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PRINCIPAL INVESTIGATOR:

Timothy M Juergens MD

CONTRACTING ORGANIZATION:

University of Wisconsin System
Madison, WI 53715-1218

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14. ABSTRACT The purpose of this study is to assess sleep and wake parameters in veterans of the first Gulf War who have fatigue and other symptoms compared with veterans who do not have fatigue utilizing novel assessment techniques including temperature and high density EEG. This research study is in the data collection phase and data analysis phase. The most significant finding in this study during the previous research period was that temperature curves, which are well-tied with sleep/wake and feelings of fatigue/alertness are showing different projections in veterans endorsing fatigue than those who do not. We are looking to tie this more closely with EEG data as well. The most significant findings in this current research period are exciting EEG data related to frontal activity in the active group of subjects endorsing fatigue compared to an age and sleep breathing matched control group of healthy subjects. The finds show marked broad band reduction in neural activity in clear region of the frontal cortex in all stages of NREM sleep.				
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Introduction

This research project assesses sleep and wake parameters in veterans of the first Gulf War who have fatigue and other symptoms compared to veterans who do not have fatigue. It utilizes novel assessment of brain waves with high density EEG, which allows for high spatial and temporal resolution to provide a window into how sleep is regulated at the global and local level. This will allow us to determine how specific sleep pattern activity is altered in veterans with fatigue. Beyond the typical overnight polysomnography, this assessment includes objective wave analysis of slow wave characteristics, origin and propagation. Circadian rhythm is also assessed, including temperature and salivary melatonin measures, as well as salivary cortisol levels. Vigilance at various points is tested with a psychomotor vigilance test, and there is an optional genetic testing part of the study to assess many polymorphisms that have been associated with other fatiguing conditions and symptoms.

Body

In the Statement of Work, we anticipated being in the recruitment and running subjects in the protocol phase, which is where we are currently. We have successfully completed 14 subjects in our study at this point. We are continuing to recruit subjects. In an effort to increase our recruitment, we have recently altered our IRB protocol to allow for the inclusion of subjects who would otherwise have been eliminated based on initial recruitment criteria. These expanded criteria include allows subjects with obstructive sleep apnea (OSA) provided the disorder is currently treated. We have also allowed for the inclusion of subjects with untreated OSA with an apnea-hypopnea index of up to 20. The original criteria excluded those with an AHI over 15. We have also relaxed the exclusion criteria of body mass index to allow those with BMIs greater than 35 into the study. It is assumed that many individuals in this age range with a BMI > 35 will have sleep apnea, which is why they were originally excluded, but in light of our changed criteria for OSA, we expect to recruit many participants in this BMI-range with treated sleep apnea. We anticipate that these relaxed exclusion criteria will significantly increase our subject population. We have also expanded our recruitment advertising to include in university rheumatology clinics as well as the Madison Veterans Affairs Center.

Data collected includes core, peripheral and distal body temperature, two nights of dense array EEG, multiple symptom scales involving fatigue, pain, and other symptoms, cortisol samples to be able to note diurnal changes, as well as morning cortisol rise from natural wake. We also have collected melatonin samples in a low light environment to be able to assess dim light melatonin onset. Psychomotor vigilance task (PVT) data has been collected at various points in the day in concert with subjective fatigue and sleepiness data.

