Annals of Epidemiology 35 (2019) 66–72

Contents lists available at ScienceDirect

Annals of Epidemiology

Original article

Evaluating measures of combat deployment for U.S. Army personnel using various sources of administrative data

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ARTICLE INFO

Article history:
Received 21 December 2018
Accepted 3 April 2019
Available online 11 April 2019

Keywords:
Combat deployment
Measure validation
Administrative data

ABSTRACT

Purpose: This study's purpose is to inform future research decisions about optimal measures for identifying combat deployments. We aim to evaluate four commonly utilized measures available in population-level administrative data to identify combat deployments in recent military operations among active duty Army personnel.

Methods: We compare these measures in three ways: (1) agreement (assessing the extent to which soldiers were differentially identified as combat deployed via each measure); (2) validity (calculating the sensitivity of each measure against a criterion measure); and (3) corroboration (examining how each measure predicted subsequent incidence of traumatic brain injury and post-traumatic stress disorder).

Results: We found that using personnel records to identify deployments to Iraq, Afghanistan, and/or Kuwait captured over 98% of combat-related deployments identified via self-reported measures. The addition of Kuwait allowed for detection of nearly 100% of battle injuries, improving sensitivity from 94.5% to 99.8%. However, self-reported combat exposure measures showed the largest differential in subsequent incidence of traumatic brain injury and post-traumatic stress disorder. Completeness and accuracy of different combat deployment measures varied significantly.

Conclusions: Using personnel records to identify deployment to Iraq, Afghanistan, and/or Kuwait was the most valid and comprehensive measure of combat deployment. However, self-reported combat exposure measures were more predictive of combat-related outcomes.

Introduction

Many gaps remain in our understanding of the psychological effects of deployment to an active war zone (hereafter: combat deployment, which in this article can include deployment with and without combat exposure). A significant challenge in addressing this gap is the accurate identification of service members (SMs) who were combat deployed in support of Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND). In October 2001, the United States launched OEF, the Global War on Terrorism which was primarily conducted in Afghanistan in response to the September 11 attacks and ended in December 2014. OIF began in March 2003 with the invasion of Iraq, ending in August 2010. A transitional force of U.S. troops remained in Iraq under OND, which ended in December 2011.[1] Although Air Force, Navy, and Marine personnel served in the combat environment, most ground combat units were Army.[2,3] Combat in OEF/OIF/OND was primarily confined to Iraq and Afghanistan, but a number of countries provided theater-wide support in the region including Kuwait which served as the main launching pad for the United States–led invasion of Iraq.[2]

With the growth and availability of large administrative databases, derived from electronic health records and linked with personnel, occupational, and other data, researchers have been able to investigate effects of combat deployment on various outcomes, such as suicide, combat stress reactions, mental health disorders, and other conditions.[4–9] However, within population-wide metrics, no standard exists for defining combat deployment. In addition, definitions are often lacking or insufficient in detail. A key step within scientific research is clearly articulating how measures are defined. Without such transparency, ensuring that findings can be

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https://doi.org/10.1016/j.annepidem.2019.04.001
1047-2797/

Table 1
Sources and measures of combat deployment in support of OEF/OIF/OND from population-level administrative data

Administrative data source	Type	Description	Relevant measures of combat deployment	Variations in country definition of combat deployment
Defense Manpower Data Center, Contingency Tracking System	Personnel	Personnel deployment surveillance system	Country location	Per CENTCOM: 12 countries[12] Per Joint Staff: CENTCOM list plus six additional countries[12]
Post-Deployment Health Assessment	Self-report	Self-report health assessment required within 30 d after deployment return	Country location	Per CENTCOM: 12 countries[12] Per Joint Staff: CENTCOM list plus six additional countries[12]
			Theater of operation	Not applicable
			Combat exposure: - Encountering dead/wounded - Discharging a weapon - Feeling in danger of being killed	Not applicable
Hostile File/Imminent Danger Pay	Pay	Special pay that compensates SMs for physical danger	Eligibility based on country of deployment	16 Countries and bodies of water, nine of which overlap with CENTCOM and 11 overlap with Joint Staff[2,13]
Combat Zone Tax Exclusion	Pay	Federal income tax advantage for service in an active combat area as designated by Executive Order	Eligibility based on country of deployment	23 Countries and bodies of water,* 4 of which are unique from all above lists[14–16]

