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Ben Porter

George A. Bonanno

Paul D. Bliese
paul.bliese@moore.sc.edu

Christopher J. Philips

Susan P. Proctor

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RESEARCH ARTICLE

Combat and Trajectories of Physical Health Functioning in U.S. Service Members

Ben Porter, PhD,[1,2] George A. Bonanno, PhD,[3] Paul D. Bliese, PhD,[4]
Christopher J. Phillips, MD, MPH,[2] Susan P. Proctor, DSc,[5,6] for the Millennium Cohort Study

Introduction: Previous research has demonstrated that different forms of mental health trajectories can be observed in service members, and that these trajectories are related to combat. However, limited research has examined this phenomenon in relation to physical health. This study aims to determine how combat exposure relates to trajectories of physical health functioning in U.S. service members.

Methods: This study included 11,950 Millennium Cohort Study participants who had an index deployment between 2001 and 2005. Self-reported physical health functioning was obtained 5 times between 2001 and 2016 (analyzed in 2017), and latent growth mixture modeling was used to identify longitudinal trajectories from these assessments. Differences in the shape and prevalence of physical health functioning trajectories were investigated in relation to participants' self-reported combat exposure over the index deployment.

Results: Five physical health functioning trajectories were identified (high-stable, delayed-declining, worsening, improving-worsening, and low-stable). Combat exposure did not influence the shape of trajectories (p=0.12) but did influence trajectory membership. Relative to personnel not exposed to combat, participants reporting combat exposure were more likely to be in the delayed-declining, worsening, and low-stable classes and less likely to be in the high-stable class. However, the high-stable class (i.e., the most optimal class) was the most common trajectory class among not exposed (73.0%) and combat-exposed (64.5%) personnel.

Conclusions: Combat exposure during military deployment is associated with poorer physical health functioning trajectories spanning more than a decade of follow-up. However, even when exposed to combat, consistently high physical health functioning is the modal response.
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INTRODUCTION

Previous studies have documented different trajectories of post-traumatic stress disorder (PTSD) symptoms following military deployment and shown associations with combat exposure.[1] It is unknown whether physical health follows similar patterns. Optimal physical health is crucial to military readiness, resilience, and veteran well-being.[2] The military requires service members to meet physical standards; failure to meet these standards can result in military discharge.[3] Additionally, maintaining veterans' physical health is a core focus of the Department of Veterans Affairs.[4] Deployments and military stressors, like combat exposure, can negatively affect physical health.[5−7] Combat stress has the potential to impact multiple organ systems directly[8] and indirectly through health behaviors

From the [1]Leidos, Reston, Virginia.; [2]Department of Defense Center for Deployment Health Research, Naval Health Research Center, San Diego, California; [3]Teachers College, Columbia University, New York, New York; [4]Darla Moore School of Business, University of South Carolina, Columbia, South Carolina; [5]Military Performance Division, U.S. Army Research Institute of Environmental Medicine, Natick, Massachusetts; and [6]Research Service, VA Boston Healthcare System, Boston, Massachusetts

Address correspondence to: Ben Porter, PhD, Naval Health Research Center, 140 Sylvester Road, San Diego CA 92106. E-mail: bennett.w.porter.ctr@mail.mil.

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(e.g., drinking, smoking, and sleep).[9,10] Combat has been linked to various physical health conditions and symptoms. For example, combat exposure has been associated with new-onset cardiac problems,[6] new-onset pulmonary compaints,[7] and a higher prevalence of somatic symptoms.[5,11] Further, wartime service has been associated with poorer health trajectories among older veterans.[12] Self-reported physical health functioning has been associated with obesity, sedentary behavior, morbidity, hospitalization, and mortality.[13−15]

This study is the first of which the authors are aware to use latent growth mixture modeling (LGMM) to estimate multiple trajectories of physical health functioning within a prospectively assessed population of deployed U.S. service members, while seeking to determine the shape and prevalence of trajectories by combat exposure. LGMM estimates different patterns of change in variables over time, which are defined by growth parameters (e.g., intercept, slope, and quadratic).[16−18] Individual participants are assigned probabilistically to classes depending on how well their individual responses match those of a given trajectory. Determination of trajectory and class membership is data driven. Given the exploratory nature of LGMM, this is a descriptive study. The trajectories identified in the current study describe prognoses relating to physical health functioning across the study period and highlight differences associated with combat exposure. Such a study is important because, although prior research has shown a detriment to physical health following combat,[19] the longitudinal course of these detriments is less well documented, and no project has described empirically derived heterogeneous trajectories of physical health functioning among U.S. service members.

