0001
Ever diagnosed with a substance use disorder	1·82 (1·52–2·19)	<0·0001
Ever diagnosed with bipolar disorder	1·31 (1·05–1·65)	0·019
Ever diagnosed with any other psychotic disorder	1·58 (1·32–1·89)	<0·0001
Ever diagnosed with anxiety disorder	1·16 (0·97–1·40)	0·108
Ever diagnosed with any other mental health condition	1·73 (1·56–1·92)	<0·0001
Enlistment waivers		
Minor–non-drug-related offence waiver	1·25 (0·82–1·91)	0·296
Major–non-drug-related offence waiver	1·53 (1·31–1·79)	<0·0001
Drug-related waiver	1·13 (0·86–1·48)	0·397
Other type of waiver	0·97 (0·83–1·13)	0·689
Potentially stressful life events while in service		
Ever divorced	1·09 (0·91–1·30)	0·316
Ever demoted	1·13 (1·00–1·29)	0·059
Time in service at the time of leaving military service		
1 or 2 quarters of service	12·00 (7·78–18·52)	<0·0001
3 to 8 quarters of service	1·14 (1·01–1·29)	0·031
9 to 16 quarters of service	1·16 (1·04–1·30)	0·007
More than 16 quarters of service	1·00	
Left service (time since separation)		
Separated during the current quarter	0·14 (0·12–0·18)	<0·0001
Separated in the previous 3 quarters	1·72 (1·49–1·98)	<0·0001
Separated between 1 and 3 years ago	1·56 (1·39–1·76)	<0·0001
Separated between 4 and 5 years ago	1·19 (1·05–1·35)	0·006
Separated 6 or more years ago	1·00	

Number of person-quarter years=46 396 161. Number of service members=2 202 937. Complete survival analysis results are in the appendix. Mental health diagnoses were recorded as ICD-9 codes from the TRICARE medical records. OEF=Operation Enduring Freedom. OIF=Operation Iraqi Freedom. ..=not applicable.

***Table 4*: Hazard ratios of death by suicide among individuals who had left military service anytime between 2001 and 2011**

1·65 (1·36–2·00) if diagnosed four or more quarters ago; the equivalent HRs for bipolar were 2·44 (95% CI 1·42–4·20) and 1·40 (1·14–1·72), respectively. The regression-adjusted hazard rate of suicide was lower for individuals diagnosed with PTSD in past quarter-years, even though the crude suicide rate of those ever diagnosed was higher than for those who were never diagnosed. This finding partly reflects the fact that PTSD is often comorbid with other mental health conditions. In an additional analysis for which we combined all mental health diagnoses, we showed that the HRs associated with having any mental health diagnosis were 3·44, 4·83, and 2·68 if diagnosed during current quarter, in the previous three quarters, and four or more quarters ago, respectively (p<0·0001 for all).

Enlisted personnel with a history of law violations, as measured by receiving an enlistment entry waiver for drug and non-drug related offences, also had a raised risk of death by suicide. For example, relative to having no enlistment waiver, a waiver for a major, non-drug-related offence was associated with a 53% raised hazard rate of death by suicide (HR 1·53, 95% CI 1·31–1·79). After controlling for mental health diagnoses while in service, enlistment waivers in the other waiver category—which includes waivers for past mental health conditions—were not significantly associated with suicides. Stressful life events such as divorce (HR 1·48 if divorced in previous three quarters [95% CI 1·18–1·86]; HR 1·33 if divorced four or more quarters ago [1·14–1·55]) and demotion in rank (HRs ranged from 1·49 [95% CI 1·27–1·76] during the quarter of demotion to 1·35 [1·12–1·63] if demoted in previous three quarters) were both significantly associated with increased hazard rates of death by suicide. HRs were also raised after leaving military service: the risk of death by suicide was highest during the first year of separation