* In Afghanistan area and the Arabian Peninsula combat zones.

replicated remains a major challenge of data-driven approaches. Moreover, previous research on measures of combat deployment has not included validation. Obtaining reliable and valid measures of combat deployment is imperative in studies of deployment-related health as they affect the cohort selected, which impacts the generalizability and implications of results, as well as potentially influencing results themselves. For instance, in two different studies of the same Air Force cohort, 75 percent of SMs were identified as deployed to Iraq and Afghanistan using one measure of combat deployment, whereas only 24 percent were identified using an entirely different measure.[10,11] These differences have significant impact on policy and research implications, including the ability to estimate the psychological impact of combat deployment and the ability to compare results across studies.

Researchers and policymakers using population-level administrative data from the Military Health System commonly identify combat deployment using existing data that are routinely collected and derived from four sources: the Defense Manpower Data Center Contingency Tracking System (CTS), the Post-Deployment Health Assessment (PDHA), hostile fire/imminent danger pay (HF/IDP), and combat zone tax exclusion (Table 1). Although country location is one of the more common ways to identify combat deployment, there is no single standard or guideline for defining which countries constitute a deployment to OEF/OIF/OND, and the list of countries varies depending on the source of the information and the purpose (Table 1). Although most measures in Table 1 indicate deployment to an active war zone, two measures (PDHA 4 and 5) are derived from three questions from the PDHA and identify the presence or absence of self-reported combat exposure. These measures that identify deployments with combat exposure are categorically different than other measures that indicate deployment to an active war zone.

We conducted a limited review of studies that used population-level administrative data to identify deployments in support of OEF/OIF/OND and found that the source data used to identify combat deployment varied widely. Many studies did not specify the source of data for defining combat deployment[17,18] nor which destination countries constituted a combat deployment to OEF/OIF/OND.[4,5] Among studies that did specify the source of administrative data, the list of countries defining OEF/OIF/OND varied widely[19–24] or was not specified at all.[25–27] For example, most studies in our literature review defined OEF/OIF as deployment to Afghanistan and Iraq.[6,19,23,28–41] However, some studies also included Kuwait and Qatar.[22,42] Other studies relied on responses on the PDHA.[8,29,42–46] Less frequently, researchers used the combat zone tax exclusion or HF/IDP alone or in conjunction with specific countries to define combat deployment.[47,48]

Despite variability in how combat deployment has been determined, few studies have systematically compared different measures. Previous efforts differed in approach but all used a study sample. One study compared two different self-reported responses among SMs who were enrolled in the Millennium Cohort Study.[49] Another study compared one self-reported response in the Millennium Cohort Study against administrative data among the study sample.[50] Rather than using a study sample, our effort is based on population-level data that are routinely collected and more widely available. In addition, we extend previous research by comparing several measures of combat deployment and examining validity and level of corroboration against combat-related outcomes. In this article, we describe an approach to comparing and validating measures for identifying combat deployment using routine data collected by the Department of Defense. Our aims were to (1) examine the level of agreement between measures, (2) calculate the sensitivity of each measure against a criterion measure, and (3) assess how each measure predicts subsequent incidence of traumatic brain injury (TBI) and post-traumatic stress disorder (PTSD). Our ultimate goal was to inform future research decisions about optimal measures for identifying combat deployments.

Methods

Data sources and study population

This study relied on existing data for active duty U.S. Army soldiers available in the Person-Event Data Environment (PDE) from the Army Analytics Group. The PDE is a consolidated data repository that contains unclassified, limited, and encoded medical, demographic, occupational, branch of service and deployment data on soldiers from entry to separation from military service.[51,52] Data in the PDE are drawn from a number of databases (including non-Army sources) that are quality-controlled, encoded, linked, and integrated. Demographic, occupational, and deployment data are derived from the Defense Manpower Data Center, including the Active Duty Master and Transaction, Military Entrance Processing Command, and CTS Overseas Contingency Operations files. Medical data originate from the Defense Health Agency's Military Health System Data Repository, including records of ambulatory encounters from the Comprehensive Ambulatory Provider Encounter

