Examining The Relationship Between Sleep And Mental Health Symptoms Across Multiple Deployments In U.S. Military Service Members

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A thesis submitted to the Department of Psychology,
College of Liberal Arts and Social Sciences
in partial fulfillment of the requirements for the degree of

Master of Arts

in Psychology

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University of Houston
December 2019

ACKNOWLEDGMENTS

Material has been reviewed by the Walter Reed Army Institute of Research. There is no objection to its presentation and/or publication. The opinions or assertions contained herein are the private views of the author and are not to be construed as official, or as reflecting true views of the Department of the Army or the Department of Defense. The investigators have adhered to the policies for protection of human participants as prescribed in AR 70–25.

ABSTRACT

Background: Military service members are frequently subjected to occupational and environmental stressors, including non-conducive sleeping environments, shift schedules, and extended deployments overseas. Service members who undergo deployments in particular are at increased risk for mental health symptoms and sleep disturbance. Bidirectional relationships between sleep and mental health are routinely observed, in which poor sleep can increase risk for mental health symptoms, and psychiatric disorders increase risk of developing sleep disturbance; thus, the military population are at elevated risk for both types of problems, given the commonality of repeated and extended deployments. The purpose of the present study was to examine temporal relationships between sleep and mental health symptoms (PTSD, depression, and anxiety) in military service members across the deployment cycle.

Methods: Data from 74 U.S. Army soldiers or activated reserve/U.S. National Guard members case-matched across three time points were used for this study. All participants completed at least one 12-month deployment, with the majority undergoing multiple deployments. Symptoms of PTSD, anxiety, depression, and insomnia were assessed at all three time points.

Results: Cross-lagged hierarchical regression models revealed that, the presence of mental health symptoms (specifically PTSD) predicted subsequent insomnia symptoms, whereas initial symptoms of insomnia did not predict any subsequent mental health outcomes. However, the persistence of insomnia symptoms across the time points served to be the stronger predictor of subsequent mental health symptoms

(specifically PTSD and anxiety) versus the inverse relationship (i.e., persistent mental health symptoms predicting subsequent insomnia symptoms).

Conclusions: The present findings suggest differential associations between sleep and mental health, depending on the chronicity of symptoms. Specifically, chronic as opposed to transient symptoms of insomnia pose a more significant risk factor for the development of PTSD and anxiety. Given the high stress associated with undergoing military deployments, service members may be more susceptible to sleep-onset difficulties due to heightened vigilance, which may in turn lead to increased risk for hyperarousal-related psychopathology. These results highlight a potential target in preventing the onset of these conditions.

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Examining The Relationship Between Sleep And Mental Health Symptoms Across Multiple Deployments In U.S. Service Members

Healthy sleep hygiene is an important part of good health; in fact, the American Academy of Sleep Medicine (AASM) and the Sleep Research Society (SRS) jointly developed a consensus statement recommending adults receive no less than seven hours of sleep per night for optimal health (Consensus Conference Panel et al., 2015). The Centers for Disease Control (CDC) further emphasize that sleep duration, timing, and quality are all critical determinants of health. Unfortunately, national surveys find that between 35 to 44% of Americans report getting less than seven hours of sleep per night (Centers for Disease & Prevention, 2011; National Sleep Foundation, 2008), and 64% cannot correctly answer all three general sleep knowledge statements (i.e., "Do adults need fewer hours of sleep the older they get?", "Do successful people need less sleep than the average person?", "Does alcohol improve sleep quality?"; National Sleep Foundation, 2014), implying a lack of basic sleep education.

Sleep in the Military

Within the military, quality sleep is one of three components (along with physical activity and healthy nutrition) included in the U.S. Army Surgeon General's *Performance Triad* public health initiative to achieve "optimal soldier performance and health" (Caravalho, 2015). Military service members are highly vulnerable to inadequate sleep due to increased stress, non-conducive sleeping environments in 24-hour duty stations, shift schedules, etc. (Ferrer, Bisson, & French, 1995; Kryger, Pouliot, Peters, Neufeld, & Delaive, 2003). Those who are subject to deployments overseas are especially susceptible to sleep disturbance; Peterson et al. (2008) found that 74.4% of Air Force members rated their sleep quality as "significantly worse in the deployed setting" (Peterson, Goodie, Satterfield, & Brim, 2008). In

another comparison study, service members who were currently or had previously deployed reported shorter sleep duration than those who had never been deployed (Seelig et al., 2010). The minimum total sleep time (TST) required to maintain performance during military deployments is considered to be 4.5 hours (Peterson et al., 2008), considerably less than what is regularly recommended (i.e., seven or more hours). Although incommodious sleeping accommodations are akin to active combat deployment zones, the substantial number of military members who report worse sleep quality during deployments suggests that the limited time allotted for sleep is not enough to achieve a restful and alert state.

Effects of Sleep Loss

The deleterious effects of both acute and chronic sleep loss have been well documented in both military and civilian populations to include impaired cognitive performance and decision-making and decreased alertness and reactivity (Pilcher & Huffcutt, 1996) as well as adverse health effects, such as weight gain, cardiovascular disease, worsened immune function and higher blood pressure (Consensus Conference Panel et al., 2015). A relationship between sleep and emotion is also strongly established, as lack of sleep can lead to an increase in negative affect, such as depressive mood and anxiety, in otherwise healthy individuals (Cutler & Cohen, 1979; Franzen, Siegle, & Buysse, 2008; Kahn, Sheppes, & Sadeh, 2013). In fact, a meta-analytic study showed sleep deprivation to more intensely affect mood than cognitive and motor performance (Pilcher & Huffcutt, 1996). Chronic sleep loss is especially detrimental, as cognitive and emotional deficits are known to progressively worsen until sufficient recovery sleep has been achieved (Banks & Dinges, 2007).

At a neurobiological level, functional magnetic resonance imaging (fMRI) research has demonstrated that sleep deprivation leads to a significant increase in amygdala activation in

response to negatively-valenced stimuli, as well as a decrease in connectivity between the amygdala and the medial prefrontal cortex (mPFC) (Yoo, Gujar, Hu, Jolesz, & Walker, 2007); these results suggest that sleep loss amplifies the typical amygdalar response, particularly to negative stimuli, and that sufficient sleep may be vital in "resetting" the emotional information processing system from the previous day's challenges. In the case of deployed service members, this implies that their susceptibility to disturbed and/or restricted sleep may in turn lead to inefficient emotional processing of any combat-related exposure they experience.

Mental Health in the Military

In fact, it has been reported that between 19% to nearly 37% (Hoge, Auchterlonie, & Milliken, 2006; Seal et al., 2009) of Iraq and Afghanistan veterans meet the risk criteria for a mental health diagnosis, with variances likely due to differences in diagnostic criteria and combat exposure between deployment settings. Disparity in diagnostic rates could also be attributed to when the post-deployment assessment took place. Longitudinal studies have found soldiers report significantly higher rates of mental health concerns during a re-screening several months after returning from deployment compared to an initial screening (Bliese, Wright, Adler, Thomas, & Hoge, 2007; Milliken, Auchterlonie, & Hoge, 2007). Although the utilization of mental health services has generally increased and the stigma of mental health issues has decreased over the years (Quartana et al., 2014), the majority of service members who are diagnosed with mental health problems still do not seek services for treatment (Hoge et al., 2006; Quartana et al., 2014; Sareen et al., 2007), and half of those who do seek treatment receive "minimally adequate care" (Hoge et al., 2014). These statistics are alarming, particularly because of the dose-dependent relationship found between the number of combat experiences and meeting the screening criteria for any psychological problem (Dohrenwend et

al., 2006; Kline et al., 2010; Office of the Surgeon General, 2013). Given that the present rate of deploying is projected to be nearly five times higher than the rate of deploying 20 years ago (Adler, Huffman, Bliese, & Castro, 2005), not only do repeated, extended deployments seem to be commonplace in military life, but present-day service members are now at increased risk for adverse health outcomes as a result (Kline et al., 2010). Further, receiving inefficient or ineffective mental health care in between repeated deployments is likely to exacerbate these problems.

Sleep and Mental Health

Given the well-established relationship between sleep and emotion (Kahn et al., 2013), it is unsurprising that sleep problems are symptoms of many mental health disorders included in the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5; American Psychiatric Association, 2013) For instance, over 70% of patients with posttraumatic stress disorder (PTSD) report some degree of sleep disturbance (Ohayon & Shapiro, 2000). In fact, insomnia and nightmares are some of the most commonly reported symptoms in those diagnosed with PTSD (Germain, 2013), and poorer sleep in those with PTSD consequently leads to worsened perceptions of one's mental health (Belleville, Guay, & Marchand, 2009). Moreover, a study examining cognitive-behavioral treatment for PTSD found that persistent sleep disturbance (i.e., pre- and post-treatment) was associated with more severe posttraumatic stress, anxiety, and depressive symptoms post-treatment (Belleville, Guay, & Marchand, 2011). It is possible that persistent sleep disturbance impedes the recovery process and/or effectiveness of psychological treatments (Germain, 2013). Therefore, it is important to investigate how the persistence of sleep problems over time (i.e., not just the presence or absence of symptoms at a given time point) relates to health outcomes in service members.

