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ORIGINAL ARTICLE

Observed Relationship Behaviors and Sleep in Military Veterans and Their Partners

Jennifer Fillo, PhD[1] · Stephanie Brooks Holliday, PhD[2] · Amy DeSantis, PhD[2] · Anne Germain, PhD[3] · Daniel J. Buysse, MD[3] · Karen A. Matthews, PhD[3] · Wendy M. Troxel, PhD[2]

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Abstract

Background Emerging research has begun to examine associations between relationship functioning and sleep. However, these studies have largely relied on self-reported evaluations of relationships and/or of sleep, which may be vulnerable to bias.

Purpose The purpose of the study was to examine associations between relationship functioning and sleep in military couples. This is the first research to examine associations between observed relationship behaviors and subjective and polysomnographically measured sleep in a sample at-risk for both sleep and relationship problems.

Methods The sample included 35 military veterans and their spouses/partners. Marital functioning was coded from a videotaped conflict interaction. Analyses focused on behavioral codes of hostility and relationship-enhancing attributions. Sleep was assessed via self-report and in-home polysomnography.

Results Greater hostility was associated with poorer sleep efficiency for oneself ($b = -0.195$, $p = .013$). In contrast, greater relationship-enhancing attributions were associated with higher percentages of stage N3 sleep ($b = 0.239$, $p = .028$). Partners' hostility was also positively associated with higher percentages of stage N3 sleep ($b = 0.272$, $p = .010$). Neither hostility nor relationship-enhancing attributions was associated with self-reported sleep quality, percentage of REM sleep, or total sleep time.

Conclusions Both partners' positive and negative behaviors during conflict interactions were related to sleep quality. These findings highlight the role that effective communication and conflict resolution skills may play in shaping not only the marital health of veterans and their spouses but also the physical health of both partners as well. Understanding the links between relationship functioning and sleep may be important targets of intervention in the aftermath of war.

Keywords Marital functioning · Marital conflict · Sleep · Military · Couples

Abbreviations

BMI	Body mass index
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OND	Operation New Dawn
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
PTSD	Post-traumatic stress disorder
REM	Rapid eye movement sleep

The presence and quality of close relationships, and in particular, marital relationships, are robust predictors of health and well-being [1, 2]. A range of biopsychosocial processes may help to explain this association [1, 3]. For instance, indicators of relationship functioning including satisfaction, conflict, or supportive behaviors can impact a range of health behaviors and outcomes, including endocrine, cardiovascular, and immune functioning, as well as treatment adherence and mortality [3, 4]. In general, however, most research on potential

✉ Wendy M. Troxel
wtroxel@rand.org

[1] Research Institute on Addictions, University at Buffalo, The State University of New York, 1021 Main Street, Buffalo, NY 14203, USA

[2] RAND Corporation, 1776 Main Street, Santa Monica, CA 90401, USA

[3] Department of Psychiatry, University of Pittsburgh, School of Medicine, 3811 O'Hara Street, Pittsburgh, PA 15213, USA

pathways linking relationships with health have focused on measurements collected during waking and daylight hours, largely neglecting physiology during sleep or nighttime hours. However, humans spend roughly one third of our lives asleep, and for many (61%) Americans, sleep is a shared behavior with a spouse or romantic partner [5]. Sleep problems, in turn, are associated with a host of physical health morbidities, including increased risk of obesity [6], hypertension [7], diabetes [8, 9], and coronary heart disease [10].

Consistent with prevailing theories of sleep and arousal [11], optimal sleep is facilitated when an individual is able to downregulate vigilance and alertness [12], and this downregulation process is facilitated by feelings of security and safety. A number of factors can affect an individual's sense of security and safety, including the social environment [13, 14]. More specifically, from an attachment perspective, close relationships are a primary source for deriving both physical and emotional safety [15, 16]. In contrast, negative relationship behaviors or dynamics, such as conflict or hostility, have the potential to heighten vigilance, psychological distress, and physiological arousal, thereby disrupting sleep [12].

