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The Impact of Sleep Complaints on Physical Health and Immune Outcomes in Rescue Workers: A One-Year Prospective Study

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Abstract

Objectives—The present study examined the extent to which sleep assessed soon after a trauma predicted subsequent physical health and immune functioning in rescue workers.

Methods—Participants included 159 men and women who performed rescue and clean-up operations at the site of a major airplane crash. One hundred twenty-eight participants were retained for a one-year follow-up. Self-report measures of sleep quality and psychological distress were obtained within 2 months of the crash, and a physical health questionnaire was completed at one-year follow-up. Natural killer (NK) cell number and cytotoxicity were assessed using blood samples collected from a subset of participants (n=51) at the one-year follow-up.

Results—After adjusting for gender, age, BMI, and initial distress, initial sleep quality complaints were associated with more physical symptoms ($\beta=.32$, $p<.001$), poorer perceived health ($\beta= -.27$, $p=.009$), and increased health care utilization ($\beta=.31$, $p=.003$) at follow-up. In contrast, initial sleep quality was not associated with NK cell number ($r=.10$, $p=.55$) or activity ($r=.02$, $p=.90$). Change in sleep quality over the year following the crash was not a significant predictor of health or immune outcomes.

Conclusions—These data suggest that poor sleep quality in the aftermath of trauma signals increased risk for future adverse physical health outcomes, and underscore the importance of addressing sleep complaints soon after trauma to mitigate the negative impact on physical health.

Keywords

trauma; sleep; health; natural killer cell; rescue worker

Individuals exposed to traumatic events are at increased risk for a number of biobehavioral and physical health consequences including disturbed sleep (1, 2), physical health complaints (3), and impaired immune system functioning (4, 5). Independent of trauma, disturbed sleep has been associated with decrements in physical health outcomes (6, 7) and immune system impairments (8, 9, 10).

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Despite clear relationships amongst trauma, sleep, and health, the extent to which sleep disturbance in the aftermath of trauma predicts physical health and immune outcomes is not clearly understood. Relatively few attempts have been made to integrate these extensive, but separate, literatures. Clum and colleagues (11) examined the impact of psychological distress and disturbed sleep on concurrent physical health symptoms in a sample of 167 female rape victims. Results suggested that trauma-related sleep disturbance was significantly associated with physical health symptoms. These effects were independent of other posttraumatic stress disorder (PTSD) and depressive symptoms, although sleep disturbances only accounted for 2% of the variance in physical health symptoms. In a study of police officers, Mohr and colleagues (12) found that sleep disturbances mediated the relationship between PTSD symptoms and physical health problems (somatic symptoms and limitations in physical functioning), although their results were cross-sectional. The authors proposed sleep-related alterations in immune functioning as a possible explanation for the observed health consequences of PTSD (12).

Few studies have evaluated the relationship between sleep and immune functioning in the context of traumatic or extreme life events. In one study, sleep complaints retrospectively assessed following a powerful hurricane were shown to partially mediate the relationship between posttraumatic stress symptoms and NK cell cytotoxicity (13). Other immune outcomes (e.g., NK cell number) were not associated with sleep. In contrast, NK cell number, but not cytotoxicity, was found to mediate the relationship between posttraumatic stress symptoms and immune functioning in a sample of older adults with bereavement-related depression (14).

Taken as a whole, these studies provide preliminary support for the role of sleep disturbance as a correlate of physical health and immune outcomes in the aftermath of trauma. However, inconsistencies across studies and methodological concerns limit the conclusions that may be drawn from the present literature. For example, cross-sectional designs (11–13) prevent elucidation of clear temporal relationships, and sample-specific characteristics such as age (14) and gender (11) limit the generalizability of results. Further, the timing of data collection in these studies prevented examination of sleep in the initial wake of the event (11, 14).