Insomnia that co-occurs with a mental health disorder is now considered to be a distinct clinical entity (Wright et al., 2011b), owing to a wealth of research showing insomnia to be impairing in its own right. Relationships between sleep and mental health are nonetheless robust with bidirectional relationships routinely observed; disturbed sleep poses increased risk for mental health symptoms, and psychiatric disorders increase risk of developing sleep disturbance (Alvaro, Roberts, & Harris, 2013). Still, inconsistencies in the nature and strength of these relationships are notable. For instance, Morphy, Dunn, Lewis, Boardman & Croft (2007) found statistically significant bidirectional relationships between insomnia and both depression and anxiety, but depression was a stronger predictor and outcome of insomnia. Jansson & Lindholm (2008) also observed bidirectional relationships, but noted that anxiety was the strongest predictor of future insomnia, whereas insomnia was the strongest predictor of future depression. Relatedly, Buysse et al. (2008) prospectively examined insomnia in conjunction with depression over a 20-year period, observing that insomnia alone and insomnia comorbid with depression best explained subsequent depression versus the inverse.

Within military populations, there have been several studies that investigated the association between sleep disturbance and mental disorders, but relatively few have attempted to parse the directionality of this relationship using longitudinal data. One cross-sectional study found that the prevalence of insomnia was 19.9% in active-duty soldiers prior to deployment (underscoring an increased risk of service members in developing sleep disturbance, even in their usual working environment) and that those with insomnia concurrently self-reported "more severe mental health symptoms" (Taylor et al., 2016). Other research has shown sleep symptoms to act as a mediator between combat stressors and the development of mental health symptoms post-deployment (Macera, Aralis, Rauh, & MacGregor, 2013; Picchioni et al.,

2010). In examining metrics of overall health resilience, Seelig et al. (2016) found that insomnia symptoms were associated with worse outcomes (e.g., lower self-rated health, more lost work days, and higher odds of early military service discharge), highlighting the importance of sleep as a predictor of resilience in the military.

One of only a few longitudinal studies (Gehrman et al., 2013; Wright et al., 2011b), Wright et al (2011) examined symptoms of insomnia as both a predictor of and an outcome associated with PTSD and depressive symptoms in U.S. Army soldiers. Results indicated self-reported insomnia symptoms at 4 months post-deployment significantly predicted PTSD and depressive symptoms at 12 months post-deployment. However, inverse relationships were non-significant; PTSD and depressive symptoms at 4 months post-deployment did not significantly predict insomnia symptoms at 12 months post-deployment (Wright et al., 2011b).

To our knowledge, this has been the only longitudinal study to investigate sleep and mental health relationships in relation to deployment, with findings suggesting poor sleep to be a stronger predictor of worsened mental health problems than the inverse. Although the study by Wright et al. has many strengths (e.g., use of a cross-lagged panel design that controlled for the correlation between constructs at the same time points), many questions remain to be addressed including how sleep, particularly persistent sleep disturbance, prior to a military deployment affects post-deployment mental health, and similarly, how persistent mental health symptoms prior to a military deployment affect sleep post-deployment.

Present Study & Specific Aims

The purpose of the present study was to address these questions by investigating temporal relationships between sleep and mental health symptoms in a large sample of active-duty and activated reserve US service members across multiple time points. Specifically, we

assessed the impact of sleep and mental health symptoms at two pre-deployment periods on the same domains of functioning post-deployment. The aims of this study were as follows:

Aim 1: To examine the presence and persistence of insomnia symptoms at two pre-deployment assessments 6 months apart as predictors of changes in mental health symptoms following a subsequent deployment. Controlling for mental health symptoms at pre-deployment, we hypothesized symptoms of insomnia (i.e., difficulty falling and/or staying asleep) at either pre-deployment assessment to forecast mental health symptoms (PTSD, depression and anxiety) post-deployment, but those who report poor sleep at both pre-deployment assessments (i.e., persistent insomnia symptoms) will exhibit the most severe mental health symptoms at the post-deployment assessment.

Aim 2: To examine the presence and persistence of mental health symptoms at two pre-deployment assessments 6 months apart as predictors of changes in insomnia symptoms following subsequent deployment. Controlling for insomnia symptoms at pre-deployment, we hypothesized that chronically elevated mental health symptoms (PTSD, depression and anxiety) across the two pre-deployment time points will lead to worse sleep at post-deployment.

Aim 3: To estimate and compare the strength (i.e., temporal precedence) of directional relationships between insomnia and mental health symptoms across the deployment cycle. Consistent with previous research, we hypothesized that persistence in insomnia symptoms will be a stronger predictor of subsequent mental health, rather than the inverse relationship.

METHOD

Data Sources

Data were collected under the ongoing second Land Combat Study (LCS II) conducted by the Walter Reed Army Institute of Research (WRAIR)—this study is broadly investigating the impact of deployment and combat experiences on the mental health and well-being of military service members and their families through both cross-sectional and longitudinal methods. Service members and/or spouses completed survey questions that encompassed a variety of domains, such as demographic information, behavioral/physical health outcomes, interpersonal/occupational functioning, risk/protective factors and barriers, and indicated whether they allow their responses to be used for research purposes.

Participants

Participants used in the present study were part of a larger study among active-duty U.S. Army soldiers or activated reserve/U.S. National Guard members from an Infantry Division who were assessed at three separate time points. At Time 1 (T1; June, 2009), a total of 1,586 service members were surveyed. At Time 2 (T2; December, 2009), a total of 2,063 were surveyed. At Time 3 (T3; October, 2011), a total of 2,971 were surveyed. For the current study, case-matching across all three time points (i.e., T1, T2, and T3) was used. A total of 77 service members completed all three assessments (after accounting for attrition and missing data).

Three service members (n = 3) reported having never deployed at the T3 assessment and were therefore excluded from analyses, yielding a final sample size of N = 74. The sample was primarily male (n = 71, 95.9%), and the majority of participants were between the ages of 20-29 (n = 59, 79.7%). At T1 and T2, the majority of service members surveyed were of junior enlisted rank (E1-E4; n_{T1} = 53, 71.6%; n_{T2} = 49, 66.2%), while at T3, half of service members surveyed were non-commissioned officers (NCO; E5-E9; n_{T3} = 37, 50%). Service members

served an average of 3.74 (*SD* = 4.55) years at T1, an average of 4.41 (*SD* = 4.64) years at T2, and an average of 7.35 (*SD* = 7.11) years at T3.

At T1 and T2, 37.8% of service members (*n* = 28) reported no previous deployments. Those who did deploy previously (*n* = 46) completed one deployment on average lasting more than 30 days and were deployed an average of 15.17 (*SD* = 7.31) months since September 11, 2001. The most recent deployment location was to Iraq, during which service members endorsed an average of 10 (*SD* = 5.51) combat experiences. The entire sample completed a deployment between T2 and T3 to Iraq (from July 2010-July 2011). Thus, at T3, all participants had undergone at least one military deployment. Service members endorsed an average of 3.12 (*SD* = 3.80) combat experiences during this deployment. Full demographic characteristics of the sample are in Table 1.

Measures

Deployment History/Combat Exposure. Deployment history was assessed via a questionnaire inquiring about previous deployments including location and duration of all deployments since September 11, 2001. Service members also reported about their combat exposure during their most recent deployment (Hoge et al., 2004; Wilk et al., 2010). Responses ranged from 1 ("Never") to 4 ("Five or more times"). Each item is dichotomized into 0 "Never" and 1 "Once or more", and all combat experiences are summed to generate a total "combat exposure" score.

Posttraumatic Stress Disorder (PTSD). Symptoms of posttraumatic stress disorder (PTSD) were assessed via the Posttraumatic Stress Disorder Checklist (PCL). The PCL is a 17-item questionnaire that assesses PTSD diagnostic criteria from the Diagnostic and Statistical Manual, 4th edition (DSM-IV), with a total score range from 17 to 85. Response

options ranged in severity from 1 (“Not at all”) to 5 (“Extremely”). Participants were prompted to respond to a list of reactions “sometimes experienced following deployment or in response to other stressful life experiences”. Broad diagnostic criteria are met if participants reported at least one intrusion symptom, three avoidance symptoms, and two hyperarousal symptoms at the moderate level. Two questions assessing difficulty falling/staying asleep and having disturbing dreams were omitted in the primary analyses. The PCL demonstrated excellent internal consistency in the present sample across all three time points (α at T1 = .91, α at T2 = .95, α at T3 = .92).