A handful of studies have focused on the association between relationship functioning and sleep, although the majority have focused on self-reported evaluations of relationships (e.g., relationship satisfaction), rather than specific, observable relationship behaviors that may be relevant for sleep. These studies provide evidence for a reciprocal association between sleep and relationship functioning. For instance, there is evidence that relationship harmony [17], happiness [18], and positive daytime interactions [19] are associated with better sleep outcomes in adult samples. In contrast, negative relationship dynamics might adversely affect sleep. El Sheikh and colleagues have found that the extent to which an individual perceived himself/herself to be the target of psychological aggression was associated with poorer sleep for the individual and his/her partner, both cross-sectionally [20] and 1 year later [21]. This study highlights the ways in which relationship conflict can affect both members of a couple: not only does it affect the sleep of the partner who reports being on the receiving end of psychological conflict, but it may also impact the sleep of his/her partner. Poor sleep has also been hypothesized to negatively impact relationships, with one study finding that sleep disturbances were associated with poorer ratings of relationship quality up to 4 years later [22]. Furthermore, effective treatment of sleep disorders (e.g., obstructive sleep apnea) is associated with improvements in intimate relationships [23]. Together, this research highlights the reciprocal relationship between relationship functioning and sleep.

However, with one notable exception [24], all of the existing studies on relationship functioning and sleep have relied on self-reported measures of relationships. Although self-reports provide useful information about an individual's perception of marital functioning, they may be vulnerable to some degree of bias (e.g., in an unhappy relationship, an individual may attend more to negative events than positive events) [25]. Utilizing objective measures of specific relational behaviors, rather than self-reported evaluations of relationship characteristics, also has the advantage of potentially identifying specific behavioral targets that are particularly salient for sleep and that may be amenable to intervention. For instance, Gordon and Chen [24] used an observational measure of relationship functioning in which they videotaped couples discussing a source of conflict in their relationship in a laboratory setting, and found that participants' self-reported poorer sleep quality the night before predicted lower ratios of positive to negative affect during the conflict discussion, which is an important indicator of relationship functioning [26]. Furthermore, poorer sleep quality in one partner predicted both partners' ability to accurately read the other person's emotions. These findings are the first to provide information on how sleep may be related to observed relationship behaviors. However, this study relied exclusively on self-reported sleep quality, which can also be subject to bias in reporting [27], and cannot provide information on specific dimensions of sleep, such as specific sleep stages, which are associated with relationship characteristics (e.g., attachment anxiety) [28] and health outcomes [29, 30]. No study to date has examined the association between observed relationship behaviors with sleep, using both objective (polysomnographic) and subjective indicators of sleep.

Present Study

The present study aims to advance the current literature on relationships and sleep by being the first to examine the association between specific, observed relationship behaviors during a relationship conflict interaction and objectively measured sleep duration, efficiency, and architecture, and subjectively assessed sleep quality. These specific dimensions of sleep were chosen because each of these dimensions are linked with key health outcomes [6–10], and there is limited extant literature demonstrating that each of these outcomes are associated with indicators of relationship functioning, including attachment style [14, 19, 28, 31].

The current research is conducted in a sample of military veterans and their partners, a population that may be at-risk for disturbances in both sleep and relationship functioning. Understanding these associations in a high-risk sample is important because it may identify targets of intervention in a vulnerable population, and also may provide greater variability in key study constructs, as opposed to convenience samples of healthy couples who may have limited variability in both sleep and relationship functioning [19]. The past 15 years of protracted overseas combat in support of Operation

Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND) have exacted a significant toll on US service members and their spouses/partners, with evidence showing increased rates of relationship and sleep problems, as well as mental health problems (e.g., depression and post-traumatic stress disorder; PTSD) that can further exacerbate relationship and/or sleep problems in both returning veterans and their partners [30, 32–36]. Therefore, an understanding of the association between relationship functioning and sleep has the potential to inform screening and intervention efforts that are relevant for veteran couples as well as other populations experiencing relationship distress and/or sleep problems.

Couples in the present study participated in a laboratory interaction task, including a video-recorded conflict task. We focused on specific positive and negative relationship behaviors, relationship-enhancing attributions and hostility, respectively, as both of these behaviors have been associated with important indices of health in prior work [37–40]. We tested for both actor and partner effects, consistent with prior work showing that relationship quality (or sleep) of one partner is associated not only with one's own sleep (or relationship quality) but also with the partner's [19, 41]. Specifically, we hypothesized that actor and partner negative relationship behaviors (i.e., hostility) would be associated with poorer sleep outcomes. This may manifest in the form of shorter sleep duration, poorer sleep efficiency, and altered sleep architecture (i.e., less stage N3 sleep, more rapid eye movement sleep) (Hypothesis 1). Additionally, we hypothesized that actor and partner positive relationship behaviors (i.e., relationship-enhancing attributions) would be associated with better sleep outcomes (Hypothesis 2).