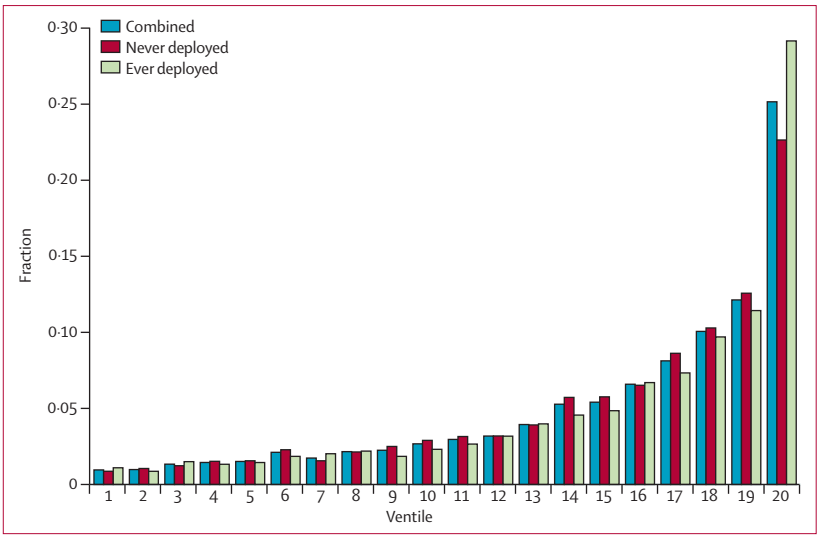

Figure: **Fraction of total suicides, by ventile of the predicted hazard of suicide**
5% of the sample is contained in each ventile. Each bar shows the percentage of deaths by suicide among the population in that ventile. The first and last ventiles represent those with the lowest and highest predicted hazard rate of suicide, respectively (calculated from the fully regression-adjusted Cox proportional hazard model).

and remained significantly raised in all subsequent years (HRs ranged from 2·49 [95% CI 2·12–2·91] if separated during the current quarter to 1·63 [1·45–1·82] if separated 6 or more years ago).

To investigate whether our results might be driven by differences between the deployed and never-deployed populations, we re-estimated our model separately for these two groups. Although mental health history was associated with increased risk of death by suicide for both groups, the risk of death by suicide was especially high among the deployed population who were diagnosed with self-inflicted injuries (HR 26·25 [95% CI 18·83–36·61]). By contrast, among those never deployed, those who were diagnosed with self-inflicted injuries have a raised HR of 4·69 (95% CI 3·49–6·30; table 3). For both deployed and never-deployed opulations, the hazard rate of death by suicide was higher after separation, but the relationship was stronger in the never-deployed sample.

We also estimated a separate model for veterans (ie, individuals from our study who were alive and separated from the military). Among veterans, having been deployed was weakly associated with a higher risk of death by suicide after discharge from service (HR 1·09 if deployed four or more quarters ago [95% CI 0·99–1·20]; table 4). Mental health diagnoses continued to be strongly associated with death by suicide among veterans (except for diagnoses of anxiety); however, stressful events occurring during the military career (divorce and demotion) did not seem to be significant risk factors. The HR of death by suicide for individuals who had only served for one or two quarter-years at the time of separation was 12·00 (95% CI 7·78–18·52). This high risk factor could reflect either the impact of the military training environment, or that even before joining the military, this population was predisposed to being more likely to die by suicide.

The nature of occupations and deployments varied widely across the Army, Navy, Air Force, and Marine Corps. HRs were generally similar in magnitude across branches, but less precisely estimated because of smaller sample sizes (appendix). Sensitivity analyses confirmed that our conclusions were robust to several changes in model specification. For example, similar to previous studies, we showed that the increased risk of death by suicide after deployment was similar irrespective of whether it was the first or a subsequent deployment. Nor did the hazard rates differ by locations of deployment (Afghanistan and Iraq versus other OEF or OIF locations).[2,14,27]

On the basis of our main model, we generated a predicted probability of death by suicide for each person-quarter. We rank-ordered these predicted values, grouped them into twenty ventiles, and plotted the fraction of deaths by suicide occurring in each ventile (figure). The risk of death by suicide was concentrated: 25% of all deaths by suicide occurred in the 20th ventile (ie, the person-quarters with the highest predicted risk). When this exercise was carried out separately for the never-deployed and ever-deployed populations, risk was even more concentrated for the deployed population, with close to 30% of suicides occurring in the 20th ventile.