The present study examined the prospective relationship between sleep disturbance assessed within two months of completing rescue and clean-up duties following a major airplane crash and physical health and immune outcomes one year later. We hypothesized that initial sleep complaints among rescue and clean-up workers would predict increased physical symptoms, poor health perceptions, greater health care utilization, and lower numbers and cytotoxicity of NK cells. We also explored the extent to which change in sleep quality during the year following the crash would predict physical health and immune outcomes, in contrast to initial sleep complaints.

Method

On September 8, 1994, USAir Flight 427 from Chicago to Pittsburgh crashed in the hills northwest of Pittsburgh and exploded on impact, killing all 132 passengers and crew aboard. The present study was part of a larger investigation of traumatic stress among rescue and emergency workers at the crash site. Procedures were approved by the University of Pittsburgh Medical Center's Biomedical Institutional Review Board.

Participants

Participants included 159 men and women employed as airport personnel, fire or emergency workers, or medical or dental personnel in the Pittsburgh metropolitan area who were

actively involved in clean-up and rescue operations following the crash. The sample was primarily male (63%) and white (92%). Age ranged from 18–68 years ($M=36.3$, $SD=10.31$). At the final time point (12 months post-crash), 31 participants were not retained, typically because they could not be contacted, resulting in a final sample size of 128. Participants who were retained did not differ significantly from participants who were not retained on demographic variables, initial distress, or initial sleep disturbance.

Procedure

Recruitment was initiated with the assistance of medical, fire and emergency unit supervisors from the crash site. Potential participants were contacted by telephone, and approximately 90% of those contacted agreed to participate in the study. Data are not available for those who declined to participate. Participants were assessed at their usual worksites. The initial assessment took place within 2 months of the crash and a follow-up assessment was conducted 12 months post-crash. During the initial assessment, participants provided written informed consent and basic demographic information, and completed questionnaires including the Symptom Checklist-90R (SCL-90R) (15) and the Pittsburgh Sleep Quality Index (PSQI) (16). Twelve months post-crash, participants again completed the PSQI (16) as well as a physical health questionnaire. At both time points, questionnaires were completed overnight and returned the following day. A subset of participants ($n=51$) agreed to venipuncture at the follow-up time point in which a 30ml blood sample was drawn from the antecubital forearm vein. Blood samples were used to examine NK cells numbers and cytotoxicity. This subsample of participants included a greater proportion of females than the full cohort at initial assessment ($X^2(1)=4.45$, $p=.04$) and follow-up ($X^2(1)=3.76$, $p=.05$), but did not differ on other study variables. Participants were paid \$25 for their participation at each time point. Data were collected between October 1994 and December 1995.

Measures

Sleep—The self-report Pittsburgh Sleep Quality Index (PSQI) (16) was used to assess subjective sleep quality. The PSQI assesses multiple components of sleep quality (e.g., sleep duration and continuity, sleep disturbance, use of sleep medications) and has a range of 0 – 21, with higher numbers reflecting greater subjective sleep quality complaints. PSQI global scores greater than 5 represent clinically significant sleep disturbance (16).

Initial Distress—Initial distress was assessed at the 2-month time point with a modified form of the Global Severity Index (GSI) of the SCL-90R (15). The GSI is derived from 90 self-reported physical (e.g. headaches, pains in chest) and psychological (e.g. unpleasant thoughts, feeling fearful, losing interest in things) symptoms, with higher values indicating greater distress. Prior to calculating initial distress in the present study, 3 items referring to sleep and 12 items referring to somatic complaints were removed to avoid overlap with sleep and health measures. Thus, initial distress in the present study is represented by the mean of the remaining 75 items which evaluate various forms of psychological distress.

Physical health—A self-report health questionnaire developed for the present study was administered at the 12-month follow-up. Participants were asked to describe their current health on a scale from 1 (*very poor*) to 5 (*excellent*). In addition, health care utilization was represented by the number of times participants visited a doctor in the past month. Finally, participants were asked to indicate whether they had experienced any of 36 non-sleep related somatic symptoms (e.g., colds, dizziness, joint pain) during the preceding 6 months. The number of physical symptoms during this period was calculated by counting the number of endorsed items. Body Mass Index (BMI) was calculated using self-reported height and weight.