Method

Participants

Participants included heterosexual married couples in which at least one member of the couple had served in OEF/OIF/OND. Couples were eligible for the study if they had been married or cohabiting for at least 2 years; were between ages 18 and 45 years; and were sharing a bed on a regular basis (>4 days/week). To maximize generalizability of the findings, individuals with stable or treated psychiatric or medical conditions (excluding cardiovascular diseases and diabetes) were eligible. Couples were not eligible if the woman was postmenopausal, pregnant, or lactating; if either member of the couple was being treated for existing cardiovascular disease or using insulin or oral medications for diabetes; if either member of the couple was using continuous positive airway pressure for sleep apnea or was diagnosed with severe, untreated sleep apnea (based on in-home apnea screening for the study); and if either member of the couple was engaged in night shift work. Documentation of military service was obtained at the first visit from at least one member of all potential couples by the provision of their DD Form 214, a form issued by the Department of Defense upon a military service member's separation from active duty military. Veterans also provided a detailed military history. The majority of the veterans were from the Army (62.16%). On average, veterans had an average of 1.8 deployments (SD = 1.10), and the length of deployments averaged 9.5 months each (SD = 3.38). The original sample consisted of 37 couples. The analytic sample was restricted to couples with behavioral relationship data and sleep data (N = 2 couples lost due to incomplete data). This resulted in a final sample of 35 couples (70 individuals). The analytic sample was similar to the overall sample in terms of study demographics (age), clinical characteristics (post-traumatic stress disorder symptoms), and most sleep variables. There were only two variables for which there was a difference between the analytic and overall sample. Those in the present analyses had been in their relationships longer [$t(57.87) = 2.12$, $p = .038$] and had shorter sleep durations than the overall sample [$t(71) = –2.32$, $p = .023$].

Study Overview

The study consisted of a screening (via telephone and in-home apnea monitoring) and diagnostic assessment to determine eligibility. During the diagnostic visit, both members of the couple completed self-report assessments, including relationship history, psychosocial functioning, and sleep quality. In addition, body mass index was measured using height and weight, and a study clinician conducted a structured interview to assess PTSD symptoms (described below). Following the diagnostic visit, couples were invited to participate in a 10-day naturalistic study, during which participants were asked to wear a wrist actigraph and complete daily sleep diaries (measures not included in the present analyses). In addition, at the start of the naturalistic study, individuals completed two nights of in-home, unattended polysomnography (PSG) sleep studies. At the conclusion of the 10-day visit, couples were invited back to the laboratory to engage in the relationship interaction task (described below). Couples were compensated for study participation. All participants provided written, informed consent, and all study procedures were approved by the institutional human subjects' protection committee.

Measures

Observer-Coded Relationship Behaviors

Couples engaged in a laboratory-based couple interaction in which they were asked to discuss a conflict area personal to their relationship, and try to come up with a resolution. To

identify the conflict area for discussion, all participants completed the Marital Problems Questionnaire, which is a screening assessment commonly used in marital therapy [42]. A research assistant used the results to identify the highest rated conflict area for each couple. Based on previous reports of the length of time necessary to get valid and reliable estimates of couple interactions [43], the conflict task lasted 15 min and was videotaped. Following the conflict task, trained, independent coders at the Rapid Marital Interaction Coding Center used the Rapid Marital Interaction Coding System [25] to code the interactions. This measure includes 11 communication categories coded in a hierarchy and has high reliabilities both for the overall system and for individual codes [44, 45]. Interrater agreement in the present sample was adequate (75.95%). Consistent with prior research, which has tended to focus on specific positive or negative dimensions of relationship behaviors, and given that there was limited variability in some of the other behavioral codes (e.g., psychological abuse, acceptance, distress-maintaining attributions), we focused specifically on codes pertaining to hostility and relationship-enhancing attributions, which showed greater variability and have previously been associated with health outcomes [37, 40]. Hostility includes both verbal and nonverbal expressions, including criticism, hostile voice tone, or rolling the eyes dramatically. Relationship-enhancing attributions refer to causal explanations for events or behaviors [25]. In the context of a conflict task, this involves attributing negative events to external or situational factors, rather than to the partner (e.g., you were late because of traffic, as opposed to some internal, blameworthy cause) whereas attributions for positive events are credited to the partner. Substantial relationship research documents the toxic role of hostility in the context of relationships and the benefits of relationship-enhancing attributions [46, 47]. Percent of hostile or relationship-enhancing attributions relative to total behaviors, for each partner, served as the primary independent variables.