Depression. Participants were screened for symptoms of depression via the Patient Health Questionnaire-9 (PHQ-9; (Kroenke, Spitzer, & Williams, 2002). This nine-item scale assesses depressive symptom severity, ranging from 1 (“Not at all”) to 4 (“Nearly every day”). The original scale from Kroenke & Spitzer (2002) assesses symptoms over the past two weeks as congruent with DSM criteria; however, for the purposes of military research, the present scale has been modified to assess symptoms over the past month. Broad diagnostic criteria for Major Depressive Disorder (MDD) are met if participants endorsed at least five symptoms, including “Feeling down, depressed, or hopeless” or “Having little interest in doing things” for more than half of the days throughout the past month. Symptom severity is measured by recoding items from 0 to 3 and summing the item scores, with a total score ranging from 0 to 27. One question assessing difficulty falling/staying asleep was omitted in the primary analyses. The PHQ demonstrated good internal consistency in the present sample across the three time points (α at T1 = .87, α at T2 = .86, α at T3 = .88).

Anxiety. Participants were screened for symptoms of Generalized Anxiety Disorder (GAD) via the Generalized Anxiety Disorder 7-Item Scale (GAD-7; Spitzer, Kroenke,

Williams, & Lowe, 2006); items range in severity from 1 ("Not at all") to 4 ("Nearly every day"). Like the modified PHQ-9, the GAD-7 has been modified from assessing symptoms over the past two weeks to assessing symptoms over the past month. Again, items were recoded from 0 to 3 and then summed to assess symptom severity, with a total score range from 0 to 21. Broad diagnostic criteria for GAD is yielded by a score of greater than or equal to 10. This measure contains no sleep-related items; thus, the complete scale was used in the primary analyses. The GAD-7 demonstrated good to excellent internal consistency in the present sample across all time points (α at T1 = .94, α at T2 = .91, α at T3 = .86).

Subjective Sleep Disturbance. Symptoms of insomnia were assessed through two questions added to the Patient Health Questionnaire-15 (PHQ-15), a well-validated and reliable self-report measure in evaluating the severity of the most prevalent somatic symptoms from the DSM-IV (Kroenke et al., 2002). The original PHQ-15 asked the degree to which patients have been bothered by trouble sleeping during the past month, ranging from 0 ("Not bothered") to 2 ("Bothered a lot"). The two added questions expanded upon this by separately asking how much participants have been bothered by 1) difficulty falling asleep; and 2) difficulty staying asleep. Participants screened positive for insomnia-like symptoms if they reported being "bothered a lot" to either question. An index of self-reported insomnia symptoms was calculated by summing the responses to these two items, with the total score ranging from 0 to 4. The questions assessing insomnia severity showed good to excellent internal consistency in the present sample across the time points (α at T1 = .91, α at T2 = .88, α at T3 = .89).

Procedures

The Study timeline is outlined in *Figure 1*. As reported, majority of service member participants (n = 46) returned from a 12-month deployment approximately 6 months prior to

T1 (deployment from December 2007 to December 2008) in support of Operation Iraqi Freedom (OIF). The T1 assessment included multiple surveys encompassing a variety of topics regarding soldier well-being and health (see Measures section). Six months after T1, service members completed the T2 assessment including the same surveys as T1. Seven months later in July 2010, the entire sample deployed to Iraq for 12 months (from July 2010 to July 2011). Three months after returning from this deployment and 15 months after T2, service members completed the final T3 assessment including the same measures at T1 and T2.

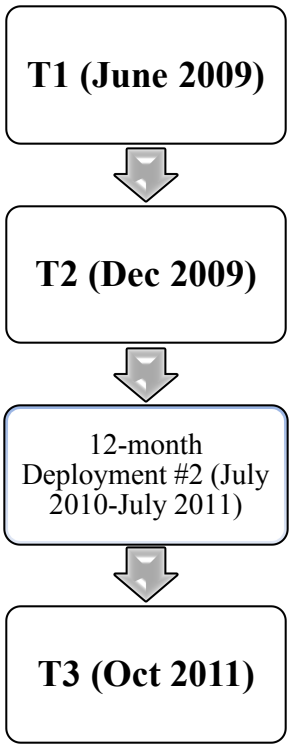

Figure 1. Assessment Timeline: T1 = Time point 1; T2 = Time point 2; T3 = Time point 3.

Institutional Review

The original study was approved by the WRAIR Human Subjects Protection Branch, which waived the documentation of informed consent in accordance with 32 Code of Federal

Regulations (CFR) §219.117 paragraph (c) (2). The present study was approved by the University of Houston Institutional Review Board (IRB).

Data Analytic Plan

Preliminary Data Analysis. First, descriptive statistics were calculated for demographic, sleep and psychosocial variables of interest. Preliminary analyses were also conducted using t-tests, analyses of variance (ANOVA), and zero-order correlations to examine associations between demographic, sleep and psychosocial variables (e.g., age, military rank, deployment history, etc.) with the following outcome variables: 1) mean scores of mental health and insomnia symptoms at each time point; 2) changes in mental health and insomnia symptoms between T1 and T2; and 3) changes in mental health and insomnia symptoms between T2 and T3.

Analytic Strategy. A series of cross-lagged hierarchical regression analyses were conducted in order to examine relationships among the variables of interest across the different time points. These analyses allowed for assessing temporal associations while simultaneously covarying for extraneous variance (Kenny, 1975). A general cross-lagged panel design is depicted in *Figure 2*, and illustrates two sources of extraneous variance: autocorrelations (A) indicate the correlation between the same variable at different time points, while synchronous correlations (B) indicate the correlation between different variables at the same time point. In order to examine how changes in sleep at one time point uniquely predict mental health outcomes at a later time point (and vice versa), autocorrelations and synchronous correlations must be included in the model.

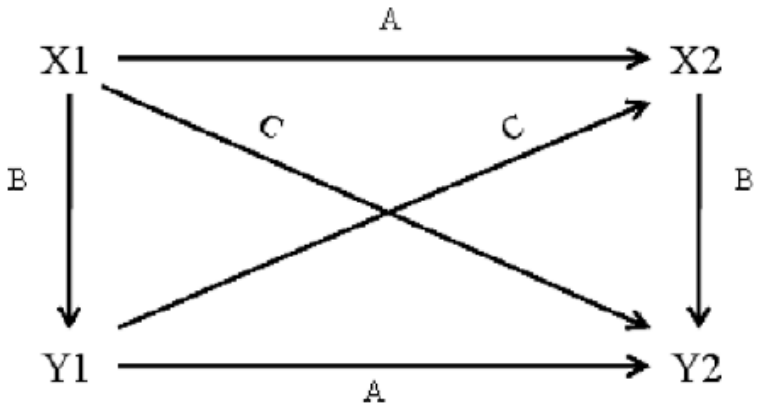

Figure 2. General cross-lagged panel design: X1 = Variable 1 at time 1; X2 = Variable 1 at time 2; Y1 = Variable 2 at time 1; Y2 = Variable 2 at time 2; A = Autocorrelations; B = Synchronous correlations; C = Cross-lagged correlations.

Aim 1: To examine the presence and persistence of insomnia symptoms at two pre-deployment assessments 6 months apart (T1 and T2) as predictors of mental health symptoms following a subsequent deployment (T3). First, a simple cross-lagged model was conducted with the following variables: Sleep1 = Insomnia symptoms at T1, MH1 = Mental health symptoms at T1, Sleep2 = Insomnia symptoms at T2, and MH2 = Mental health symptoms at T2 (see *Figure 3)*. This allowed us to initially examine insomnia symptoms as predicting mental health across the 6-month "recovery" period following Deployment #1, while simultaneously examining the strength of autocorrelations and synchronous correlations.

Next, to examine whether the presence of pre-deployment insomnia symptoms (i.e., at T2) independently predicts post-deployment mental health (i.e., at T3), a second simple cross-lagged model was conducted with the following variables: Sleep2 = Insomnia symptoms at T2, MH2 = Mental health symptoms at T2, Sleep3 = Insomnia symptoms at T3, and MH3 = Mental health symptoms at T3 (see *Figure 4*).

Finally, to examine whether persistent insomnia symptoms independently predicts pre- to post-deployment changes in mental health symptoms, two unstandardized residual change scores were computed: the first examined changes in insomnia symptoms during the first two time points following Deployment #1 (i.e., T1 and T2); the second examined changes in mental health pre- and post-Deployment #2 (i.e., T2 and T3). Associations between these residual scores were then examined in a secondary cross-lagged model with the following variables: SleepΔ1 = Changes in insomnia symptoms between T1 and T2, MHΔ1 = Changes in mental health between T1 and T2, SleepΔ2 = Changes in insomnia symptoms between T2 and T3, and MHΔ2 = Changes in mental health between T2 and T3 (see *Figure 5*).