Additionally, this study seeks to determine whether other factors, including PTSD, are associated with prevalence of any trajectories. It is expected that exposure to combat is associated with poorer physical health functioning trajectories. Further, it is anticipated that most service members report consistently high levels of physical health functioning.[1,20,21] Additionally, previous work has shown a decline in physical health functioning following deployment, particularly among National Guard personnel.[19] Thus, a trajectory that experiences poorer physical health functioning following deployment is anticipated. Finally, it is hypothesized that personnel who began with relatively poor physical health functioning improve in the absence of combat.[1]

METHODS

Study Population

The Millennium Cohort Study is the largest prospective study of U.S. service members collected to date.[22] The initial panel of the Millennium Cohort Study used a population-based sampling method to enroll a representative population of service members from all branches and components. Between 2001 and 2016, enrolled participants were asked to complete a survey online or by mail approximately every 3 years. Participants provided their informed consent. Study procedures were approved by the Naval Health Research Center IRB (protocol number NHRC.2000.0007). Analyses were conducted in 2017.

This study included 12,197 participants from the first Millennium Cohort panel who began and completed a deployment in support of conflicts in Iraq and Afghanistan between their baseline (2001−2003) and first follow-up assessment (2004−2005). Of these participants, 208 were excluded for missing combat exposure data, and 39 were excluded for having fewer than 2 observations. All analyses were conducted on the remaining 11,950 service members. All participants were serving in the military at baseline, but most separated from the military during the study period.

Measures

Physical health functioning was assessed with the Physical Component Summary of the Veterans RAND 36-Item Health Survey.[23,24] Scoring was automated with standardized algorithms, normed to the 1998 general U.S. population, and constructed to have a mean of 50 and SD of 10, with higher scores indicating better physical health functioning.

Combat was measured at the first assessment after the index deployment. Combat was considered endorsed with any reported exposure to maimed civilians/soldiers, prisoners of war/refugees, dead/decomposing bodies, instances of physical abuse (torture, beating, or rape), or witnessing a person's death. Previous research has shown that this measure distinguishes personnel exposed to combat from those not exposed to combat.[25]

Participants self-reported their marital status and education. Age, sex, race/ethnicity, rank, service component, and service branch were obtained from administrative records held by the Defense Manpower Data Center. BMI (kg/m^2) was calculated from self-reported height and weight. Never smokers reported having never smoked 100 cigarettes, former smokers reported having smoked >100 cigarettes but successfully quit, and current smokers did not report having quit. Depression was assessed with the 9-item depression scale from the Patient Health Questionnaire.[26] PTSD was assessed using the PTSD Checklist−Civilian Version.[27] Defense Manpower Data Center records were used to identify participants who were deployed in the 1990−1991 Gulf War and in 1998−2000 to Bosnia, Kosovo, and southwest Asia. All covariates were reported at baseline.

Statistical Analysis

The authors used LGMM to model multiple distinct trajectories of physical health functioning over time.[16] LGMM creates categorical latent (i.e., unobserved) variables that classify individuals based on growth parameters derived from longitudinal data.[16−18] Individuals are assigned to a given class in a probabilistic fashion reflecting how well their trajectory fits that of a given latent class. The procedure itself is descriptive in nature: Researchers do not specify the shape or composition of latent classes, as these are determined empirically. LGMM results in archetypal trajectories of change over time that describe likely prognoses of individuals but may be of limited diagnostic utility for clinical practice.

Five waves of surveys were collected in assessment cycles beginning in 2001, 2004, 2007, 2011, and 2014. Time was scaled to reflect the relative time between the surveys. The means of the intercept, slope, and quadratic parameters were free to vary between latent trajectories, but variance parameters were held equal across trajectories to promote comparison between classes. Furthermore, the variance of the quadratic term was not estimated to facilitate model convergence.