PSG Sleep Studies

In-home sleep studies (PSG) were collected over two consecutive nights. A light weight, 22-channel portable Compumedics Siesta Ambulatory PSG monitor was used to collect PSG sleep data. A study staff member and sleep technologist arrived at participants' homes in the evening to attach study electrodes and sensors, verify signal integrity online using a laptop computer and show participants how to disconnect the electrodes, sensors, and monitor in the morning. Sleep parameters were averaged over the two recording nights to enhance reliability of the sleep assessments. Trained PSG technologists scored the EEG sleep record for each night of sleep studies using standard sleep stage scoring criteria in 30 s epochs per AASM criteria [48]. PSG measures of interest, including sleep efficiency (ratio of time spent asleep/time spent in bed after sleep onset), sleep duration, percentage of rapid eye movement (REM) sleep, and percentage of stage N3 sleep were selected because they have previously found to be associated with indicators of the presence or quality of relationships as well as key health outcomes, including cardiovascular disease or mortality [28, 49–52].

Subjective Sleep Quality

The Pittsburgh Sleep Quality Index (PSQI) [53] was administered as a measure of subjective sleep quality. This measure comprises 19 items that assess several aspects of sleep quality, including sleep latency, sleep duration, and sleep efficiency. Scores on the PSQI range from 0 to 21, with higher scores being indicative of poorer sleep quality. PSQI scores greater than 5 are considered indicative of clinically significant sleep disturbances. The measure has demonstrated excellent psychometric properties, including good internal consistency (α = 0.83), test-retest reliability (r = .85), and sensitivity for identifying clinically significant sleep disturbances (89.6%) [53]. Internal consistency in the current study was lower than previously reported (α = 0.64), likely due to the small sample size.

Covariates

Age, sex, and body mass index (BMI; weight in kilograms/height in square meters; BMI ≥25 is considered overweight) were included as covariates, given strong associations between each of these variables and sleep disturbances and disorders (as reviewed in [54]). This sample includes veterans, a population known to be at-high risk for PTSD [55], and their spouses, who are also at increased risk for mental health problems in the post-deployment period [36, 56]. Therefore, we additionally controlled for current PTSD symptom severity using the Clinician Administered PTSD Scale [57]. This is a structured clinical interview evaluating PTSD symptoms over the past month, including the frequency and intensity of each symptom. Intensity scores for all symptoms were summed to provide an overall severity score for the past month. Scores in the 20–39 range are considered mild, 40–59 are moderate, and 60–79 are severe. This measure is the gold standard for the assessment of PTSD and has excellent psychometric properties across a range of clinical populations and settings [58, 59].

Data Analytic Strategy

Analyses were conducted using Actor-Partner Interdependence Modeling [60]. This is a dyadic data analytic approach used to model the non-independence that naturally exists in interpersonal relationships. This approach examines each individual's outcome as a function of (a) their own predictor variables, called *actor effects*, and (b) their partner's predictor variables, called *partner effects*. With this approach, the dyad is treated as the unit of

analysis. Couple members are nested within the same dyad, so they each function as "actors" and "partners" in the analyses. This approach provides independent estimates of actor and partner effects.

All analyses were run with SPSS mixed modeling procedures. Sex was coded as −1 for women and 1 for men. All other predictor variables were grand mean centered. Because hostility and relationship-enhancing attributions were coded from the same interaction, and to provide a more stringent test of their independent relations with sleep variables, actor and partner terms for both behavioral codes were entered simultaneously in all models. Further, all analyses controlled for the effects of participant age, sex, BMI, and current PTSD symptoms. Analyses initially also included interactions between sex and each behavioral code; however, none of these interactions were significant, and were therefore dropped from the analyses to improve model fit. Additionally, because the PTSD measure contains two items pertaining to nighttime symptoms, analyses were rerun with these items removed (to avoid redundancy with the outcomes). Results were nearly identical when we included PTSD scores with these nighttime symptoms removed; therefore, analyses reported below used the full PTSD symptom score.