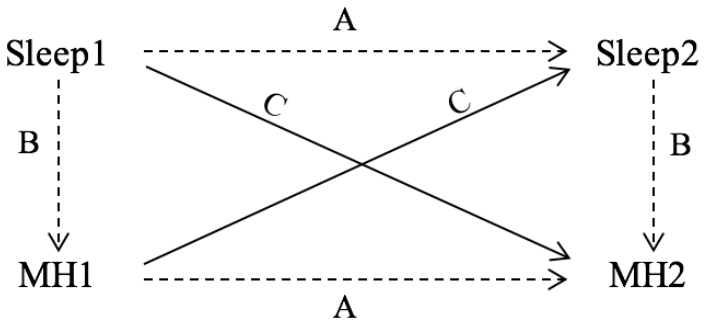

Figure 3. Associations between insomnia symptoms and mental health across the 6-month "recovery" period following Deployment #1: Sleep1 = Insomnia symptoms at T1; MH1 = Mental health symptoms at T1; Sleep2 = Insomnia symptoms at T2; MH2 = Mental health symptoms at T2; A = Autocorrelations; B = Synchronous correlations; C = Cross-lagged correlations.

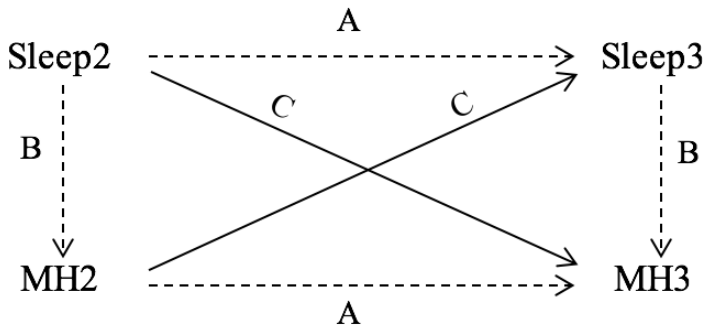

Figure 4. Associations between insomnia symptoms and mental health pre- and post-Deployment #2: Sleep2 = Insomnia symptoms at T2; MH2 = Mental health symptoms at T2; Sleep3 = Insomnia symptoms at T3; MH3 = Mental health symptoms at T3; A = Autocorrelations; B = Synchronous correlations; C = Cross-lagged correlations.

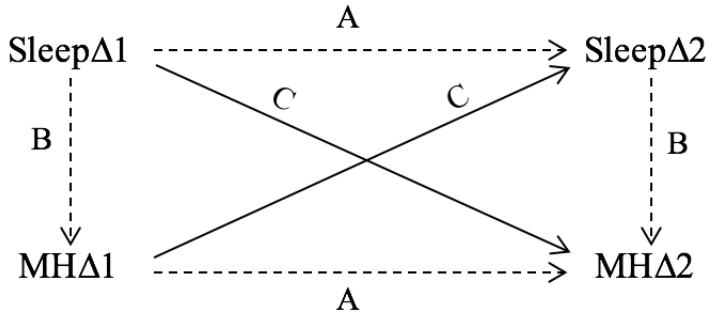

Figure 5. Associations between changes in sleep and mental health post-Deployment #1 and changes in insomnia symptoms and mental health across Deployment #2: SleepΔ1 = Changes in insomnia symptoms from T1 to T2; MHΔ1 = Changes in mental health symptoms from T1 to T2; SleepΔ2 = Changes in insomnia symptoms from T2 to T3; MHΔ2 = Changes in mental health symptoms from T2 to T3; A = Autocorrelations; B = Synchronous correlations; C = Cross-lagged correlations.

Aim 2: To examine the presence and persistence of mental health symptoms at two pre-deployment assessments 6 months apart (T1 and T2) as predictors of insomnia

symptoms following subsequent deployment (T3). First, the first simple cross-lagged model from Aim 1 (*Figure 3)* was used to initially examine mental health symptoms as predicting insomnia symptoms across the 6-month "recovery" period following Deployment #1, while simultaneously examining the strength of autocorrelations and synchronous correlations

Next, the second simple cross-lagged model from Aim 1 (*Figure* 4) will be used to examine whether the presence of pre-deployment mental health symptoms (i.e., at T2) independently predicts post-deployment insomnia symptoms (i.e., at T3).

Finally, to examine whether persistent mental health symptoms independently predict pre- to post-deployment changes in insomnia symptoms, two unstandardized residual change scores were computed: the first examined changes in mental health during the first two time points following Deployment #1 (i.e., T1 and T2); the second examined changes in insomnia symptoms pre- and post-Deployment #2 (i.e., T2 and T3). Associations between these residual scores were then examined in the same secondary cross-lagged model as Aim 1 (*Figure 5*).

Aim 3: To estimate and compare the strength of directional relationships between insomnia symptoms and mental health symptoms across periods of the deployment cycle. Strengths of directional relationships between variables of interest were estimated by comparing effect sizes for each association. Because the purpose of the study was to examine which variable is the stronger predictor (i.e., symptoms of insomnia or mental health symptoms), the strengths of both effect sizes were compared equally.

RESULTS

Missing Data

At T1, approximately 4% of participants were missing all items from at least one mental health scale, while an additional 1% were missing one item. At T2, approximately 5% of participants were missing all items from the PCL, while an additional 5% were missing 1-2 items on at least one mental health scale. At T3, approximately 1% of participants were missing all items from the PCL, while an additional 7% were missing 1-2 items on at least one mental health scale. Thus, over the course of the three time points, eight participants were missing at least one mental health scale, and an additional eight participants were missing 1-2 items on at least one mental health scale. Participants with whole scales missing were omitted from analyses requiring that variable. Given that individually missing items were determined to be missing at random and contributed to less than 20% of the respective scales, they were imputed using person-mean imputation (Bono, Ried, Kimberlin, & Vogel, 2007; Downey & King, 1998).

Descriptive Statistics for Study Variables

PTSD. At T1, participants reported an average PCL score of 24.53 (*SD* = 10.38), with 5.4% meeting screening criteria for PTSD (i.e., at least one intrusion symptom, three avoidance symptoms, and two hyperarousal symptoms at the moderate level). At T2, participants reported an average PCL score of 24.75 (*SD* = 11.27), with approximately 8% meeting screening criteria for PTSD. At T3, participants reported an average PCL score of 25.25 (*SD* = 11.09), with 5.4% meeting broad screening criteria for PTSD.

Depression. At T1, participants reported an average PHQ-9 score of 3.15 (*SD* = 4.72), with approximately 8% meeting screening criteria for MDD (i.e., endorsement of at least 5 symptoms, including depressed mood or anhedonia, for more than half of the days). At T2, participants reported an average PHQ-9 score of 2.92 (*SD* = 4.37), with 1.4% meeting broad

screening criteria for MDD. At T3, participants reported an average PHQ-9 score of 3.99 (*SD* = 5.13), with approximately 7% meeting screening criteria for MDD.

Anxiety. At T1, participants reported an average GAD-7 score of 3.18 (*SD* = 4.99), with approximately 12% meeting broad screening criteria for GAD (i.e., scored ≥ 10 on the GAD-7). At T2, participants reported an average GAD-7 score of 2.80 (*SD* = 4.36), and approximately 11% met broad screening criteria for GAD. At T3, participants reported an average GAD-7 score of 3.17 (*SD* = 4.20), with 9.5% meeting broad screening criteria for GAD.

Subjective Sleep Disturbance. Across all three time points, between 70-80% of participants reported needing 6 or more hours of sleep per day in order to feel well rested, but the majority (55-69%) reported receiving 5 or fewer hours of sleep per day during the past week. Accordingly, while 20-23% of participants met broad screening criteria for insomnia-like symptoms, 85-88% screened positively for receiving insufficient sleep.

Preliminary Analyses

Independent samples *t*-tests were conducted to identify differences in relevant study variables based on deployment history at T1. Unsurprisingly, there were significant between-group differences in years in the military ($t(69) = -4.72$, $p < .001$), such that the previously deployed group tended to have more years of military service compared to those who had never deployed at T1. In terms of mental health symptoms, the previously deployed group reported significantly higher PCL scores at T1 ($t(65) = -2.10$, $p = .04$) and at T3 ($t(66) = -2.36$, $p = .02$) than non-deployers, coinciding with post-deployment assessment points. Interestingly, at T2, PCL scores among previous-deployers and non-deployers were not statistically different (primarily because non-deployers reported increased PCL symptoms compared to at T1).

There were no statistically significant differences in depression, anxiety, or insomnia symptoms among the deployed and non-deployed groups at each time point.

Zero-order correlations between relevant psychosocial variables and study variables across all three time points are reported in Table 4. PCL and PHQ-9 total scores (omitting the sleep-related items) were used. Years in the military and number of deployments completed did not significantly correlate with any other variable. However, total months deployed at both T1 and T3 were positively associated with PCL scores across all three time points (r's = .24 to .35, p's < .05), although effect sizes were small to moderate. Total months deployed at T3 was also positively associated with PHQ-9 scores at T3 (r = .32, p = .006). Number of combat experiences were positively associated with PCL scores (r's = .34 to .53, p's ≤ .005), as well as GAD-7 scores (r's = .27 to .33, p's < .03) across the time points; however, this variable was significantly correlated with PHQ-9 scores at T3 only (r = .33, p = .004). Mental health and insomnia symptom scores were significantly inter-correlated at each time point (r's = .38 to .82, p's < .01), and respective symptom scores were significantly correlated across the three time points (r's = .33 to .57, p's < .01).