Table 2
Measures of combat deployment evaluated in this study

Measure	Description
CTS 1	CTS country: Iraq and/or Afghanistan (IZ/AF)
CTS 2	CTS country: Iraq, Afghanistan, and/or Kuwait (IZ/AF/KU)
PDHA 1	PDHA country: Self-reported Iraq and/or Afghanistan (IZ/AF)
PDHA 2	PDHA country: Self-reported Iraq, Afghanistan, and/or Kuwait (IZ/AF/KU)
PDHA 3	PDHA operation: Self-reported OEF/OIF/OND
PDHA 4	PDHA combat exposure: Any of the following endorsed (encountered dead/wounded, discharged weapon, felt in danger of being killed)
PDHA 5	PDHA combat exposure: All of the following endorsed (encountered dead/wounded, discharged weapon, felt in danger of being killed)

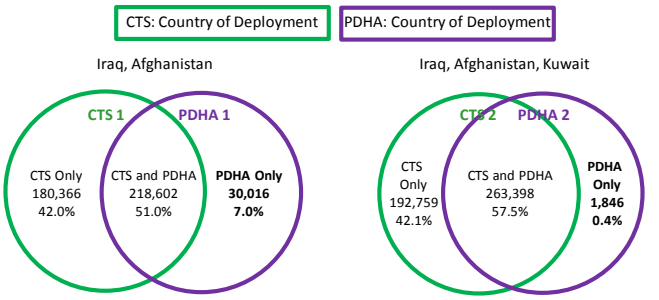

Fig. 1. Percent agreement on country of deployment comparison. The areas displayed in each section of the diagram are meant to show movement in overlap with changing definitions and are not representative of the percentages in the figure.

Record and hospitalizations from the Standard Inpatient Data Record used at military treatment facilities. The TRICARE Encounter Data—institutional and noninstitutional claims records from civilian treatment facilities (if reimbursed through TRICARE) supplement the military treatment facilities medical data. The Theater Medical Data Store (TMDS) maintains similar electronic health records for services rendered while soldiers are deployed.

On our request for data from the PDE, Army Analytics Group system administrators monitored automated data transport programs that assembled and positioned data for us. We enacted additional processes to eliminate duplicate records, check for missing values in key data elements, note values outside a specified range, verify total number of records provided against known occupation totals, and ensure that generated fields, calculations, and transformations were correct.

Using the PDE, we identified all deployments lasting at least 30 days among active duty soldiers from CTS that had a start date in one of the following periods: (1) October 1, 2005—September 30, 2006; (2) October 1, 2007—September 30, 2008; or (3) October 1, 2010—September 30, 2011. These time points were selected to capture different troop surges and draw-downs in deployments to OEF/OIF/OND and to allow for representation of two PDHA forms: the 2003 and 2008 versions. For soldiers who had multiple deployments within one of the three timeframes, we limited inclusion to their first deployment in that period. We then matched PDHAs to deployments if (1) the completion date on the PDHA was within 60 days of the deployment end date in CTS or (2) the arrival date in PDHA was within 7 days of the start date in CTS.

Outcomes

We developed several measures of combat deployment from CTS and PDHA (Table 2). CTS measures 1 and 2 and PDHA measures 1, 2, and 3; all indicate deployment to an active war zone, whereas PDHA variables 4 and 5 indicate the presence and level of combat exposure. We did not include measures of HF/IDP or combat zone tax exclusion as these were infrequently used by researchers in our literature review, and there was insufficient variance in these variables to add meaningful comparison as 99% of deployments, regardless of location, indicated HF/IDP and tax exclusion. Deployments were assigned a yes/no value for each measure in Table 2, which we compared in three ways:

(1) Agreement (assessing the extent to which soldiers were differentially identified as combat deployed via each measure);
(2) Validity (calculating the sensitivity of each measure against a criterion measure); and
(3) Corroboration (examining how each measure predicted subsequent incidence of TBI and PTSD).

We compared countries of deployment listed in the CTS records with those listed in each soldier's PDHA to assess agreement between data sources. We examined Iraq and Afghanistan (IZ/AF: CTS 1 vs. PDHA 1) and the addition of Kuwait (CTS 2 vs. PDHA 2). We then compared the CTS country of deployment measures to additional measures of combat deployment, including any combat exposure via the PDHA (PDHA 4) and operation identified by self-report in the PDHA (PDHA 3). To further assess the impact of multiple combat exposure types, we included a measure that identified soldiers endorsing all three combat exposures on the PDHA (PDHA 5).