Results

Preliminary Analyses

Sleep efficiency was highly skewed and was transformed for primary analyses. Means and standard deviations for variables included in the analyses, as well as relationship length, are presented in Table 1. The values are shown for the full sample and separately for men and women. Independent samples *t* tests were used to evaluate gender differences in the variables. Men and women differed significantly on two variables. Men had greater current PTSD symptom severity, and women had higher percentages of Stage N3 sleep. The effect sizes for both of these differences were large ($d \geq 0.8$). One additional comparison fell within the medium to large range (Cohen's d = 0.3–0.5; sleep efficiency); however, this difference was not significant, likely due to the small sample size in the current study. Correlations between all variables used in the present analyses are presented in Table 2. Some correlations fell within the medium to large range, but were not statistically significant. Of particular note are the moderate, but non-significant correlations for women between PSQI and both actor hostility (r = .30, p = .079) and partner hostility (r = .30, p = .081), as well as stage N3 sleep and actor relationship-enhancing attributions (r = .33, p = .058). However, there were significant correlations between husbands' and wives' age, BMI, current PTSD symptoms, hostility, relationship-enhancing attributions, and sleep duration. These correlations demonstrate that non-independence exists between couple members' data. As described above, this covariation was controlled for through the use of multilevel modeling. Also noteworthy are the non-significant associations between hostility and relationship enhancing behaviors within individuals and between partners for both men and women, providing further support for the decision to include both relationship measures simultaneously in models.

Table 1 Means and standard deviations of study variables

	Full sample (N = 70)		Men (N = 35)		Women (N = 35)			
Variable	*M*	SD	*M*	SD	*M*	SD	*t*	*d*
Age	30.88	5.38	31.49	5.73	30.28	5.00	0.94	0.23
Body mass index	26.60	4.09	26.77	4.26	26.42	3.98	0.36	0.09
Current PTSD symptoms	30.96	20.64	38.66	19.85	23.26	18.67	3.34***	0.80
% actor hostility	6.06	9.68	6.51	9.55	5.60	9.92	0.39	0.09
% actor relationship-enhancing attributions	9.11	7.97	9.64	9.11	8.57	1.14	0.56	0.13
PSQI	5.00	2.68	5.20	2.74	4.80	2.64	0.62	0.15
% stage N3 sleep	18.37	8.26	15.14	6.81	21.70	8.38	−3.56***	0.86
% REM sleep	24.47	5.04	25.12	3.85	23.79	6.02	1.10	0.26
Sleep efficiency (%)	88.99	4.82	88.22	4.50	89.78	5.06	−1.35	0.32
Sleep duration (minutes)	419.31	58.85	416.86	59.13	421.34	59.35	−0.35	0.08

Descriptive statistics are presented using raw (non-transformed) PSG variables

PSQI Pittsburgh Sleep Quality Index, *PTSD* post-traumatic stress disorder, *REM* rapid eye movement sleep

***p < .001

Table 2 Correlations among study variables for men and women

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	(0.82***)	0.59***	−0.11	0.12	0.19	−0.18	−0.07	−0.04	−0.47**	0.29	−0.16	−0.14
2. Body mass index	0.13	(0.29*)	0.16	0.22	0.19	0.03	−0.07	0.24	−0.34	0.25	0.14	−0.04
3. Current PTSD symptoms	−0.20	−0.04	(0.32**)	0.44**	0.06	0.23	0.07	0.51**	−0.16	−0.04	−0.19	−0.22
4. % actor hostility	0.17	0.34*	0.06	(0.55***)	0.55***	−0.11	−0.10	0.47**	−0.01	0.20	−0.13	−0.20
5. % partner hostility	0.24	0.26	0.16	0.55***	(0.55***)	−0.12	−0.07	0.18	0.21	0.02	0.14	−0.11
6. % actor relationship--enhancing attributions	−0.09	0.14	−0.18	−0.07	−0.10	(0.39***)	0.42*	−0.15	0.20	−0.29	0.03	−0.05
7. % partner relationship--enhancing attributions	−0.32	−0.15	−0.01	−0.12	−0.11	0.42*	(0.39***)	−0.35*	−0.05	0.07	0.05	0.08
8. PSQI	0.19	0.15	0.53***	0.30	0.30	0.06	−0.13	(0.23)	−0.25	0.08	−0.17	−0.21
9. % stage N3 sleep	−0.34	0.05	0.07	−0.14	0.05	0.33	0.10	0.13	(−0.09)	−0.35*	0.37*	0.20
10. % REM sleep	0.32	0.18	−0.20	−0.06	0.06	−0.16	−0.18	−0.17	−0.07	(0.12)	0.04	0.41*
11. Sleep efficiency	0.02	0.06	0.10	−0.25	0.04	−0.18	−0.24	0.00	0.38*	0.40*	(−0.16)	0.52***
12. Sleep duration	−0.00	0.29	−0.04	−0.07	−0.23	−0.07	−0.25	−0.21	−0.30	0.28	0.15	(0.65***)