Separate three-factor (T1, T2, T3) repeated-measures ANOVAs did not produce statistically significant results across time for all variables of interest, indicating that mean symptom scores did not vary significantly between time points in the full sample. A mixed-design (i.e., deployment group x time point) ANOVA was then conducted to examine outcome variables across time based on T1 deployment status (i.e., previous versus no previous deployments). For PTSD and anxiety symptoms, as well as sleep time discrepancy, there were no statistically significant effects for time or the interaction (group x time). There was a statistically significant interaction for depressive symptoms ($F(2, 140) = 3.82$, p = .02). These

results indicate that depressive differed across time for previous deployers vs. non-deployers. Follow-up paired t-tests with a Bonferroni correction indicated that among non-deployers, there were no statistically significant changes in depressive symptoms across time. Conversely, among previous deployers, there was a statistically significant increase in depressive scores from T2 to T3 ($t(45) = -3.20$, $p = .003$). Correlations among unstandardized residual change scores (i.e., change in study variables between T1-T2 and T2-T3) are reported in Table 4. Change scores between T1-T2 were all significantly moderately inter-correlated (r's = .34 to .68, $p < .01$). With the exception of PTSD and insomnia symptoms ($r = .17$, $p > .05$), all other change scores between T2-T3 were significantly correlated with each other (r's = .46 to .72, p's < .01). These results indicate that residual changes in symptom scores were positively associated with each other.

Cross-Lagged Hierarchical Regression Analyses

In order to minimize overlapping symptoms between insomnia and mental health outcomes (i.e., shared content variance), PCL and PHQ-9 total scores omitting the sleep disturbance items were used in the current analyses. Inclusion of the sleep-related items did not change the pattern of results, but strengthened the effects.

Aim 1: To examine the presence and persistence of insomnia symptoms at two pre-deployment assessments 6 months apart (T1 and T2) as predictors of mental health symptoms following a subsequent deployment (T3). Cross-lagged models with T2 mental health symptoms (i.e., PTSD, depression, and anxiety) as criterion variables revealed that, independent of respective mental health symptoms at T1 and insomnia symptoms at T2, insomnia symptoms at T1 was not a significant predictor of any mental health outcome at T2. Specifically, in the first step of the model, mental health symptoms at T1 and insomnia

symptoms at T2 accounted for between 29-54% of the variance. In the second step, insomnia symptoms at T1 accounted for between 0-1% of the variance (see Table 6 for complete T1 to T2 cross-lagged analyses).

Next, cross-lagged models with mental health symptoms at T3 as criterion variables showed that insomnia symptoms at T2 was not a unique predictor of any mental health outcome at T3. In the first step, mental health symptoms at T2 and insomnia symptoms at T3 accounted for between 27-38% of the variance. In the second step, insomnia symptoms at T3 accounted for between .3-1% of the variance (see Table 7 for complete T2 to T3 cross-lagged analyses).

Finally, cross-lagged models examining T2-to-T3 residualized changes (**Δ**2) in mental health symptoms revealed that, independent of T1-to-T2 changes (**Δ**1) in respective mental health symptoms and **Δ**2 insomnia symptoms, **Δ**1 insomnia symptoms was a significant predictor of **Δ**2 anxiety symptoms ($\boldsymbol{\beta}$ = .25, p = .03) accounting for 5% of the variance in anxiety scores. This suggests that greater increases in insomnia symptoms between T1 and T2 uniquely predicted elevations in anxiety between T2 and T3. However, **Δ**1 insomnia symptoms was not a significant predictor of **Δ**2 depressive symptoms or PTSD symptoms beyond **Δ**1 mental health and **Δ**2 insomnia (see Table 8 for complete **Δ**1-**Δ**2 cross-lagged analyses). For all models, the addition of deployment status at T1 did not improve model fit.

Aim 2: To examine the presence and persistence of mental health symptoms at two pre-deployment assessments 6 months apart (T1 and T2) as predictors of insomnia following subsequent deployment (T3). Cross-lagged models with insomnia symptoms at T2 as the criterion variable revealed that, independent of insomnia symptoms at T1 and respective mental health symptoms at T2, only PTSD symptoms at T1 was a statistically significant predictor of T2 insomnia symptoms. However, this was in the opposite direction as predicted;

specifically, greater PTSD symptoms at T1 was associated with fewer insomnia symptoms at T2 ($\boldsymbol{\beta}$ = -.26, p = .04). In the first step of the model, insomnia symptoms at T1 and PTSD symptoms at T2 accounted for 31% of the variance, while in the second step, PTSD symptoms at T1 accounted for 4% of the variance. Depressive and anxiety symptoms at T1 were not statistically significant predictors of T2 insomnia symptoms ($\boldsymbol{\beta}$ = -.19, p = .09 and $\boldsymbol{\beta}$ = -.17, p = .12 respectively), each accounting for 2% of the variance (see Table 6).

Next, models with insomnia symptoms at T3 as the criterion variable showed that only PTSD symptoms at T2 was a unique predictor; specifically, greater PTSD symptoms at T2 was associated with greater insomnia symptoms at T3 ($\boldsymbol{\beta}$ = .26, p = .02). In the first step, insomnia symptoms at T2 and PTSD symptoms at T3 accounted for 27% of the variance, while in the second step, PTSD symptoms at T2 accounted for 5% of the variance. Depressive and anxiety symptoms at T2 were not statistically significant predictors ($\boldsymbol{\beta}$ = .11, p = .35 and $\boldsymbol{\beta}$ = .02, p = .84 respectively), and accounted for between 0-1% of the variance (see Table 7).

Finally, models with T2-to-T3 changes (**Δ**2) in insomnia symptoms as the criterion variable revealed that independent of T1-to-T2 changes (**Δ**1) in insomnia symptoms and **Δ**2 in respective mental health symptoms, no **Δ**1 mental health symptoms were significant predictors of **Δ**2 insomnia symptoms. Specifically, **Δ**1 insomnia symptoms and **Δ**2 mental health symptoms accounted for between 3-31% of the variance, while in the second step, **Δ**2 insomnia symptoms accounted for between .1-2% of the variance (see Table 8). For all models, the addition of deployment status at T1 did not improve model fit.

Aim 3: To estimate and compare the strength of directional relationships between insomnia and mental health symptoms across periods of the deployment cycle. Beta coefficients from the previous hierarchical regressions were examined in order to compare the

relative strength of predictor variables. Contrary to our hypotheses, mental health symptoms at T1 served as stronger predictors of insomnia symptoms at T2 than the inverse association (i.e., insomnia symptoms at T1 predicting mental health symptoms at T2). See Table 6. Similar trends were observed in comparing predictor variables from T2 and T3 (see Table 7).

Conversely, in examining beta coefficients across residualized changes in variables across T1-T2 and T2-T3 (i.e., **Δ**1 and **Δ**2), greater increases in insomnia symptoms were a better predictor of subsequent increases in mental health symptoms than the inverse (i.e., increases in mental health symptoms predicting subsequent increases in insomnia symptoms). See Table 8. This suggests that greater persistence of insomnia symptoms across T1 and T2 are more important in predicting subsequent persistence in mental health symptoms across T2 and T3.

DISCUSSION

Sleep disturbance is a common consequence of mental health disorders, with the majority of DSM-5 disorders listing some degree of sleep disturbance as a symptom (American Psychiatric Association, 2013). However, bidirectional relationships between sleep and mental health are also frequently observed, in which poor sleep can increase risk for mental health symptoms, and psychiatric disorders increase risk of developing sleep disturbance (Alvaro et al., 2013). Military service members are at elevated risk for both types of problems, given unique occupational and environmental stressors. The aim of the present study was to investigate temporal relationships between sleep and mental health symptoms in service members before and after a military deployment. The current sample is particularly novel in that service member participants were case-matched and assessed at three different time points surrounding a combat deployment. By comparison, previous longitudinal

research has more commonly included post-deployment assessments only that do not fully capture the full deployment cycle.

The study's first aim was to examine the presence and persistence of insomnia symptoms at two pre-deployment assessment points six months apart as predictors of mental health symptoms three months after a one year deployment. Contrary to our hypothesis as well as findings from previous research (Gehrman et al., 2013; Pigeon, Campbell, Possemato, & Ouimette, 2013; Wright et al., 2011b), we found the presence of insomnia symptoms at either T1 or T2 did not uniquely predict later PTSD, depression, or anxiety symptoms (at T2 and T3, respectively). These findings are similar however to results from another study finding that while pre-deployment nightmares predicted later PTSD, insomnia symptoms did not (van Liempt, van Zuiden, Westenberg, Super, & Vermetten, 2013). We did not examine nightmares in the current study, but nightmares have been found to give rise to and/or worsen insomnia in combat service members (Bramoweth & Germain, 2013). Also, similar to the current study, the study by van Liempt and colleagues included service members with and without previous deployments. In contrast, a study by Gehrman et al. (2013) that excluded service members with prior deployments who screened positively for psychiatric symptoms at baseline, found that those with symptoms of insomnia at pre-deployment had higher odds of developing new-onset PTSD, depression, and anxiety post-deployment. Thus, the latter study may have been better able to capture the effects of 'pure' insomnia as a risk factor for the development of subsequent mental health problems. At the same time, because insomnia infrequently occurs in the absence of concurrent psychiatric symptoms, the generalizability of such findings may be more limited.