After examining level of agreement between measures, we assessed the sensitivity (and 95% confidence interval) of each measure in detecting the presence of a battle injury among deployed soldiers. We chose this criterion measure because a battle injury, if coded correctly, would only result from combat deployment. A battle injury was defined in this study as present if the soldier had a TMDS record between the start date and 30 days after the end date of deployment in which a value of "201" (battle injury) was entered in the injury type variable.

Finally, we assessed differences in incident TBI and PTSD diagnoses between soldiers whose deployment met the definition for each measure and those whose deployment did not. Combat deployment is associated with increased risk of TBI and PTSD, which have been called the "signature wounds" of the wars in Afghanistan and Iraq. We categorized soldiers as having an incident PTSD diagnosis if they had an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code of 309.81 in the first or second diagnostic position of an inpatient or outpatient visit. We categorized soldiers as having an incident TBI diagnosis if they had an ICD-9-CM code V15.5* with a Department of Defense diagnostic extender signifying "global war on terror-related" (extenders 1–5) in the first or second diagnostic position of an inpatient or outpatient visit. Diagnoses must have occurred during or within one year of deployment.

Statistical analysis

Given variation in the prevalence of and high expected agreement between measures in this study, which would negatively impact kappa scores, we calculated the B-statistic to assess agreement between each pair of measures. The B-statistic measures the ratio between the sum of areas of agreement and the sum of areas of marginal totals depicted in an agreement chart and is less affected by changes in prevalence and asymmetry in marginal distributions than the kappa statistic.

Table 3
B-statistic matrix between measures of combat deployment from CTS and PDHA

CTS measure	PDHA measure				
	PDHA 1	PDHA 2	PDHA 3	PDHA 4	PDHA 5
CTS 1	0.36	0.35	0.73	0.47	0.14
CTS 2	0.45	0.48	0.86	0.55	0.12

Scientific and human subjects research approvals

This study was reviewed and determined "exempt from human subjects research" by the Defense Health Agency Human Research Protection Program Office. In addition, regulatory and compliance oversight of the PDE is also provided by the Army Human Research Protections Office, the Army's internal equivalent of an "Institutional Review Board."

Results

Using the PDE, we first identified a total of 549,086 deployments among Army personnel from CTS in three 1-year periods. Of those deployments, 15% (82,363) did not match to a PDHA and were removed from further analysis that included PDHA measures.

Agreement

Among those that matched, agreement between CTS and PDHA country locations ranged from 51.0% to 57.5% (Fig. 1). However, PDHAs were frequently missing country location, potentially contributing to the large "CTS only" portions of the figure. Notably, using the measure, CTS 1 missed the 30,016 deployments identified by the PDHA 1 as combat deployed ("PDHA only" in the left diagram). Among these 30,016 deployments in which the PDHA listed IZ/AF but CTS did not, 95% listed Kuwait in CTS (data not shown). Consequently, the addition of Kuwait to each measure improved agreement as evidenced by the decreased "PDHA only" portion in the right-side diagram in Figure 1. To verify that Kuwait was in fact the important addition, we also assessed the addition of other countries identified by both the Joint Staff and U.S. Central Command as OEF/OIF/OND-related (e.g. Qatar, Saudi Arabia, Uzbekistan). When substituting other countries of interest for Kuwait, we did not see the improved capture of combat deployments identified via PDHAs.

When we compared CTS country of deployment measures to additional measures of combat deployment, including the self-reported operation from the PDHA (PDHA 3) and combat exposure via the PDHA (PDHA 4), we observed high agreement between CTS and PDHA 3 (B-statistic 0.73–0.86) and moderate agreement between CTS and PDHA 4 (B-statistic 0.47–0.55) (Table 3). However, less than 50% of deployments met CTS, PDHA 3, and PDHA 4 measure definitions simultaneously (Fig. 2). More than 60,000 deployments had self-reported combat exposure and/or an operation of OEF/OIF/OND from the PDHA but did not list IZ/AF in CTS (Fig. 2; see A, B, and C in the left diagram). Of those 60,000, 90% (54,000) were captured by simply adding Kuwait (CTS 2) to the country definition (see reduced A, B, and C in the right diagram).