Unadjusted models with 2 to 6 latent trajectory classes were examined to determine the optimal number of trajectories, which was selected using a combination of the Bayesian information criterion, Lo-Mendell-Rubin−adjusted likelihood ratio test, bootstrapped likelihood ratio test, and the interpretability of the trajectories.[17,18] Additionally, trajectories were required to have ≥2% of the total population to prevent unstable classes.

Then, combat exposure was entered as a known class to compare trajectories of combat-exposed and not exposed personnel. This estimated trajectories in each level of combat exposure separately.[16] Differences between trajectory shapes were calculated using the Satorra−Bentler chi-square difference test. An omnibus test compared all trajectories simultaneously. Differences in trajectory prevalence were evaluated using chi-square tests derived from the posterior probability.

To reduce the number of covariates, only covariates that had significant associations with trajectory membership were considered for inclusion in the final model. Variance inflation factors >4.0 indicated collinearity.

In the adjusted model, covariates were entered directly into the LGMM simultaneously as predictors of trajectories. The fully adjusted model included sex, age, race/ethnicity, marital status, education, service component, service branch, rank, BMI, smoking status, depression, PTSD, and Gulf War deployment. Given the exploratory nature of this study, associations were not adjusted for multiple comparisons. This approach is analogous to multinomial regression.

Additional analyses were conducted to determine whether any covariate moderated the association between combat and trajectory. Interactions with significant bivariate associations were then added, consisting of marital status X combat, Gulf War deployment X combat, and service component X combat. Further, baseline PTSD X combat was included because of its importance in military populations.

Of the 11,950 participants included in the current study, 79% were missing 0 or 1 Physical Component Summary values across the 5 assessments. Approximately 1% of responses were missing because of item nonresponse and the remaining instances because of survey nonresponse. Missing outcome values were handled using full information maximum likelihood estimation and missing covariates using multiple imputation.[28] The overall level of missing covariates was low. Twenty-five imputations were computed with an imputation model that included all study variables and 13 principal components derived from all available Millennium Cohort data.[29] These analyses allowed for the inclusion of participants even if they were missing a covariate. All analyses were conducted using Mplus, version 8.0.

RESULTS

Demographic, military, and health characteristics of the study population are presented in Table 1. Results from models with 2 to 6 trajectories are presented in Table 2. Bayesian information criterion and bootstrapped likelihood ratio test values continued to decline across all solutions, as has been found in previous studies with large sample sizes.[1,30,31] However, the 6-class solution had a significant Lo−Mendell−Rubin likelihood ratio test, and 1 class contained <2% of the study population, which can yield unstable solutions. Thus, the 5-class solution was selected. This solution had high entropy (0.83), indicating good class separation.

The 5-class solution's trajectories are presented in Appendix Figure 1, available online. The high-stable class (72.6%) had high levels of physical health functioning across the study. The delayed-declining class (12.8%) had high levels of physical health functioning at the first 3 assessments, which declined thereafter. The worsening class (5.5%) had high levels of physical health functioning at baseline, which declined by the second time point and remained low thereafter. The improving-worsening class (5.1%) had poor physical health functioning at baseline, increased until the third time point, and then declined. The low-stable class (3.9%) had poor physical health functioning throughout the study.

The omnibus Satorra−Bentler chi-square difference test (chi-square[15]=21.4, p=0.12) indicated that the shape of the trajectories did not differ by combat exposure (Figure 1). Therefore, trajectories' shapes were held equal for the remainder of analyses. However, differences were observed in the proportion of participants with combat exposure in each class (Table 3). Relative to participants not exposed to combat, fewer combat-exposed personnel were classified as high-stable and more were classified as worsening and low-stable. There was no significant difference in the delayed-declining or improving-worsening classes.

Bivariate analyses were conducted to reduce the number of included covariates. They indicated that all covariates were associated to participants' most likely trajectory except for 1998−2000 deployment (p=0.66). Bivariate associations with latent class are provided in Appendix Table 1, available online. Length of service was collinear with age (variance inflation factors >4) and so models excluded length of service.