Correlations among variables collected from women appear below the diagonal, and those collected from men appear above the diagonal. The values on the diagonal (in parentheses) are correlations between measures collected from each partner (e.g., the correlation between men's and women's sleep efficiency)

PSQI Pittsburgh Sleep Quality Index, *PTSD* post-traumatic stress disorder, *REM* rapid eye movement sleep

* $p < .05$; ** $p < .01$; *** $p < .001$

Primary Analyses

To evaluate Hypotheses 1 and 2, we ran a series of models examining relations between participants' conflict interaction behaviors (i.e., hostility and relationship-enhancing attributions) and subjective sleep quality, as well as PSG-assessed percent stage N3 sleep, percent REM sleep, sleep efficiency, and sleep duration. Each model included the fixed effects of actor and partner hostility and relationship-enhancing attributions. Additionally, all analyses controlled for the effects of participant age, sex, BMI, and current PTSD symptom severity. Results are presented in Table 3.

Subjective Sleep Quality

After controlling for covariates, there were no significant associations between actor or partner hostility or relationship-enhancing attributions and PSQI scores. However, there was a significant association between actor PTSD symptom severity and PSQI scores. Greater actor PTSD symptom severity was associated with higher PSQI scores, indicating poorer sleep quality.

PSG Variables

After controlling for covariates, both partner hostility and actor relationship-enhancing attributions were significantly, positively, and independently related to percentage of stage N3 sleep. There were no significant associations between actor or partner hostility or relationship-enhancing attributions and REM sleep percentage. For sleep efficiency, there was a significant negative association with actor hostility such that higher actor hostility was associated with poorer sleep efficiency. Finally, there were no significant associations between actor or partner hostility or relationship-enhancing attributions and sleep duration.

Discussion

The present research examined associations between relationship interaction patterns and sleep quality among OEF/OIF/OND veterans and their spouses. It addresses limitations of prior research by examining behavioral measures of relationship functioning and by utilizing both self-report and PSG measurements of sleep. Overall, these results reveal multiple

Table 3 Sleep variables as a function of actor and partner hostility and relationship-enhancing behaviors

	Outcome variable									
	PSQI		% Stage N3 sleep		% REM sleep		Sleep efficiency		Sleep duration	
Fixed effects	*b*	SE	*b*	SE	*b*	SE	*b*	SE	*b*	SE
Intercept	5.000***	0.26	18.475***	0.80	24.452***	0.67	89.051***	0.51	418.111***	9.25
Actor age	0.019	0.06	−0.602***	0.16	0.148	0.11	−0.191	0.11	−1.497	1.69
Actor body mass index	0.046	0.07	−0.091	0.22	0.197	0.15	0.272	0.15	1.416	1.65
Actor sex	−0.387	0.30	−2.545**	0.89	0.759	0.66	−0.581	0.65	−0.965	5.34
Actor current PTSD symptoms	0.066***	0.01	−0.059	0.04	−0.020	0.03	−0.006	0.03	−0.023	0.38
Actor hostility	0.057	0.04	−0.092	0.10	0.055	0.07	−0.195*	0.08	−0.434	0.77
Partner hostility	0.008	0.03	0.272**	0.10	−0.059	0.07	0.153	0.08	−1.129	0.78
Actor relationship-enhancing attributions	0.002	0.04	0.239*	0.10	−0.134	0.07	−0.036	0.08	−0.456	0.89
Partner relationship-enhancing attributions	−0.067	0.04	−0.143	0.11	0.065	0.08	−0.071	0.08	−0.881	0.88

For sex, 1 = men, −1 = women. Estimates from the raw (not transformed) sleep efficiency data are presented for ease of interpretation. However, statistical tests are based on the analysis using the transformed variable

PSQI Pittsburgh Sleep Quality Index; *PTSD* post-traumatic stress disorder; *REM* rapid eye movement sleep.