Discussion

Our analysis contributes several important insights to the scientific literature. First, we showed that the hazard rate of death by suicide among those on deployment was lower than the hazard rate among the never-deployed population, but the hazard rate was significantly higher upon returning from deployment and it remained raised 16 quarters after deployment. This is in contrast to findings from two previous studies that failed to distinguish currently deployed from the previously deployed.[1,2] This finding might reflect the positive psychological impact of belonging to a group with a definitive purpose, and is consistent with evidence of the delayed onset of psychological disorders.[28,29] Thus, our results support the mandate in the 2012 US National Defense Authorization Act to continue screening military individuals for risks for suicide up to 18–30 months post-deployment.

Second, by use of clinical records, the results of our study highlighted the importance of a broad array of underlying mental disorders as significant risk factors for death by suicide. Although efforts to screen for suicide risk exclusively among patients with major depression might identify many of those at risk, our results showed that such a narrow focus might not be adequate, and there is a need for a broad array of stigma reduction efforts and for health-care systems to ensure that there is adequate capacity for treatment.

Third, we showed that individuals with a history of law violations had a significantly higher risk of suicide. This result indirectly confirms the rationale behind restrictions

on enlistments for these individuals, and suggests that costs are associated with the policy of offering these enlistment waivers. However, once we controlled for mental disorder diagnoses while in service, receiving a waiver for other reasons (which include waivers for having mental disorders) was not associated with increased risk. Mental-disorder waivers might be granted for milder conditions that have resolved. Furthermore, individuals who were willing to report past mental health problems during the waiver process are probably very different from individuals who had conditions that were unrecognised, or for which information was deliberately withheld.

Finally, we showed that the risk of suicide almost tripled during the first year after separation from the military and remained raised even after 6 years of separation. Additionally, we showed that the risk of suicide was 12 times higher among those who only served for a short time (6 months) before separating. The increased risk of suicide could reflect the lingering effects of stressful military experiences, the difficulties of reintegrating into civilian life, or a pre-enlistment disposition to death by suicide. Identification of these causes (which unfortunately our model could not do) is an important area for future research.

Our study had several limitations. First, we did not note mental health diagnoses after separation from service; this classic measurement error probably biases HRs towards a value of 1. Second, our TRICARE data might not capture all incidents of mental health disorders, because of stigma associated with mental health problems in the military. If undiagnosed cases of mental health disorders are positively correlated with suicide (as were the observed diagnoses), our estimates are lower bounds of the true relationships. Third, we did not analyse deployments other than those under OEF or OIF (eg, deployments in other regions), nor activation status for reservists called up for reasons unrelated to OEF or OIF. To the extent that these events were similar in nature to those under OEF or OIF, these missing data would bias HRs towards 1. Fourth, we did not address how resting time between two deployment assignments might affect the association of deployment with death by suicide. Finally, there are many non-military life stressors that we did not include (eg, financial stability, housing, and employment status) that might be the underlying causal mechanisms behind the relationships we estimate.

Despite these limitations, we noted that nearly 25% of deaths by suicide occurred in the highest ventile of predicted suicide risk, similar to the rate of suicides among veterans who had recently used Department of Veterans Affairs health services.[30] Given the substantial increase in military suicides after separation, future efforts focused on suicide risk among veterans need to capture a more complete mental health history from additional sources, such as the Department of Veterans Affairs or private insurers, or both, and capture major life events both during and after a service member has left service, to increase the concentration of risk in refined prediction models that could be used for targeted outreach with high-risk veterans.

In conclusion, deaths by suicide among current and former service members continues to be a pressing issue. By examining a comprehensive set of risk factors, we showed three major findings. First, the strongest risk factors of suicide were previous incidents of self-inflicted injuries and previously diagnosed mental health disorders. Second, we refined our understanding of the association between deployment and suicide through our findings that the risk of suicide was lower during deployment, increased substantially during the first seven quarters after deployment, and remained high up to 6 years after deployment. Third, we showed that suicide risk was very high among those who were separated during the initial training period; and, conditional on time-in-service, the risk of death by suicide remained high after separation from service for all veterans. Finally, despite the wealth of data at our disposal, our understanding of the risk factors of suicide could still be improved with more comprehensive data, particularly for veterans. Such data are crucial if we are to use prediction models to target the most at-risk service members and veterans for preventive interventions.

Contributors

Y-CS and JMC conceived the study concept and design, did the statistical analysis, and drafted the initial manuscript. Y-CS and TVW obtained the data. TVW provided critical revision of the manuscript.

Declaration of interests

We declare no competing interests.

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