Validity: Sensitivity calculations

During the three timeframes, 111 battle injuries never matched to a deployment. Among deployments that matched to an injury ($n = 3926$), CTS 1 (country listed as IZ/AF) had high sensitivity in detecting battle injuries (94.5%), with the addition of Kuwait (CTS 2) further improving sensitivity (99.8%) (Table 4). Any self-reported combat exposure (PDHA 4) also had high sensitivity for detecting this criterion (95.3%).

Corroboration: combat-related outcomes

We identified a total of 21,497 incident TBI diagnoses and 17,509 PTSD diagnoses. Deployments that met CTS country measures had

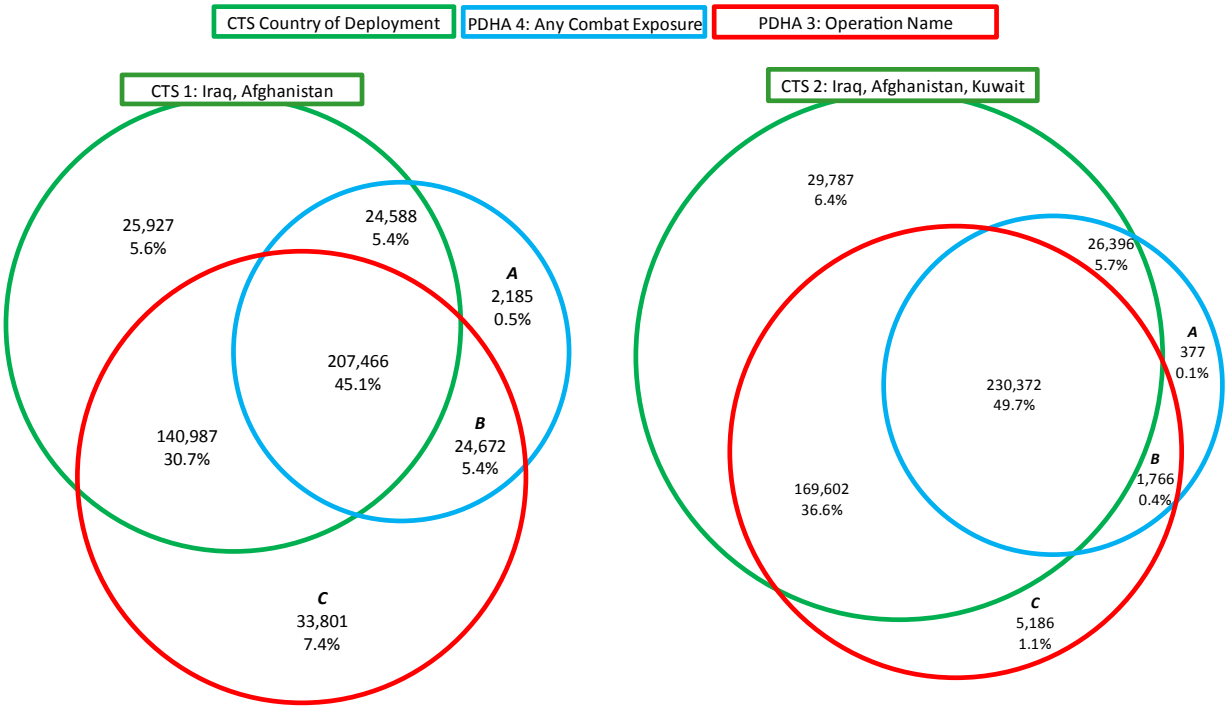

Fig. 2. Percent agreement on measures of combat deployment comparison. The areas displayed in each section of the diagram are meant to show movement in overlap with changing definitions and are not representative of the percentages in the figure.