It should be noted that assessment of insomnia symptoms in military samples varies widely across studies. Most commonly, one or two sleep-related items from various types of scales have been used. Researchers have raised concerns that such a narrow measurement approach may artificially inflate the prevalence rates of insomnia (e.g., Taylor et al., 2016). Other questions relate to individual variability in the interpretation of questions. For instance, the PCL and PHQ ask about the degree to which respondents are "bothered" by insomnia symptoms rather than their actual frequency. Since the current study assessed insomnia symptoms via two added questions to the PHQ, wording was intentionally kept consistent with the original measure (e.g., how much are you bothered by difficulty falling and staying asleep) but the degree to which responses capture individual distress versus symptom severity is unclear. For instance, it has been shown that individuals adapt their perception of subjective sleepiness in response to chronic sleep restriction (e.g., Van Dongen, Maislin, Mullington, & Dinges, 2003); thus, they may not perceive their sleep disturbances to be distressing when symptoms persist over extended periods of time. Interestingly, the study by van Liempt et al. (2013) which produced similar results to the current study also assessed insomnia via questions related to how bothered participants were by their sleep problems. Other studies, in contrast, have inquired about frequency or severity of symptoms (e.g., Gehrman et al., 2013). Both frequency of symptoms and associated distress represent diagnostic criteria for insomnia and should ideally be considered.

The second aim of the study was to examine the presence and persistence of mental health symptoms at T1 and T2 as predictors of insomnia symptoms following a subsequent deployment (T3). We found that PTSD symptoms at T1 and T2 were significantly associated with later symptoms of insomnia but that directionality of this association differed across

time points. Specifically, greater PTSD symptoms at T1 were associated with fewer insomnia symptoms at T2 whereas greater PTSD symptoms at T2 were associated with greater insomnia symptoms at T3. The circumstances between these time points likely help to explain differential relationships. All service members were at home with their families between T1 and T2 assessments whereas the entire sample was deployed between T2 and T3. It is possible that those with the most severe PTSD symptoms at T1 sought mental health or sleep-related treatment which may have served to improve functioning at the T2 assessment. Sleep-focused treatment in particular, such as cognitive-behavioral therapy for insomnia (CBT-I) has been shown to be effective in reducing symptoms of insomnia as well as co-occurring psychiatric and medical conditions including PTSD (Germain, Shear, Hall, & Buysse, 2007; Talbot et al., 2014) and depression (Manber et al., 2008). However, only 4% of the sample reported receiving help for a stress-related, emotional, alcohol, or familial problem at T1. Relatedly, while we observed a reduction in symptoms of insomnia from T1 to T2, similar decreases in mental health symptoms (i.e., PTSD, depression, or anxiety) were not observed; rather, mental health symptoms remained stable across time. Again, because assessment of insomnia symptoms was based on the degree to which symptoms were bothersome to participants (rather than their severity), the presence of co-occurring mental health symptoms may have rendered perception of sleep problems as comparative less troublesome.

Service members with greater PTSD and insomnia symptoms at T1 may have also tried to reduce their symptoms through the use of various substances including alcohol, licit and illicit drugs. Epidemiologic research has found 20% of individuals with PTSD to report using psychoactive substances to relieve their symptoms (Leeies, Pagura, Sareen, & Bolton,

2010). Although they did not examine sleep specifically, Jacobson et al. (2008) observed increased rates of alcohol use and alcohol-related problems following deployments with combat exposure. Significant correlations between PTSD symptoms and both alcohol use and symptoms of insomnia have also been observed in service members returning from combat (Lande, 2012; Wright, Britt, Bliese, & Adler, 2011a). Although we did not assess substance use, service members with greater PTSD symptoms at T1 may have been more likely to use alcohol or other sedating substances to reduce insomnia symptoms. The impact of sedatives on sleep disturbance has been studied extensively. Alcohol in particular has been shown to reduce sleep onset latency, causing drinkers to fall asleep quicker, but also increases wakefulness or light sleep during the second half of the sleep period (Roehrs & Roth, 2001). Despite the sleep disrupting "rebound" effect during the second half of the night, the influence of alcohol or other sedatives would likely be effective in mitigating difficulty falling asleep and associated distress.

In examining symptom changes from T2 to T3, we found significant increases in depressive and insomnia symptoms among service members with at least one previous deployment. We also found greater PTSD symptoms at T2 uniquely predicted greater symptoms of insomnia at T3. Interestingly, PTSD symptoms at T2 did not differ among previous deployers and non-deployers specifically because non-deployers reported an increase in symptoms at T2 compared to T1. These findings add a growing literature identifying cumulative deployments as a risk factor to later psychopathology. In a previous study, Reger, Gahm, Swanson, & Duma (2009) compared groups that underwent either one or two deployments to Iraq, and found that the odds of screening positive for PTSD were significantly higher in the two-deployment group, but not for other psychiatric conditions.

This suggests that a reintegration period in-between multiple deployments may not necessarily reduce mental health risk. Relatedly, another study observed a protective effect of increased dwell time in between deployments, such that a 2:1 month dwell-to-deployment ratio resulted in the lowest mental health referral rate in those with high levels of combat exposure (MacGregor, Heltemes, Clouser, Han, & Galarneau, 2014). Altogether, these findings suggest that not only do increased deployments pose cumulative psychiatric vulnerability, but greater dwell time in between deployments might counteract such risk.

Finally, we tested whether the persistence of insomnia and mental health symptoms across T1 and T2 uniquely predicted pre- to post-deployment changes (i.e., T2 and T3) in mental health and insomnia symptoms, respectively. Our primary hypothesis, that persistent insomnia symptoms would be the stronger predictor of subsequent mental health versus the inverse relationship was largely supported. Specifically, we found that persistent insomnia symptoms between T1 and T2 uniquely predicted elevations in PTSD and anxiety but not in depression at T3. In contrast, we found that persistent mental health symptoms from T1 and T2 were not significant predictors of subsequent insomnia symptoms. This is particularly interesting when compared to the first set of findings, in which the presence of insomnia symptoms at any individual time point did not uniquely predict subsequent mental health outcomes. These contrasting results suggest that chronic as opposed to transient symptoms of insomnia pose a more significant risk factor for the development of mental health problems. This interpretation is consistent with a wealth of research showing regular sufficient sleep to be essential for emotional well-being (e.g., Kahn et al., 2013; Yoo et al., 2007). However, the nonsignificant association with subsequent depression was surprising, given the wealth of research demonstrating robust relations between insomnia and mood disturbance (Meerlo,

Havekes, & Steiger, 2015; Taylor, 2008). It may be that our measure of depression which assessed symptoms over the past month lacked sensitivity for capturing more transient mood disturbances.

van Liempt et al. (2013) has speculated that insomnia "in the aftermath of trauma" may lead to the development of PTSD, whereas insomnia occurring before or directly after a traumatic event does not. Notably, our study did not find a significant correlation between combat exposures and insomnia symptoms at T2 or T3 suggesting that chronic insomnia symptoms on its own constitutes a potent risk factor for the development and maintenance of PTSD and anxiety. Although precise mechanisms linking insomnia with psychopathology are unknown, PTSD, anxiety disorders and insomnia can each be considered disorders of hyperarousal. In those with PTSD and anxiety disorders, hyperarousal manifests in difficulty with concentration, irritability, hypervigilance, and restlessness (American Psychiatric Association, 2013). A hyperarousal model of insomnia posits that hyperarousal experienced during the day, both cognitive and physiological, leads to difficulty initiating and maintaining sleep at night (Roth, 2007). From a cognitive standpoint, those who experience problems sleeping can start to worry or ruminate excessively about their sleep and develop maladaptive sleep-related behaviors that further exacerbate insomnia (Riemann et al., 2010), such as daytime napping. From a physiological standpoint, insomnia may also result in neurophysiological changes, such as alterations in hypothalamic-pituitary-adrenal (HPA) axis and metabolic activity (Roth, 2007). Indeed, insomnia patients have been found to exhibit higher levels of cortisol, as well as faster heart and metabolic rates (Bonnet & Arand, 1998; Nofzinger et al., 2004; Vgontzas et al., 1998). Thus, the conditioning effects of chronic insomnia may directly influence the development of hyperarousal-related psychopathology.