Adjusting for covariates, the trajectories' shapes remained similar to unadjusted analyses (Appendix Figure 2, available online). However, in both groups, fewer participants were classified in the high-stable class and more were classified in the delayed-declining class relative to the unadjusted model (Table 3). Additionally, combat

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Table 1. Associations of Covariates With Physical Health Functioning Trajectory Class Membership: U.S., 2001–2016

Covariate (*n*)	Low-stable OR (95% CI)	Improving-worsening OR (95% CI)	Worsening OR (95% CI)	Delayed-declining OR (95% CI)
Combat exposure (ref=no exposure; *n*=5,937)				
Combat exposed (*n*=6,013)	1.69 (0.99, 2.88)	1.16 (0.77, 1.77)	2.44 (1.69, 3.51)	1.46 (1.10, 1.94)
Age (scaled in 10-year increments)				
Continuous (mean=33.1, SD=8.3)	2.51 (2.10, 2.99)	1.38 (1.13, 1.68)	1.79 (1.53, 2.09)	1.63 (1.45, 1.84)
Sex (ref=male; *n*=9,728)				
Female (*n*=2,222)	2.58 (1.79, 3.72)	1.92 (1.46, 2.52)	2.21 (1.71, 2.85)	1.81 (1.46, 2.23)
Race (ref=white, non-Hispanic; *n*=8,470)[a]				
Black, non-Hispanic (*n*=1,297)	1.33 (0.94, 1.88)	1.29 (0.95, 1.74)	1.26 (0.93, 1.70)	1.58 (1.24, 2.02)
Other race/ethnicity (*n*=2,176)	1.11 (0.75, 1.65)	1.09 (0.80, 1.49)	1.42 (1.09, 1.85)	1.21 (0.97, 1.49)
Marital status (ref=currently married; *n*=8,093)				
Never married (*n*=2,415)	0.44 (0.18, 1.06)	0.84 (0.58, 1.23)	0.70 (0.43, 1.16)	0.56 (0.39, 0.79)
Formerly married (*n*=1,442)	1.04 (0.90, 1.22)	1.02 (0.89, 1.16)	1.12 (1.00, 1.25)	1.03 (0.93, 1.14)
Education (ref=less than college; *n*=6,495)[a]				
College (*n*=4,069)	0.85 (0.63, 1.14)	0.68 (0.53, 0.88)	0.80 (0.63, 1.02)	0.79 (0.65, 0.95)
Advanced degree (*n*=1,385)	0.58 (0.30, 1.11)	0.42 (0.24, 0.75)	0.63 (0.38, 1.05)	0.58 (0.40, 0.84)
Pay grade (ref=enlisted; *n*=8,778)				
Officer (*n*=3,172)	0.24 (0.13, 0.44)	0.45 (0.30, 0.67)	0.35 (0.24, 0.51)	0.45 (0.34, 0.58)
Service component (ref=Reserve/National Guard; *n*=4,649)				
Active duty (*n*=7,301)	3.38 (1.94, 5.92)	2.10 (1.48, 2.98)	2.32 (1.61, 3.34)	2.22 (1.75, 2.83)
Service branch (ref=Army; *n*=5,568)				
Navy/Coast Guard (*n*=1,448)	0.56 (0.44, 0.72)	0.72 (0.61, 0.86)	0.70 (0.59, 0.83)	0.71 (0.62, 0.82)
Marines (*n*=600)	0.41 (0.19, 0.89)	0.67 (0.42, 1.08)	0.52 (0.30, 0.92)	0.88 (0.60, 1.29)
Air Force (*n*=4,334)	0.36 (0.27, 0.49)	0.48 (0.37, 0.62)	0.48 (0.38, 0.61)	0.62 (0.51, 0.77)
BMI (scaled in 5-point increments)				
Continuous (mean=26.0; SD=3.2)	2.41 (1.94, 2.99)	1.67 (1.39, 2.02)	1.73 (1.44, 2.09)	1.71 (1.49, 1.96)
Smoking status (ref=never; *n*=6,803)[a]				
Current smoker (*n*=2,061)	1.70 (1.23, 2.36)	2.13 (1.66, 2.72)	2.10 (1.64, 2.68)	1.53 (1.23, 1.90)
Former smoker (*n*=2,994)	1.32 (0.98, 1.77)	1.28 (1.00, 1.64)	1.20 (0.95, 1.51)	1.22 (1.02, 1.46)
Depression screening (ref=negative screen; *n*=11,615)[a]				
Positive screen (*n*=265)	2.45 (1.22, 4.92)	2.34 (1.29, 4.24)	1.30 (0.68, 2.49)	1.48 (0.88, 2.49)
PTSD screening (ref=negative screen; *n*=11,406)[a]				
Positive screen (*n*=367)	4.76 (1.83, 12.38)	2.80 (1.39, 5.64)	2.34 (1.08, 5.08)	1.34 (0.63, 2.89)
1990–1991 Gulf War deployment (ref=not deployed to Gulf War; *n*=10,192)[a]				
Gulf War deployed (*n*=1,758)	1.68 (1.17, 2.40)	1.59 (1.11, 2.26)	1.10 (0.79, 1.52)	1.19 (0.89, 1.59)