Table 4
Sensitivity of measures of combat deployment against criterion measure

Measure	Battle injury	
	Sensitivity	95% CI
CTS 1	94.5%	93.8%–95.3%
CTS 2	99.8%	99.7%–99.9%
PDHA 1	77.2%	75.2%–79.2%
PDHA 2	78.9%	77.0%–80.9%
PDHA 3	88.8%	87.4%–90.2%
PDHA 4	95.3%	94.4%–96.2%
PDHA 5	56.2%	53.5%–59.0%

higher incident TBI and PTSD diagnoses than those that did not (Fig. 3A and B). Conversely, deployments that met PDHA country measures had lower incidence than those that did not, although PDHA countries were frequently missing. The difference in incidence of TBI and PTSD for soldiers meeting versus not meeting PDHA combat exposure measures (PDHA 4 and PDHA 5) was higher than the difference in incidence for all other measures, suggesting that these two PDHA combat exposure measures were more predictive of combat-related outcomes.

Discussion

Despite previous sample-based studies, we believe that this was the first study to directly compare and validate measures available in population-level administrative data to identify combat deployments among Army soldiers. This study demonstrated that completeness and accuracy of such measures varied significantly. Our findings indicated that CTS-identified deployment to Iraq, Afghanistan, and/or Kuwait was the most valid and comprehensive measure of deployment to an active war zone, but that PDHA self-report measures (PDHA 4 and 5) were most predictive of combat exposure. We found that CTS-identified deployments to Iraq, Afghanistan, and/or Kuwait (CTS 2) captured over 98% of deployments endorsing combat and self-reporting OEF/OIF/OND on the associated PDHA. The inclusion of CTS deployments to Kuwait increased the accuracy of this measure by capturing an additional 24,000 deployments endorsing any combat exposure in PDHA, over 28,000 with IZ/AF as country of deployment in PDHA, and over 51,000 deployments supporting OEF/OIF/OND in PDHA. These findings were consistent with Kuwait's role in OEF/OIF/OND as the main launching pad for U.S. forces.

Furthermore, the addition of Kuwait allowed for detection of nearly 100% of battle injuries, improving sensitivity from 94.5% to 99.8%. The identification of deployment to Kuwait that resulted in battle injuries further substantiated that at least a portion of soldiers coded as being deployed to Kuwait may in fact experience combat. In addition, given that many deployments did not have a corresponding PDHA, and many PDHAs did not record countries of deployment, using CTS country of deployment enabled the capture of more deployments to an active war zone than PDHA measures alone. The measure of CTS-identified deployments to Iraq, Afghanistan, and/or Kuwait (CTS 2) demonstrated the highest validity in identifying soldiers with combat deployment, as evidenced by battle injuries. Thus, using CTS country of deployment may allow researchers, policymakers, and other decision makers to obtain more accurate estimates of combat deployment among over 1.3 million active duty SMs.

While CTS country of deployment demonstrated the highest validity in identifying soldiers deployed to an active war zone, PDHA combat exposure measures were more predictive of combat-related outcomes, such as PTSD and TBI, consistent with other research indicating that self-reported metrics are better than administrative data for adequately assessing combat exposures.[53,54] However, soldiers who endorsed combat exposures on a PDHA (compared with those who do not) may have been more likely to be referred, receive follow-up care, screening, and a PTSD or TBI diagnosis as a result. Furthermore, researchers should exercise caution when using PDHA country of deployment measures to identify combat deployments, as values in the present study were frequently missing, thereby reducing reliability.

Limitations

The findings of this study should be interpreted with consideration of its limitations. For example, we defined cases of PTSD based on reports of indicator diagnoses (ICD-9-CM) during at least one outpatient or inpatient visit during or within one year of deployment. Such a method of case finding possibly captured PTSD cases outside the context of combat deployment. In addition, for soldiers who had multiple deployments within one of the three timeframes, we limited inclusion to their first deployment in that period which could have resulted in an underestimate of battle injuries, TBI, and PTSD counts. Inherent to studies that use administrative data, misclassification due to coding error may impact results in our study. Deployments may not have had all appropriate countries included in the CTS record, potentially resulting in misclassification of deployments in our measures. For example, deployments to Kuwait, as identified by CTS, that had self-reported combat exposure may have actually been deployments to IZ/AF but were not accurately updated in CTS. In addition, undiagnosed and misdiagnosed cases of TBI and PTSD, as well as incomplete capture or miscoding of battle injuries in TMDS, were also possible. However,