Military service members are subject to a variety of occupational stressors (e.g., military trainings/exercises, permanent changes of station, temporary duty). Deployments overseas comprise the most extreme form of stress, including preparing to leave loved ones for extended periods of time, combat exposure, threats of injury, etc. These frequent stressors could render service members particularly vulnerable to the onset of insomnia due to heightened arousal and vigilance. Accordingly, past reports have estimated prevalence rates of insomnia in the military to range from 19.9% to 35%, depending on the clinical severity of the samples (Bryan, 2013; Mysliwiec et al., 2013; Seelig et al., 2010; Taylor et al., 2016). The current study adds to this literature by examining the psychological impacts of persistent insomnia in active-duty service members.

Results also highlight a potentially salient preventative target for military populations. As previously discussed, screening practices in the military for identifying sleep disturbance typically assess for current frequency of symptoms by using sleep-related items from a broader psychiatric scale. The advantages of these types of questions notwithstanding (e.g., ease of administration and interpretation), they may miss information that would otherwise be captured in a clinical interview, such as duration of symptoms and associated distress. Furthermore, current decisions for determining duty-readiness among service members are clinician-based and largely subjective (e.g., McDonald, Adler, & Wilk, 2018). The present study, as well as other military-based studies, provides an empirical framework in factors related to duty-readiness, and underscore the value of assessing symptoms from a multidimensional perspective and determining potential need for treatment. According to the hyperarousal theory of insomnia, if chronic symptoms of insomnia are identified, they can be mitigated prior to the occurrence of additional stressors via cognitive restructuring and/or

behavioral techniques to regulate physiological elevations (e.g., progressive muscle relaxation). The resolution of disturbed sleep might establish a stronger foundation for resilience in the face of stressors faced by military personnel. Support for this comes from previous research finding CBT-I improves sleep disturbance as well as co-occurring psychological problems (for a full review, see Taylor & Pruiksma, 2014).

Limitations.

Several limitations warrant consideration in the interpretation of these findings. First, although the present study included a sufficient sample size across three time points for the present analyses, the number of participants with available data across all three time points was much smaller than the full sample at each time point. Rather than a self-selection bias, this was largely due to the mobility of an active-duty sample. Also, a vast majority of service members surveyed at each time point provided consent to use their data for research purposes. Still, there may be some bias in that those who reported clinically meaningful symptoms may have been removed from duty. While the attrition rate was expected given that many service members do not remain in the same location for the follow-up assessments following a deployment (e.g., moving on to new duty stations or transitioning out of the military), and other longitudinal studies using military samples have faced the same challenges (e.g., Wright et al., 2011b), replication in larger samples is needed.

A second limitation is the use of self-report measures. Although a downward trend in mental health stigma within the U.S. Army has been reported, nearly 44% of soldiers surveyed still reported stigma as of 2011 (Quartana et al., 2014). Thus, we cannot rule out the possibility that service members may have underreported or denied certain symptoms despite their presence. Further, we used the PCL-S in order to assess for symptoms of PTSD, but we

did not inquire about the specific index trauma that service members were responding to when completing the measure. Therefore, it may be possible that service members endorsed a non-combat index trauma when reporting on the PTSD symptoms. Another methodological limitation is the lack of a validated measure for assessing symptoms of insomnia. We used two questions added to the PHQ-15 that asked participants how much they were bothered by difficulty falling or staying asleep. Although this was an improvement on the original PHQ-15 which only inquired about "trouble sleeping" (Kroenke et al., 2002), the use of a validated measure such as the ISI (Morin, Belleville, Belanger, & Ivers, 2011) would have been more rigorous. However, the questions used do assess for the core feature of Insomnia Disorder, namely subjective distress associated with sleep discontinuity. Notably, data collected were a part of a larger study in which sleep was not a primary variable, and the prevalence rates of insomnia symptoms in our study were similar to a previous study that used the ISI in a large military sample (Taylor et al., 2016). Future research should nonetheless utilize validated sleep-related questionnaires to determine whether relationships among variables change.

Various durations between assessment points also constitutes a potential limitation and may reduce the generalizability of findings. Prior research has shown disparity in mental health diagnostic rates depending on whether assessments take place immediately after returning from deployment or several months later (e.g., Milliken et al., 2007). However, like other prospective military studies, we observed relatively low levels of mental health symptoms across all time points (Koffel, Polusny, Arbisi, & Erbes, 2013; Wright et al., 2011b). The time points used for assessment are also consistent with the U.S. Army's deployment health assessment points taken throughout the deployment cycle ("Deployment Health Assessment Program," n.d.); thus, the implications of the present paper can be

generalized to Soldiers who undergo extended deployments outside of the Continental U.S. Further, the focus of the study was on relationships among changes in symptoms across multiple deployment cycles, which we were able to quantify using residual change scores. Future research may consider replication with a continuous-time model to account for variations in time intervals (Kuiper & Ryan, 2018), as well as replication with more frequent assessment points to incorporate contextual factors relevant to the deployment cycle (e.g., post-deployment symptom changes).

Conclusions.

This study was the first to examine reciprocal relationships based on both the presence and persistence of insomnia and mental health symptoms among active-duty service members across three time points spanning 28 months. Our findings reveal persistent insomnia symptoms as the strongest predictor of later increases in mental health symptoms. These results highlight chronic insomnia symptoms to pose a specific vulnerability for the development of subsequent mental health problems in service members, and indicate a potential preventative target for military personnel prior to a secondary deployment or other occupational stressor.

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TABLES

Table 1

Demographic Characteristics of Study Sample

N	74 (95.9% male)
Age at T1: *n* (%)	
18-19	2 (2.7%)
20-24	44 (59.5%)
25-29	18 (24.3%)
30-39	9 (12.2%)
≥ 40	1 (1.14%)
Highest level of civilian education at T1: *n* (%)	
High school diploma/GED	44 (59.5%%)
Some college/Associate's degree	26 (35.1%)
Bachelor's degree	5 (6.8%)
Marital status at T1: *n* (%)	
Single/Never married	29 (39.2%)
Married	37 (50%)
Separated	3 (4.1%)
Divorced	2 (2.7%)
Missing	3 (4.1%)
Years married to current spouse at T1	2.64 (2.91)
Number of children in household at T1	.70 (1.03)
Military rank at T1: *n* (%)	
E1-E4	49 (66.2%)
E5-E9	22 (29.7%)
Officer/Warrant officer	3 (4.1%)
Years in the military at T1	3.74 (4.55)

Note. Unless otherwise noted, values represent *Mean (Standard deviation)*. T1 = Time point 1; E = Enlisted.

Table 2

Deployment History for Study Sample

Previously deployed at T1: *n* (%)	46 (62.2%)
Number of deployments lasting more than 30 days	1.39 (.65)
Months deployed since 09/11/2001	15.17 (7.31)
Number of deployments completed since 09/11/2001:	
Iraq	2.20 (.45)
Kuwait	1.30 (.54)
Afghanistan	1.00 (0)
Other	1.14 (.35)
Number of combat exposures during most recent deployment	9.98 (5.51)
Previously deployed at T3: *n* (%)	74 (100%)
Months deployed since 09/11/2001	20.73 (9.68)
Number of deployments completed since 09/11/2001:	
Iraq	1.74 (.68)
Kuwait	1.16 (.41)
Afghanistan	1.00 (0)
Other	1.07 (.25)
Number of combat exposures during most recent deployment	3.12 (3.80)

Note. Unless otherwise noted, values represent *Mean (Standard deviation)*. T = Time point.

Table 3

Descriptive Statistics for Study Variables

Mental health and sleep symptom scores at T1	
PTSD	24.53 (10.38)
Met screening criteria	5.4%
Depression	3.15 (4.72)
Met screening criteria	8%
Anxiety	3.18 (4.99)
Met screening criteria	12%
Insomnia	1.11 (1.54)
Met screening criteria	23%
Mental health and sleep symptom scores at T2	
PTSD	24.75 (11.27)
Met screening criteria	8%
Depression	2.92 (4.37)
Met screening criteria	1.4%
Anxiety	2.80 (4.36)
Met screening criteria	11%
Insomnia	.88 (1.57)
Met screening criteria	20.3%
Mental health and sleep symptom scores at T3	
PTSD	25.25 (11.09)
Met screening criteria	5.4%
Depression	3.99 (5.13)
Met screening criteria	7%
Anxiety	3.17 (4.20)
Met screening criteria	9.5%
Insomnia	1.20 (1.52)
Met screening criteria	23%

Note. Unless otherwise noted, values represent *Mean (Standard deviation)*. T = Time point; PTSD = Posttraumatic stress disorder.