Immune measures—Blood samples were collected in a subset of participants to examine NK cell number and activity. A 30ml sample was drawn from the antecubital vein for all participants that agreed and were able to provide blood ($n=51$). All samples were collected in the morning to avoid diurnal variation. Individuals with immune-altering medical conditions or medication use were excluded from sampling. Enumeration of cells and functional assays were performed on fresh blood samples by the Immunologic Monitoring and Diagnostic Laboratory at the University of Pittsburgh Cancer Institute following the laboratory procedures of Whiteside and colleagues (17). Number of NK cells was determined with flow cytometry, and cytotoxicity (i.e. NK activity as represented by mean % lysis) was determined from isolated lymphocytes. Four effector to target cell (K562 cells) ratios (50:1, 25:1, 12.5:1, and 6.25:1) were calculated and averaged to obtain the mean % lysis. As a control technique, concurrent analysis was performed on 3 cryopreserved and 1 fresh control sample. Assays were rejected if results were more than 2 SDs from the laboratory's mean (18).

Data Analyses

The goal of the present study was to examine the extent to which sleep quality complaints following trauma exposure predicted subsequent physical health and immune function. Bivariate correlations (Pearson's r and Spearman's ρ) were conducted to determine the extent to which sleep quality complaints were associated with physical health (physical symptoms, doctor visits, perceived health) and immune outcomes (NK cell number and function) 12 months after the crash. Based on these correlations, hierarchical linear regression models evaluated the extent to which sleep predicted subsequent health outcomes after adjusting for relevant covariates. In each model, age, gender, BMI, and initial distress were entered in Step 1, and sleep quality complaints (global PSQI score) assessed within 2 months of the crash was entered in Step 2. Exploratory analyses examined the extent to which change in sleep quality over the year following the crash was associated with health and immune outcomes at the one-year follow-up. Change scores were calculated by subtracting sleep quality scores at the 12-month follow-up from sleep quality scores at the initial assessment. Bivariate correlations were conducted to examine associations between continuous sleep change scores and the health and immune outcomes of interest. In addition, participants were categorized into 3 groups: no change (change in PSQI score=0), reduced sleep complaints (PSQI score at follow-up is lower than at baseline), or increased sleep complaints (PSQI score at follow-up is higher than at baseline). A One-Way Analysis of Variance (ANOVA) was conducted to examine group differences in health and immune outcomes.

Examination of data normality revealed that number of NK cells was skewed; therefore, the natural log of NK cell number was used for analyses. In addition, number of doctor visits was square root transformed prior to analyses to correct for skewness.

Results

Demographic, health, and immune characteristics are described in Table 1. Subjective sleep quality complaints were observed at both the 2-month and 12-month assessments. Forty-seven percent of crash workers at the 2-month assessment and 39% of crash workers at the 12-month assessment reported clinically significant sleep quality complaints (PSQI global score >5). Over the year following the crash, average sleep quality complaints were relatively stable (Mean change = $-.12$, $SD=2.89$). However, examination of this variable revealed that the fluctuation in sleep quality complaints following the crash was masked by averaging across participants; 37.5% of participants reported fewer sleep quality complaints (mean PSQI global score decreased 2.60, $SD=2.20$) while 42.5% reported more sleep quality

complaints (mean PSQI global score increased 2.57, $SD=1.68$), and 20.0% reported no change.

Overall, the sample reported good current health and averaged less than one doctor visit in the past month, with 53.2% of the sample reporting no doctor visits during this time. However, most participants (83.6%) reported experiencing at least one physical symptom in the past six months.