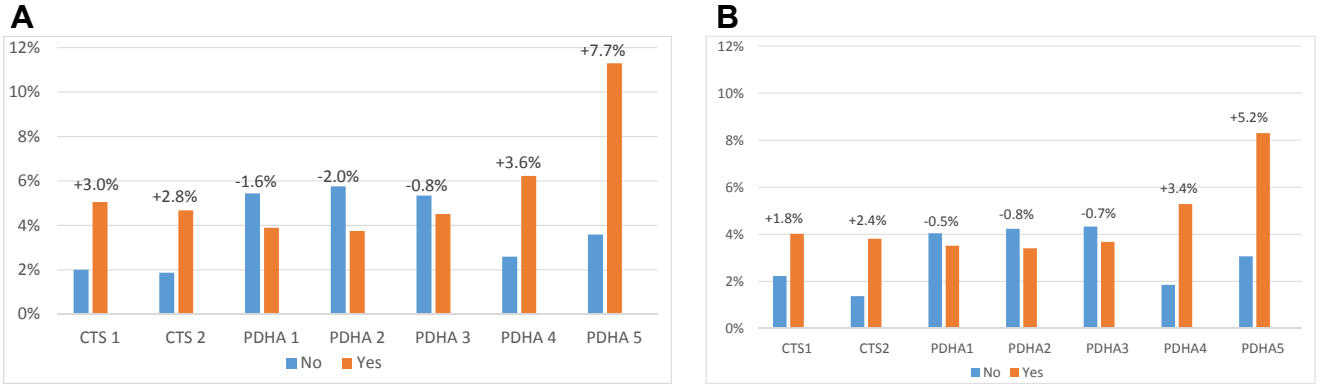

Fig. 3. (A) Difference in incident TBI diagnoses among deployed soldiers, by combat deployment measure. (B) Difference in incident PTSD diagnoses among deployed soldiers, by combat deployment measure.

we applied these definitions uniformly across all combat deployment measures, which should have limited resulting bias. Another limitation of this study was our use of self-report data from the PDHA. Soldiers may not have accurately recalled or reported their actual level of combat experience. Finally, the study was limited to Army soldiers and findings may not be generalizable to other services.

Study strengths and implications

Despite these limitations, our study also had a number of strengths. The large sample size (over 450,000 deployments) allowed us to investigate outcomes with low prevalence rates. In addition, we evaluated not only several commonly used measures of combat deployment but also measures that are routinely collected and accessible in population-level administrative data to researchers, policymakers, and others. Our study provided compelling evidence for researchers and policymakers to use the measure of CTS-identified deployment to Iraq, Afghanistan, and/or Kuwait when identifying deployments to an active war zone with or without combat exposure. Excluding Kuwait or relying on the PDHA could lead to a significant underestimation of the number of SMs who were combat deployed and to imprecise estimates that could have research, policy, and economic implications. For example, given that combat deployment is an important variable relating to mental health and behavioral outcomes, such as PTSD,[7,20,55] depression,[6,55] and substance use disorder,[6,55] accurate identification of such deployments is critical to estimating its psychological impact and the ability to compare results across studies. Based on our findings, explicit and precise definitions of combat deployment are needed in studies examining this variable.

Conclusion

We recommend, based on the findings in this study, that when interested in identifying Army soldiers who were deployed to an active war zone, researchers use CTS-identified deployments to IZ/AF/KU. Furthermore, when researchers are interested specifically in combat experience and exposure, our research indicates that self-reported measures from the PDHA are more predictive of combat-related outcomes than CTS measures, consistent with prior research.[29,42,43] Although population-level administrative variables may appear to be face valid, administrative data may not reliably and validly reflect constructs of interest, given that these data are rarely intended for research purposes. Therefore, establishing the validity of similar variables in administrative data is essential. Given increased reliance on administrative data sets to inform policy decisions, we believe that the approach used in this study can be used by researchers and policymakers who rely on administrative data to assess other types of exposures and experiences. Although our study pertained to U.S. combat deployments, other countries might also consider a similar methodological approach. Future efforts should continue to establish sound methodologies to validate constructs of interest in administrative data, especially when multiple measures are available.

Acknowledgment

The authors thank Dr. Don E. Workman for reviewing and editing their article. The authors are grateful to Dr. Derek Smolenski for his input on their data analysis. The research presented in this paper is that of the authors and does not reflect the official policy of the Department of Defense. No financial disclosures nor conflicts of interest were reported by the authors of this paper.

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