* $p < .05$; ** $p < .01$; ***$p < .001$

ways in which both partners' positive and negative behaviors during conflict interactions relate to sleep quality.

Consistent with prior research demonstrating negative health effects of hostility in relationships [37], our findings showed that displaying greater hostility in a conflict interaction with one's partner was associated with poorer sleep efficiency. This finding suggests that hostile interpersonal behaviors may contribute to sleep problems. In contrast, displaying greater relationship-enhancing attributions was associated with higher percentages of stage N3 sleep, the stage of sleep that has shown suggestive links with restorative cognitive and metabolic processes [61, 62]. Surprisingly, partners' hostility was also positively associated with higher percentages of stage N3 sleep. One can only speculate that these seemingly counterintuitive findings may reflect greater engagement in the conflict discussion, rather than a "beneficial" effect of greater hostility, per se. Additionally, it is well established that slow-wave activity, which occurs during stage N3 sleep, shows not only homeostatic regulation but also local use-dependent regulation as well [63]. Although speculative, it is possible that emotional engagement in the relationship, whether positive or negative, could lead to use-dependent increases in slow-wave activity within emotion-regulating circuits. These circuits include dorsolateral and medial prefrontal frontal regions [64, 65], which are also known to be critical to the generation of slow wave activity [66, 67]. However, additional research is needed to determine whether this is a robust effect that can be replicated in other samples.

Our primary analyses revealed no evidence for sex differences in the associations between hostility or relationship-enhancing attributions and sleep outcomes. However, prior research suggests that women may be more physiologically and emotionally responsive to negative aspects of relationship functioning compared to men [1, 2, 68, 69]. Further, with regard to sleep, there has been limited evidence to suggest that associations between sleep and relationship-functioning may be gender-dependent [19]. Indeed, some evidence of sex differences was suggested in the zero-order correlations between variables. For example, medium to large associations were found between actor hostility and higher PSQI scores, as well as partner relationship-enhancing attributions and lower PSQI scores, for men but not for women in the sample. Additionally, results revealed some medium to large, yet non-significant, correlations between focal variables for women but not for men. Although the interactions between sex and these variables were not significant in the primary analyses, given the relatively small sample size, it is likely that the current study was under-powered to detect sex differences in observed associations. Additionally, the lower reliability of the PSQI in the current sample may have undermined the magnitude of these associations. Given that there have been very few studies to specifically evaluate relationship functioning in relation to sleep in men and women simultaneously, this remains a topic worthy of further inquiry.

Military veterans and their spouses constitute a population particularly at risk for problems related to sleep and relationship functioning [30, 32–36]. Despite the potentially high-risk nature of the sample, couples in this study were well-adjusted, as indicated by low levels of hostility (even in a conflict task), and healthy sleep profiles, based on PSG outcomes. PTSD symptoms

fell in the mild range for veterans and spouses in the current sample, and 35.7% of the veterans met diagnostic criteria for current PTSD. Additionally, on average, veterans' PSQI scores were above the clinical threshold of 5, which indicates poor sleep quality [53], and is consistent with prior research in veterans [30]. However, these scores are still relatively low in comparison to military samples used in prior research [30]. Furthermore, PTSD symptoms were significantly associated with PSQI scores, which is not surprising, given that sleep disturbances are a hallmark symptom of PTSD. However, this association remained even after nighttime symptoms were removed from the PTSD scores. Additionally, the effects of hostility and relationship-enhancing attributions were significant above and beyond current PTSD symptoms for the objective sleep measures, and PTSD symptoms were not significantly associated with any PSG variables. Therefore, the associations between relationship functioning and sleep found in the present research are likely not attributable to the PTSD symptoms in this population.