Bivariate correlations suggested that initial sleep quality complaints were associated with self-reported physical symptoms ($r=.53, p<.001$), doctor visits ($r=.36, p<.001$), and perceived health ($r=-.29, p=.001$), but not with NK number ($r=.10, p=.56$) or function ($r=.02, p=.90$; see Table 2). Hierarchical linear regression models were then used to examine associations among initial sleep quality complaints and physical health (number of physical symptoms, number of doctor visits, and perceived health) after adjusting for gender, age, BMI, and initial distress.

Regression results are displayed in Table 3. The model accounted for 41.7% of the variance in physical symptoms ($F(5, 107)=15.29, p<.001$). Examination of individual predictors revealed that sleep quality ($\beta=.32, p<.001$) was a significant predictor of physical symptoms after controlling for age, BMI, gender and initial distress. The model was also significant for health care utilization ($F(5, 108)=4.53, p=.001$), and explained 17.4% of the variance in number of doctor visits. Sleep quality complaints were the only significant predictor ($\beta=.31, p=.003$) in this model. Results for perceived health were similar, such that the model was significant ($F(5, 111)=4.53, p=.001$; $R^2=.17$) and sleep quality complaints were the only significant individual predictor ($\beta=-.27, p=.009$).

We also sought to determine whether change in sleep over the year following the crash might serve as a more meaningful predictor of assessed health outcomes. However, continuous change scores (change in global PSQI score from 2 to 12 months post-crash) were not significantly correlated with gender, age, BMI, initial distress, or any of the health or immune outcomes. Similarly, one way ANOVAs revealed that health and immune outcomes did not differ as a function of categorical sleep trajectory groups (improved sleep, worsened sleep, no change in sleep). Therefore, change in sleep was not tested in regression models.

Discussion

This prospective study examined the impact of sleep soon after trauma on subsequent indices of physical health and immunity. Subjective sleep quality assessed within 2 months of rescue and clean-up work at the crash site predicted several physical health outcomes after controlling for other factors known to influence health and functioning following traumatic events. The percent of variance in physical health outcomes prospectively explained by sleep quality complaints in the present sample fell within the range reported in cross-sectional studies (11, 12), and parallels the findings of studies prospectively examining posttraumatic sleep as a predictor of mental health problems, such as PTSD (19, 20).

Our work has further expanded the study of sleep and health following trauma by evaluating two previously unexamined physical health outcomes: health care utilization and general perceived health. Although researchers of the Amsterdam air disaster (21, 22) reported that crash workers experienced elevated levels of sleep disturbance, physical symptoms, and number of doctor visits in comparison to controls, they did not explicitly test the relationship between sleep and health. Thus, the present study was the first to show that posttraumatic

sleep quality is a modest, but significant, predictor of perceived general health and health care utilization one year later.

In contrast to physical health outcomes, sleep was not prospectively associated with NK cell number or function one year post-crash. Previous investigations of trauma, sleep and NK cells have yielded contradictory results. While Ironson and colleagues (13) reported significant findings for NK cell cytotoxicity, but not number, Hall and colleagues (14) found the opposite results. These cross-sectional studies did not examine long-term immune consequences of stress-related sleep disturbances. The present findings demonstrated that subjective sleep quality complaints in the acute aftermath of trauma and at one-year follow-up did not significantly affect NK cell number or function. In contrast, chronic sleep disturbances associated with ongoing life events have been shown to affect immunity as measured by antibody response to an influenza vaccination (23). The present results are somewhat limited by the small size of this subsample (n=51). Participants included in analyses of immune outcomes were generally representative of the full cohort, with no significant between-group differences in age, BMI, initial distress, sleep quality, or physical health. However, the subsample did include a greater proportion of females than the full sample, and NK cell number and activity were significantly higher for females than males. Thus, the present study is further limited in generalizability to rescue workers as a whole. Future studies of the longitudinal impact of traumatic stress and disturbed sleep on immunocompetence would benefit from a more thorough examination of behavioral and physiological factors that may contribute to sustained immune dysfunction in association with disturbed sleep (smoking, alcohol use, neuroendocrine activation).