[a]Frequency does not sum to 11,950 because of missing data.
PTSD, post-traumatic stress disorder.

Table 2. Model Fit and Selection Criteria for Latent Physical Health Trajectory Classes: U.S., 2001–2016

Fit indices	2 classes	3 classes	4 classes	5 classes	6 classes
BIC, n	336,435	334,462	333,562	332,825	332,373
p-value for LMR	<0.001	<0.001	<0.001	<0.001	0.36
p-value for BLRT	<0.001	<0.001	<0.001	<0.001	<0.001
Entropy	0.925	0.907	0.810	0.827	0.827
Class 1, %	91.0	85.5	73.5	72.6	69.5
Class 2, %	9.0	7.8	12.5	12.8	11.2
Class 3, %	—	6.7	7.0	5.5	8.7
Class 4, %	—	—	6.9	5.1	6.3
Class 5, %	—	—	—	3.9	2.6
Class 6, %	—	—	—	—	1.7

BIC, Bayesian information criterion; BLRT, bootstrapped likelihood ratio test; LMR, Lo-Mendell-Rubin likelihood ratio test.

exposure was a significant predictor of worsening and delayed-declining classes in the adjusted model (Table 1).

Army service, enlisted personnel, current smoking, older age, higher BMI, PTSD, and female sex were associated with categorization in almost all negative trajectories (i.e., not high-stable; Table 1).

Interactions of combat with marital status, 1990–1991 Gulf War deployment, service component, and PTSD were added to the adjusted model. All associations of combat with trajectory are presented by strata in Appendix Table 2, available online. However, the only significant interaction in the adjusted model was service component moderating the association between combat and the worsening and delayed-declining classes. The association between combat and the worsening class was weaker among active duty (AOR=1.44, 95% CI=1.10, 1.89) than Reserve/National Guard personnel (AOR=2.55, 95% CI=1.84, 3.55). Similarly, the association between combat and the delayed-declining class was weaker among active duty (AOR=1.08; 95% CI=0.88, 1.32) than Reserve/National Guard personnel (AOR=1.54, 95% CI=1.19, 1.98).

Sensitivity analyses indicate that results remained consistent under the following 4 situations: (1) including PTSD as a time-varying covariate, (2) including PTSD assessed at time 2, (3) including service component and separation status as a time-varying covariate, and (4) excluding participants with a single combat exposure.

