Combat and Trajectories of Physical Health Functioning in US Service Members

Ben Porter
George A. Bonanno
Paul D. Bliese
paul.bliese@moore.sc.edu
Christopher J. Philips
Susan P. Proctor

Follow this and additional works at: https://scholarcommons.sc.edu/man_facpub

Part of the Business Administration, Management, and Operations Commons

Publication Info
Published in American Journal of Preventive Medicine, Volume 57, Issue 5, 2019, pages 637-644.
© 2019 American Journal of Preventive Medicine. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/). Am J Prev Med 2019;57(5):637–644

This Article is brought to you by the Management Department at Scholar Commons. It has been accepted for inclusion in Faculty Publications by an authorized administrator of Scholar Commons. For more information, please contact dillarda@mailbox.sc.edu.
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.

INTRODUCTION

Previous studies have documented different trajectories of post-traumatic stress disorder (PTSD) symptoms following military deployment and shown associations with combat exposure. It is unknown whether physical health follows similar patterns. Optimal physical health is crucial to military readiness, resilience, and veteran well-being. The military requires service members to meet physical standards; failure to meet these standards can result in military discharge. Additionally, maintaining veterans’ physical health is a core focus of the Department of Veterans Affairs. Deployments and military stressors, like combat exposure, can negatively affect physical health. Combat stress has the potential to impact multiple organ systems directly and indirectly through health behaviors.
Combat has been linked to various physical health conditions and symp-
toms. For example, combat exposure has been associated with
new-onset cardiac problems,\(^6\) new-onset pulmonary compa-
ts,\(^7\) and a higher prevalence of somatic symp-
toms.\(^5,11\) Further, wartime service has been associated
with poorer health trajectories among older veterans.\(^12\)
Self-reported physical health functioning has been associ-
ated with obesity, sedentary behavior, morbidity, hospi-
talization, 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. ser-
vice 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., inter-
cept, slope, and quadratic).\(^16−18\) Individual participants
are assigned probabilistically to classes depending on how
well their individual responses match those of a given tra-
jectory. 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 longi-
tudinal course of these detriments is less well documented,
and no project has described empirically derived heteroge-
neous trajectories of physical health functioning among
U.S. service members.

Additionally, this study seeks to determine whether
other factors, including PTSD, are associated with preva-
lence of any trajectories. It is expected that exposure to
combat is associated with poorer physical health func-
tioning trajectories. Further, it is anticipated that most
service members report consistently high levels of physi-
cal health functioning.\(^1,20,21\) Additionally, previous work
has shown a decline in physical health functioning fol-
lowing 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 function-
ing 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 ser-
vice 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. Par-
ticipants provided their informed consent. Study procedures
were approved by the Naval Health Research Center IRB
(protocol number NHRC.2000.0007). Analyses were con-
ducted in 2017.

This study included 12,197 participants from the first Millenni-
num Cohort panel who began and completed a deployment in
support of conflicts in Iraq and Afghanistan between their base-
these participants, 208 were excluded for missing combat expo-
sure data, and 39 were excluded for having fewer than 2 observa-
tions. 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 Com-
ponent Summary of the Veterans RAND 36-Item Health Sur-
vey.\(^23,24\) 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 bet-
ter 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 reporting
having smoked >100 cigarettes but successfully quit, and cur-
rent 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 trajec-
try profiles of physical health functioning over time.\(^16\) LGMM
creates categorical latent (i.e., unobserved) variables that classify indi-
viduals based on growth parameters derived from longitudinal
data.\(^16−18\) Individuals are assigned to a given class in a proba-
bilistic fashion reflecting how well their trajectory fits that of a
given latent class. The procedure itself is descriptive in nature: Researches do not specify the shape or composition of latent
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
<table>
<thead>
<tr>
<th>Covariate (n)</th>
<th>Low-stable OR (95% CI)</th>
<th>Improving-worsening OR (95% CI)</th>
<th>Worsening OR (95% CI)</th>
<th>Delayed-declining OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combat exposure (ref=no exposure; n=5,937)</td>
<td>1.69 (0.99, 2.88)</td>
<td>1.16 (0.77, 1.77)</td>
<td>2.44 (1.69, 3.51)</td>
<td>1.46 (1.10, 1.94)</td>
</tr>
<tr>
<td>Age (scaled in 10-year increments)</td>
<td>2.51 (2.10, 2.99)</td>
<td>1.38 (1.13, 1.68)</td>
<td>1.79 (1.53, 2.09)</td>
<td>1.63 (1.45, 1.84)</td>
</tr>
<tr>
<td>Sex (ref=male; n=9,728)</td>
<td>2.58 (1.79, 3.72)</td>
<td>1.92 (1.46, 2.52)</td>
<td>2.21 (1.71, 2.85)</td>
<td>1.81 (1.46, 2.23)</td>
</tr>
<tr>
<td>Race (ref=white, non-Hispanic; n=8,470)</td>
<td>1.33 (0.94, 1.88)</td>
<td>1.29 (0.95, 1.74)</td>
<td>1.26 (0.93, 1.70)</td>
<td>1.58 (1.24, 2.02)</td>
</tr>
<tr>
<td>Marital status (ref=currently married; n=8,093)</td>
<td>0.44 (0.18, 1.06)</td>
<td>0.84 (0.58, 1.23)</td>
<td>0.70 (0.43, 1.16)</td>
<td>0.56 (0.39, 0.79)</td>
</tr>
<tr>
<td>Education (ref=less than college; n=6,495)</td>
<td>0.85 (0.63, 1.14)</td>
<td>0.68 (0.53, 0.88)</td>
<td>0.80 (0.63, 1.02)</td>
<td>0.79 (0.65, 0.95)</td>
</tr>
<tr>
<td>Pay grade (ref=enlisted; n=8,778)</td>
<td>0.24 (0.13, 0.44)</td>
<td>0.45 (0.30, 0.67)</td>
<td>0.35 (0.24, 0.51)</td>
<td>0.45 (0.34, 0.58)</td>
</tr>
<tr>
<td>BMI (scaled in 5-point increments)</td>
<td>2.41 (1.94, 2.99)</td>
<td>1.67 (1.39, 2.02)</td>
<td>1.73 (1.44, 2.09)</td>
<td>1.71 (1.49, 1.96)</td>
</tr>
<tr>
<td>Smoking status (ref=never; n=6,803)</td>
<td>1.70 (1.23, 2.36)</td>
<td>2.13 (1.66, 2.72)</td>
<td>2.10 (1.64, 2.68)</td>
<td>1.53 (1.23, 1.90)</td>
</tr>
<tr>
<td>Depression screening (ref=negative screen; n=11,615)</td>
<td>1.32 (0.98, 1.77)</td>
<td>1.28 (1.00, 1.64)</td>
<td>1.20 (0.95, 1.51)</td>
<td>1.22 (1.02, 1.46)</td>
</tr>
<tr>
<td>PTSD screening (ref=negative screen; n=11,406)</td>
<td>2.45 (1.22, 4.92)</td>
<td>2.34 (1.29, 4.24)</td>
<td>1.30 (0.68, 2.49)</td>
<td>1.48 (0.88, 2.49)</td>
</tr>
<tr>
<td>Gulf War deployed (ref=not deployed to Gulf War; n=10,192)</td>
<td>4.76 (1.83, 12.38)</td>
<td>2.80 (1.39, 5.64)</td>
<td>2.34 (1.08, 5.08)</td>
<td>1.34 (0.63, 2.89)</td>
</tr>
<tr>
<td>n=1,758</td>
<td>1.68 (1.17, 2.40)</td>
<td>1.59 (1.11, 2.26)</td>
<td>1.10 (0.79, 1.52)</td>
<td>1.19 (0.89, 1.59)</td>
</tr>
</tbody>
</table>