We also sought to explore the impact of change in sleep quality following trauma exposure on physical health outcomes. Results demonstrated that sleep quality in the wake of trauma is a variable process, with the majority of participants reporting a clinically significant increase or decrease in sleep quality during the year following the crash. However, participants' change in sleep over the year was not significantly associated with any of the physical health or immune outcomes assessed, nor was it associated with demographic characteristics or initial psychological distress. Though nonsignificant, change in sleep quality did demonstrate small correlations with NK cell number and activity, such that sleep improvement over the year following the crash was associated with lower NK cell number and activity one year post-crash. This may suggest that NK cells are influenced by chronic patterns of sleep quality, but not trauma-related sleep disturbance, and that acute trauma-related sleep disturbance alone does not exert long-term influence on immune functioning. Previous work (13) has reported that an increase in sleep problems from pre- to post-hurricane exposure was associated with impaired immune functioning. However, pre-hurricane sleep problems were assessed retrospectively at the same time as post-hurricane sleep problems, which may have limited their ability to evaluate true changes in sleep after trauma. Our longitudinal data suggest that initial sleep is a better predictor of one-year physical health outcomes than are changes in sleep quality over time. Larger prospective studies with more frequent assessments may be needed to examine sleep trajectory profiles in the aftermath of trauma including assessment of biological, behavioral and psychological pathways linking sleep to long-term physical health consequences (e.g. neuroendocrine alterations, health behaviors, psychopathology, coping).

The present study is not without limitations. Most notably, there was no assessment of sleep quality prior to the crash, and therefore we cannot clearly distinguish between pre- and post-crash sleep quality complaints. Lack of pre-trauma assessment is a common issue in trauma research due to the unexpected nature of most traumatic events. Some studies have attempted to measure pre-trauma sleep by retrospective assessment following trauma exposure (13, 24), but this approach suffers from retrospective bias and the influence of

psychophysiological factors present in the aftermath of trauma. Despite this methodological concern, the temporal relationship between trauma and sleep has been cautiously inferred from the robustness of sleep complaints across a wide range of traumatized populations (25). In addition, data were not collected to determine whether crash workers experienced any other types of traumatic events during the course of the study, and it is possible that other life stressors may have influenced physical health in the year following the crash. The present study also suffered from relatively high attrition with only 80% of participants retained for the one-year follow-up, but analyses revealed no significant differences in demographic characteristics, distress, or sleep quality between those who were and were not retained.

Limitations were also present in our assessment of physical health. Physical health outcomes were measured by self-report. However, it has been suggested that self-reports of health are reasonably accurate (26) and scores on self-report assessments of physical health have been associated with morbidity and mortality (27, 28). The present findings were further limited by the relatively good health of the sample which limited variability of physical health outcomes. For example, approximately 80% of the sample rated their physical health as either “good” or “excellent”. Similarly, over half of the sample did not visit a doctor during the time period queried, resulting in limited variability of health care utilization. That sleep quality was a significant predictor of perceived health and health care utilization, despite the limited range of outcomes in the present study suggests that the relationship is likely robust. The present study is further strengthened by its prospective design and its evaluation of change in sleep quality in relation to subsequent physical health and immune outcomes.

The present findings highlight the importance of addressing initial sleep disturbances in an attempt to buffer the negative health consequences of traumatic stress, and to improve identification of individuals likely to benefit from intervention. Considerable efforts have been made to identify factors present in the acute aftermath of trauma that increase risk for the development of psychological disorders such as PTSD (29, 30). These findings have been incorporated into attempts to improve the early identification of trauma victims at high risk for PTSD (31) and to improve the efficacy of early intervention and treatment efforts (32, 33). Despite growing evidence that physical health is similarly compromised in trauma victims, the identification of acute risk factors to inform preventative measures has received far less attention. Sleep disturbance soon after trauma may serve as both an early marker of vulnerability and a plausible mechanism for the long-term physical health consequences of trauma exposure. Future research should elucidate the direct and indirect mechanisms through which posttraumatic sleep complaints contribute to negative health outcomes. Although more research is needed, the present data suggest that sleep complaints soon after trauma exposure may be used to allocate intervention resources to high risk individuals. Further, the use of targeted sleep interventions administered in the acute aftermath of trauma may buffer the adverse effects of trauma on physical health.