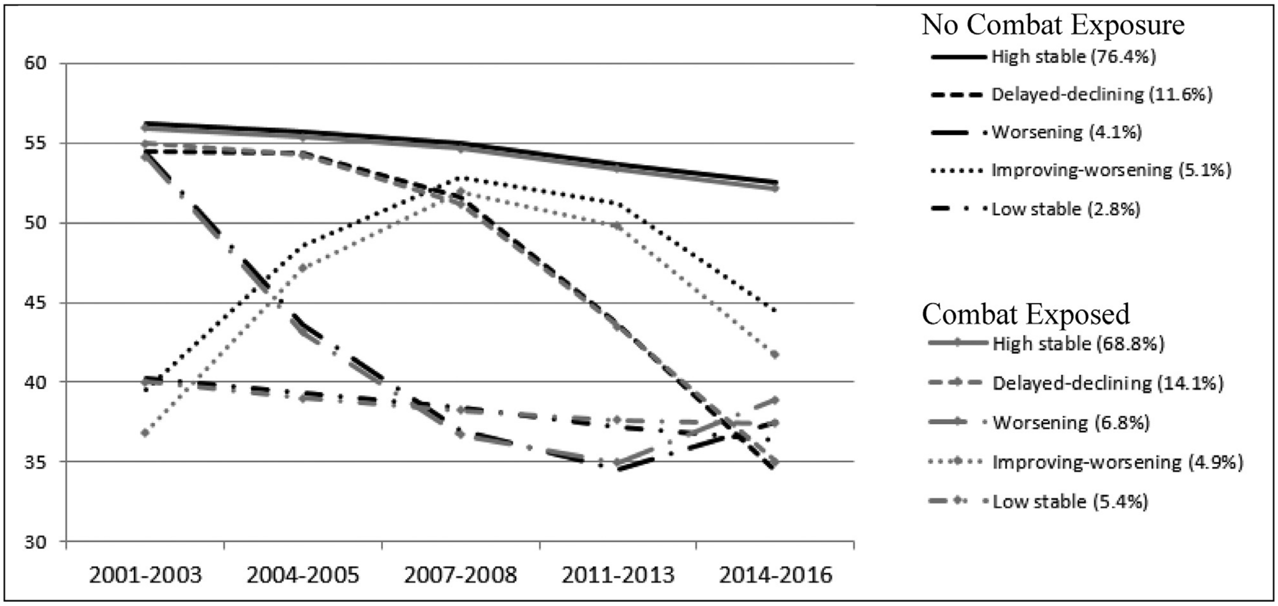

Figure 1. Five trajectory classes of physical health functioning, trajectory parameters free to vary by combat exposure, unadjusted for covariates.

Table 3. Physical Health Functioning Trajectory Class Prevalence in Unadjusted and Adjusted Models: U.S., 2001–2016

Class	Unadjusted model			Fully adjusted model[a]		
	Combat %	No combat %	χ^2 (*p*-value)	Combat %	No combat %	χ^2 (*p*-value)
High-stable	68.2	74.9	65.2 (<0.001)	64.5	73.0	101.5 (<0.001)
Delayed-declining	13.9	12.7	3.7 (0.06)	17.1	15.1	9.0 (0.003)
Worsening	7.1	4.4	41.9 (<0.001)	7.6	4.3	57.0 (<0.001)
Improving-worsening	5.4	5.2	0.2 (0.66)	5.7	5.1	2.4 (0.12)
Low-stable	5.3	2.8	48.7 (<0.001)	5.1	2.5	55.3 (<0.001)

[a]Model adjusted for sex, age, race/ethnicity, marital status, education, service component, service branch, rank, BMI, smoking status, depression, PTSD, Gulf War deployment, marital status X combat, Gulf War deployment X combat, PTSD X combat, and service component X combat.
PTSD, post-traumatic stress disorder.

DISCUSSION

This study is the first to describe physical health functioning trajectories among deployed service members over a 15-year period. Five trajectories were identified and labeled high-stable, delayed-declining, worsening, improving-worsening, and low-stable. Participants reporting combat exposure were more likely to be classified in trajectories with declining or low physical health functioning. However, the most common class was the high-stable class containing 64.5% and 73.0% of combat-exposed and not exposed participants, respectively. This finding mirrors PTSD and anger trajectory studies that show the healthiest, most resilient trajectory is modal among U.S. service members.[1,20,21]