Table 4

Zero-Order Correlations among Study Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. T1 Total months deployed	---														
2. T1 Combat exposure	-.11	---													
3. T1 PCL	.30*	.50**	---												
4. T1 PHQ-9	.10	.25	.63**	---											
5. T1 GAD-7	.08	.33*	.69**	.72**	---										
6. T1 Insomnia	.06	.43*	.60**	.56**	.47**	---									
7. T2 PCL	.24*	.41**	.46**	.48**	.51**	.38**	---								
8. T2 PHQ-9	-.03	.24	.16	.57**	.44**	.44**	.68**	---							
9. T2 GAD-7	.16	.31*	.43**	.50**	.49**	.50**	.80**	.82**	---						
10. T2 Insomnia	-.13	.15	.19	.36**	.24*	.54**	.38**	.59**	.64**	---					
11. T3 Total months deployed	.85*	.15	.27*	.12	.12	.21	.25*	.03	.15	-.003	---				
12. T3 Combat exposure	.09	.30*	.40**	.11	.48**	.26*	.34**	.12	.31**	.15	.09	---			
13. T3 PCL	.28*	.19	.43**	.27*	.52**	.29*	.44**	.17	.40**	.18	.35**	.53**	---		
14. T3 PHQ-9	.27*	.14	.42**	.49**	.49**	.45**	.48**	.34**	.46**	.28*	.32**	.33**	.79**	---	
15. T3 GAD-7	.07	.07	.25*	.36**	.47**	.30**	.41**	.36**	.42**	.33**	.19	.27*	.74**	.75**	---
16. T3 Insomnia	.04	.22	.18	.30**	.31**	.33**	.53**	.46**	.43**	.52**	.20	.07	.47**	.52**	.59**

Note. PCL and PHQ scores omitting sleep disturbance items were used. T = Time point; PCL = Posttraumatic stress disorder checklist; PHQ = Patient health questionnaire; GAD = Generalized anxiety disorder.
*$p < .05$. **$p < .01$.

Table 5

Zero-Order Correlations among Unstandardized Residual Change Scores

	1	2	3	4	5	6	7	8	9	10	11	12
1. T1 Total months deployed	---											
2. T1 Combat exposure	-.11	---										
3. **Δ**1 PCL	.18	.39**	---									
4. **Δ**1 PHQ	.14	.18	.68**	---								
5. **Δ**1 GAD	.01	.19	.52**	.64**	---							
6. **Δ**1 Insomnia	.16	.43**	.50**	.45**	.34**	---						
7. T3 Total months deployed	.85**	.15	.28*	.12	.05	.26*	---					
8. T3 Combat exposure	.09	.30*	.28*	.05	.38**	.21	.09	---				
9. **Δ**2 PCL	.14	.35*	-.13	.04	.02	.11	.09	.11	---			
10. **Δ**2 PHQ	-.12	.17	-.24*	-.13	-.06	-.01	-.08	.01	.67**	---		
11. **Δ**2 GAD	.14	.29*	.06	-.03	-.13	.17	.08	.22	.70**	.72**	---	
12. **Δ**2 Insomnia	-.18	.01	.06	-.04	-.13	-.03	-.13	.13	.17	.49**	.46**	---

Note. PCL and PHQ scores omitting sleep disturbance items were used. T = Time point; **Δ**1 = T1-to-T2 change; **Δ**2 = T2-to-T3 change;
PCL = Posttraumatic stress disorder checklist; PHQ = Patient health questionnaire; GAD = Generalized anxiety disorder.
*$p < .05$. **$p < .01$.

Table 6

T1 to T2 Cross-Lagged Regression Analyses

Step	R	Adjusted R^2	R^2 Change	F Change	β	*p*
Predicting T2 PCL:						
1. T1 PCL	.54	.27	.29	13.75	.41	< .001
T2 Insomnia					.31	.006
2. T1 Insomnia	.52	.26	.00	.01	-.01	.92
Predicting T2 Insomnia:						
1. T1 Insomnia	.56	.29	.31	14.94	.57	< .001
T2 PCL					.28	.02
2. T1 PCL	.60	.32	.04	4.22	-.26	.04
Step	**R**	**Adjusted R^2**	**R^2 Change**	**F Change**	**β**	***p***
Predicting T2 PHQ:						
1. T1 PHQ	.74	.53	.54	41.33	.43	< .001
T2 Insomnia					.54	< .001
2. T1 Insomnia	.74	.53	.01	.73	-.09	.40
Predicting T2 Insomnia:						
1. T1 Insomnia	.70	.48	.50	33.79	.40	< .001
T2 PHQ					.58	< .001
2. T1 PHQ	.72	.49	.02	2.90	-.19	.09
Step	**R**	**Adjusted R^2**	**R^2 Change**	**F Change**	**β**	***p***
Predicting T2 GAD:						
1. T1 GAD	.68	.45	.47	30.41	.33	.001
T2 Insomnia					.45	< .001
2. T1 Insomnia	.69	.45	.01	.86	.11	.36
Predicting T2 Insomnia:						
1. T1 Insomnia	.65	.41	.43	25.45	.39	.001
T2 GAD					.47	< .001
2. T1 GAD	.67	.42	.02	2.48	-.17	.12

Note. PCL and PHQ scores omitting sleep disturbance items were used. T = Time point; PCL = Posttraumatic stress disorder checklist; PHQ = Patient health questionnaire; GAD = Generalized anxiety disorder.

Table 7

T2 to T3 Cross-Lagged Regression Analyses

Step	R	Adjusted R^2	R^2 Change	F Change	β	*p*
Predicting T3 PCL:						
1. T2 PCL	.52	.25	.27	12.14	.29	.02
T3 Insomnia					.37	.01
2. T2 Insomnia	.53	.25	.01	.93	-.12	.34
Predicting T3 Insomnia:						
1. T2 Insomnia	.63	.38	.40	22.16	.36	.001
T3 PCL					.28	.01
2. T2 PCL	.67	.43	.05	5.87	.26	.02
Step	**R**	**Adjusted R^2**	**R^2 Change**	**F Change**	**β**	***p***
Predicting T3 PHQ:						
1. T2 PHQ	.53	.26	.28	13.81	.17	.22
T3 Insomnia					.48	< .001
2. T2 Insomnia	.53	.25	.003	.28	-.07	.60
Predicting T3 Insomnia:						
1. T2 Insomnia	.65	.40	.42	25.73	.34	.01
T3 PHQ					.38	< .001
2. T2 PHQ	.65	.40	.01	.87	.11	.35
Step	**R**	**Adjusted R^2**	**R^2 Change**	**F Change**	**β**	***p***
Predicting T3 GAD:						
1. T2 GAD	.62	.37	.38	21.94	.25	.04
T3 Insomnia					.53	< .001
2. T2 Insomnia	.62	.36	.01	.52	-.09	.48
Predicting T3 Insomnia:						
1. T2 Insomnia	.68	.45	.47	30.81	.36	.002
T3 GAD					.46	< .001
2. T2 GAD	.68	.44	.00	.04	.02	.84

Note. PCL and PHQ scores omitting sleep disturbance items were used. T = Time point; PCL = Posttraumatic stress disorder checklist; PHQ = Patient health questionnaire; GAD = Generalized anxiety disorder.

Table 8

Cross-Lagged Regression Analyses for T1-to-T2 Changes Predicting T2-to-T3 Changes

Step	R	Adjusted R^2	R^2 Change	F Change	β	*p*
Predicting **Δ**2 PCL:						
1. **Δ**1 PCL	.22	.02	.05	1.60	-.27	.06
Δ2 Insomnia					.19	.11
2. **Δ**1 Insomnia	.31	.05	.05	3.37	.25	.07
Predicting **Δ**2 Insomnia:						
1. **Δ**1 Insomnia	.18	.001	.03	1.04	-.15	.31
Δ2 PCL					.20	.11
2. **Δ**1 PCL	.22	.01	.02	1.23	.16	.27
Step	**R**	**Adjusted R^2**	**R^2 Change**	**F Change**	β	*p*
Predicting **Δ**2 PHQ:						
1. **Δ**1 PHQ	.50	.23	.25	11.65	-.14	.23
Δ2 Insomnia					.49	< .001
2. **Δ**1 Insomnia	.51	.22	.004	.33	.07	.57
Predicting **Δ**2 Insomnia:						
1. **Δ**1 Insomnia	.56	.29	.31	15.70	-.09	.47
Δ2 PHQ					.57	< .001
2. **Δ**1 PHQ	.57	.29	.01	.72	.10	.40
Step	**R**	**Adjusted R^2**	**R^2 Change**	**F Change**	β	*p*
Predicting **Δ**2 GAD:						
1. **Δ**1 GAD	.45	.18	.20	8.85	-.16	.16
Δ2 Insomnia					.44	< .001
2. **Δ**1 Insomnia	.51	.22	.05	4.85	.25	.03
Predicting **Δ**2 Insomnia:						
1. **Δ**1 Insomnia	.46	.19	.21	9.30	-.11	.37
Δ2 GAD					.46	< .001
2. **Δ**1 GAD	.46	.18	.001	.08	-.03	.78

Note. PCL and PHQ scores omitting sleep disturbance items were used. T = Time point; **Δ**1 = T1-to-T2 change; **Δ**2 = T2-to-T3 change; PCL = Posttraumatic stress disorder checklist; PHQ = Patient health questionnaire; GAD = Generalized anxiety disorder.