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Glossary

NK natural killer

PTSD	posttraumatic stress disorder
BMI	body mass index

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Table 1

Sample characteristics of participants recruited at baseline (n=159), participants retained for one-year follow-up (n=128), and participants included in NK cell analyses at one-year follow-up (n=51).

	Initial assessment (n=159)	One-year follow-up (n=128)	Biochemical follow-up subsample (n=51) ^a
	Mean (SD)	Mean (SD)	Mean (SD)
<u>2 months post-crash</u>			
Age	36.26(10.31)	36.45(10.22)	36.94(10.19)
BMI, kg/m^2	27.04(4.87)	27.01(4.89)	26.70(4.48)
Initial distress ^b	.41(.39)	.41(.39)	.38(.34)
Sleep complaints ^c	5.99(3.23)	5.94(3.10)	6.33(2.97)
Gender, n(% male)	100(62.9%)	80(62.5%)	27(52.9%)
<u>12 months post-crash</u>			
Sleep complaints ^c	--	5.68(3.61)	5.75(2.88)
Physical symptoms	--	5.01(4.57)	4.91(4.47)
Doctor visits	--	.86(1.41)	.68(.96)
General health	--	3.90(.85)	3.94(.69)
NK cell number	--	--	285.21(204.53)
Mean % lysis	--	--	16.0(9.68)

Note. Significant group differences were present only for gender.

^a This group of participants represents a subsample of those retained at one-year follow-up represented in analysis of NK cells.

^b SCL-90R Global Severity Index with sleep and somatic items removed.

^c PSQI global sleep quality.

Table 2

Bivariate correlations among distress, sleep quality, physical health, and NK cell number and activity

	1	2	3	4	5	6	7	8
1. Initial distress	–							
2. Initial sleep quality complaints	.52***	–						
3. One-year sleep quality complaints	.42***	.64***	–					
4. Change in sleep quality ^a	–.04	–.28**	.56***	–				
5. Physical symptoms	.52***	.53***	.57***	.13	–			
6. Doctor visits	.25**	.36***	.40***	.10	.38***	–		
7. General health	–.25**	–.29**	–.38***	–.14	–.36***	–.19*	–	
8. NK cell number	–.09	.10	–.06	–.12	–.18	.10	.15	–
9. Mean % lysis	–.13	.02	–.15	–.18	–.15	–.20	.15	.60***

Note. Due to missing data, sample size ranged from 117 to 128 for physical health outcomes and 40 to 51 for immune outcomes;

^a Higher values indicate improvement in sleep quality from baseline to follow-up.

* p<.05,

** p<.01,

*** p<.001.

Results of hierarchical linear regression models testing the impact of initial sleep quality complaints on subsequent physical health outcomes (n=128)

Table 3

	Physical Symptoms				Doctor Visits				Perceived Health			
	Beta	R ²	Δ F		Beta	R ²	Δ F		Beta	R ²	Δ F	
Step 1		.35	14.19***			.10	3.17*			.12	3.70**	
Gender ^a	-.21**				-.10				-.04			
BMI	.03				.14				-.13			
Age	.08				-.02				-.04			
Distress	.34***				.10				-.17			
Step 2		.42	13.25***			.17	9.06**			.17	7.02**	
Sleep quality complaints	.32***				.31***				-.27**			

Note.

^a 1=female, 2=male.

* p<.05,

** p<.01,

*** p<.001.