We cannot infer causal associations or directionality of associations from the current study. In fact, prior research [19–23] suggests bidirectional relationships between sleep and relationship functioning. It is possible that poor sleep increases the likelihood of negative interactions between couples and that general patterns of negative interactions affect sleep. For instance, experimentally induced sleep deprivation is associated with increases in negative affect and decreases in positive affect, as well as disruptions in cognitive performance, which could have a direct impact on marital adjustment [70]. The interrelationship between these constructs over time [71] is a key direction for future research.

Although we cannot make conclusions regarding the direction of associations, these findings may have implications for interventions. A recent study examined the sleep of couples participating in a marital intervention [71]. Couples who received treatment experienced improvements in marital satisfaction; in turn, husbands experienced significant reductions in insomnia symptoms. This suggests that interventions designed to improve marital functioning may also have significant benefits for sleep. Based on the results of the current study, targeting hostility as a specific relationship behavior may be particularly effective.

Partners may also play a key role in sleep interventions. For example, Rogojanski and colleagues [72] provided a framework for incorporating partners into cognitive behavioral therapy for insomnia (CBT-I), and a recent study found that patients completing a course of CBT-I who described more positive support from their partners experienced improvements in self-rated sleep [73]. By teaching partners how to be supportive of one another—for example, by increasing the use of relationship enhancing attributions or decreasing hostile interactions—individuals receiving sleep-related treatments may experience even greater improvements.

Strengths and Limitations

The present study has a number of strengths. It contributes to a growing literature on the links between relationship quality and health. Sleep is a particularly important health outcome to examine given that it is a shared activity within couples and one with both behavioral and physiological components. From a methodological perspective, this is the first study to utilize objective, behavioral measures of marital functioning, and PSG measurement of sleep. Objective measures circumvent potential biases in participants' self-reports, such as the under-reporting of negative marital evaluations or negative marital behavior due to social desirability. Additionally, we investigated associations between relationship functioning and sleep in a population particularly at-risk for disturbances in both areas of functioning. Approximately 2.6 million service members have deployed since 2001 as part of OEF/OIF/OND. Deployment takes a significant toll on veterans and their partners physically, psychologically, and interpersonally. Understanding and abating these negative consequences for both veterans and their families will continue to be a critical public health issue for the USA for years to come. The present findings highlight the role that communication and conflict resolution skills may play in shaping not only the marital health of these individuals but also the physical health of both partners as well.

This study also has some limitations. First, the generalizability of the findings may be limited by the relatively small size of the sample and limited geographic area from which it was recruited. These findings need to be replicated with larger and more diverse samples of veterans and civilian populations. Whereas the present findings demonstrate significant associations between relationship functioning and sleep quality, this research focused on two specific behaviors in the context of a conflict interaction. We were unable to examine some other potentially relevant interaction behaviors included in the Rapid Marital Interaction Coding System due to considerable restriction of range for those behaviors during the conflict interaction. Other relationship behaviors may be more strongly associated with sleep in different, more positive relationship interaction contexts (e.g., support, goal-setting).

Conclusion

The present research demonstrates ways in which relationship functioning is associated with different dimensions of sleep among OEF/OIF/OND veterans and their spouses. These findings suggest that understanding the links between relationship functioning and sleep may be

particularly important targets of intervention. Future investigations of the aspects of military service that contribute to relationship functioning and sleep in this population—such as deployment, mental health concerns (e.g., PTSD, substance misuse), or lack of social support [32–34, 56, 74]—will further inform intervention efforts. This research contributes to burgeoning research on the dyadic nature of sleep and links between relationship quality and health, highlighting the importance of considering sleep as an important pathway through which relationships influence health.

Compliance of Ethical Standards

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Authors' Statement of Conflict of Interest and Adherence to Ethical Standards With respect to potential conflicts of interest, Daniel J. Buysse has worked as a paid consultant to the following (<$5000 per year for each): Cereve, Inc.; Emmi Solutions; Merck; Philips Respironics; CME Outfitters; and Medscape. He received licensing royalties for the Pittsburgh Sleep Quality Index, Insomnia Symptom Questionnaire, and Consensus Sleep Diary (intellectual property rights). He also received payment for CME lectures from Astellas and Servier. The remaining authors have no conflicts of interest to declare. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. This article does not contain any studies with animals performed by any of the authors.

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