Many expectations about trajectories of service members' physical health functioning trajectories were verified by the results. Combat exposure was related to the delayed-declining and worsening classes, which supported expectations that exposure to combat would negatively affect subsequent physical health functioning. However, the shape of physical health functioning trajectories did not statistically differ by combat exposure, and no noncombat deployment recovery was observed for a subpopulation reporting poor physical health trajectories at baseline, as was observed in a previous study describing trajectories of PTSD by combat.[1] Results indicated that there is a trajectory that declined following the index deployment (the worsening trajectory). Combat and service component interacted to predict this trajectory, such that the association between combat and this group was stronger among Reserve/National Guard participants than active duty personnel. This is similar to previous results indicating a more detrimental effect of combat on physical health functioning among Army National Guard compared with Army active duty personnel.[19]

The trajectories of physical health functioning looked similar to mental health trajectories examined in previous studies,[1,20,21] with the modal trajectory being the healthiest and other trajectories capturing declining, improving, and consistently poor health. This finding may reflect the subjective nature and self-evaluation intrinsic to mental health screening and the Veterans RAND 36-Item Health Survey.

Not smoking and maintaining a healthy BMI had a stronger asssociation with physical health functioning trajectories than combat exposure. These results highlight the increased risk of poor current and future physical health functioning associated with factors that can be controlled. As such, this study supports military efforts to curb smoking and promote a healthy weight because these results suggest that they are effective preventive strategies for maintaining future physical health functioning of service members and veterans.

This study indicated that PTSD is one of the greatest risk factors for poor physical health functioning trajectories. Notably, baseline PTSD was predictive of trajectories with concurrent poor baseline physical health functioning as well as trajectories that had worsening physical health functioning across the study period. In one sensitivity analysis, PTSD at follow-up was the strongest predictor of most negative health trajectories (Appendix Table 3, available online). The inclusion of this covariate reduced the association between combat and the worsening trajectory, but did not eliminate it or the other associations. This finding indicated that the results are not likely because of PTSD resulting from combat exposure.

Limitations

Assessing participants approximately every 3 years prevented the identification of short-term fluctuations. However, this assessment strategy allowed for modeling physical health functioning over an extended period with relatively little participant burden, which likely reduced attrition. This study did not examine associations between trajectories and mortality and morbidity. Future research should examine such variables predicted by latent class. Further, the outcome measure for this study was based on self-report and so includes perceptual biases of participants. Service members' perceptions of high physical health functioning likely differ from those of civilians; therefore, results may not be objectively comparable with civilian studies. However, such perceptual differences would likely have uniform influence on all responses and thus are not likely to affect overall conclusions. Similarly, only a crude measure of combat exposure was available, and a degree of misclassification may exist in this study.[25] The associations from this study are correlational and do not imply causation, and, given the number of examined associations, it is possible that some of the statistically significant associations are spurious.

This study also contained several notable strengths. The most unique strength was the assessment period of the current study spanning a critical 15-year period, thus permitting examination of long-term trends in physical health functioning following deployment. Additionally, all baseline assessments occurred before participants' initial deployment in support of the conflicts in Iraq and Afghanistan, representing a true baseline for these conflicts. The use of full information maximum likelihood and multiple imputation allowed the inclusion of participants missing some covariates or a survey wave. Additionally, the large representative sample allowed for reliable and precise estimates that likely generalize to the deployed U.S. military population of this era. Although the current study was conducted in a large cross-section of the U.S. military, findings should be replicated in additional samples. Similarly, future studies could examine different aspects of military service and how they may affect health trajectories (e.g., service component or separation status).

CONCLUSIONS

This study demonstrates that service members typically have high levels of physical health functioning before and after a military deployment regardless of whether they have been exposed to combat, and prognoses are generally good regarding physical health functioning. However, relative to no combat exposure, combat exposure is significantly related to the worsening and delayed-declining classes, even after adjusting for a wide array of covariates. The increased risk of categorization in the delayed-declining trajectory indicates the increased association between combat and worsening physical health functioning may persist for several years. Yet, the trajectory shape of physical health functioning trajectories did not differ by combat exposure. Furthermore, this study identifies other risk factors for negative physical health functioning trajectories including predeployment PTSD, smoking, and higher BMI. These factors generally have a larger impact on trajectories than combat and may be used in future research and interventions to identify populations at risk for worsening physical health functioning.

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SUPPLEMENTAL MATERIAL

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