aFrequency does not sum to 11,950 because of missing data.

PTSD, post-traumatic stress disorder.
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.


<table>
<thead>
<tr>
<th>Fit indices</th>
<th>2 classes</th>
<th>3 classes</th>
<th>4 classes</th>
<th>5 classes</th>
<th>6 classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIC, n</td>
<td>336,435</td>
<td>334,462</td>
<td>333,562</td>
<td>332,825</td>
<td>332,373</td>
</tr>
<tr>
<td>p-value for LMR</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.36</td>
</tr>
<tr>
<td>p-value for BLRT</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Entropy</td>
<td>0.925</td>
<td>0.907</td>
<td>0.810</td>
<td>0.827</td>
<td>0.827</td>
</tr>
<tr>
<td>Class 1, %</td>
<td>91.0</td>
<td>85.5</td>
<td>73.5</td>
<td>72.6</td>
<td>69.5</td>
</tr>
<tr>
<td>Class 2, %</td>
<td>0.0</td>
<td>7.8</td>
<td>12.5</td>
<td>12.8</td>
<td>11.2</td>
</tr>
<tr>
<td>Class 3, %</td>
<td>9.0</td>
<td>6.7</td>
<td>7.0</td>
<td>5.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Class 4, %</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>6.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Class 5, %</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3.9</td>
</tr>
<tr>
<td>Class 6, %</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

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

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


<table>
<thead>
<tr>
<th>Class</th>
<th>Unadjusted model</th>
<th>Fully adjusted modela</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Combat % No combat %</td>
<td>$\chi^2$ (p-value)</td>
</tr>
<tr>
<td>High-stable</td>
<td>68.2 74.9</td>
<td>65.2 (&lt;0.001)</td>
</tr>
<tr>
<td>Delayed-declining</td>
<td>13.9 12.7</td>
<td>3.7 (0.06)</td>
</tr>
<tr>
<td>Worsening</td>
<td>7.1 4.4</td>
<td>41.9 (&lt;0.001)</td>
</tr>
<tr>
<td>Improving-worsening</td>
<td>5.4 5.2</td>
<td>0.2 (0.66)</td>
</tr>
<tr>
<td>Low-stable</td>
<td>5.3 2.8</td>
<td>48.7 (&lt;0.001)</td>
</tr>
</tbody>
</table>

*aModel 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.

www.ajpmonline.org
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.

ACKNOWLEDGMENTS

CJP and SPP are military service members or employees of the U.S. Government. This work was prepared as part of their official duties. Title 17, USC § 105 provides that copyright protection under this title is not available for any work of the U.S. Government. Title 17, USC § 101 defines a U.S. Government work as work prepared by a military service member or employee of the U.S. Government as part of that person's official duties.

Report No. 18–52 was supported by the U.S. Navy Bureau of Medicine and Surgery under work unit no. 60002. The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Departments of the Navy or Army, Department of Defense, Department of Veteran Affairs, or the U.S. Government.

The study protocol was approved by the Naval Health Research Center IRB in compliance with all applicable Federal regulations governing the protection of human subjects. Research data were derived from an approved Naval Health Research Center, IRB protocol number NHRC.2000.0007.

Support for this project was provided under Federal Interagency agreement # 2012-FRS-0028 as a collaboration between the Millennium Cohort Study, Department of Veterans Affairs Office of Research and Development, and Department of Veterans Affairs Office of Patient Care Services.

No financial disclosures were reported by the authors of this paper.

SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2019.06.015.

REFERENCES