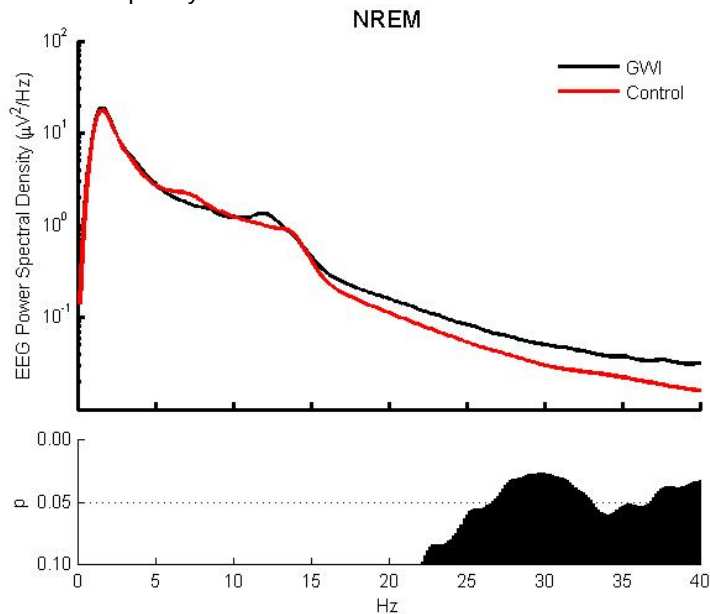
OVERNIGHT PSG REPORT

Given that we have been unable to recruit veterans without fatigue during this reporting period, we have performed comparisons of our fatigued veterans (N=9) with 9 age-matched healthy control subjects on standard polysomnographic parameters. These includes variables such as respiratory events (apneas and hypopneas), time spent in each sleep stage (N1, N2, N3), sleep efficiency, total sleep time, REM duration and latency, wake after sleep onset, and arousals. Despite marked differences in sleep topography, there were no differences in any polysomnographic parameter between groups, although there was a trend ($p=0.07$) toward a *higher* arousal index in the control subjects. Interestingly, in our preliminary analysis of fatigued veteran's versus those without fatigue, there were more EEG arousals in the control group than the active group (on index—events/hour, spontaneous arousals, and total arousal count), with an index of 17.9 arousals/hour in the control group compared to 6.6 arousals/hour in the active group ($p=0.03$). These data, along with those presented below, suggest that standard PSG metrics are incapable of capturing the subtle, but physiologically important changes in sleep in subjects with fatigue.

EEG ANALYSIS

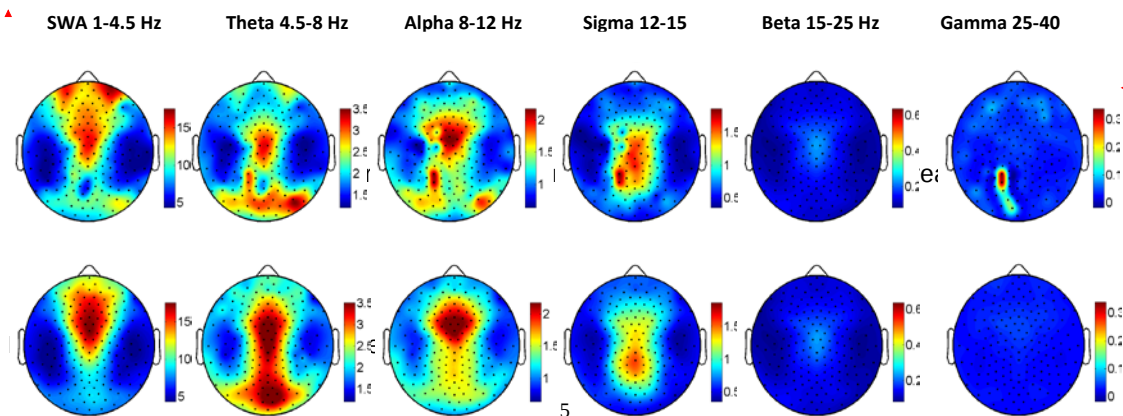
We have also conducted comparisons of all night spectral power as well as sleep topography in our 9 fatigued veteran's versus healthy control subjects.

Comparisons of the all night power spectra demonstrate a slight increase in high-frequency activity (28-32 Hz) in the GWI group relative to the healthy control subjects, although no differences were observed in low frequency.



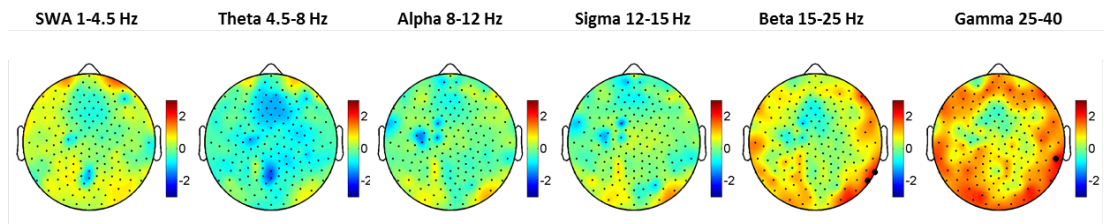
We next examined the topographical distribution of absolute EEG power for specific frequency bands of interest (SWA, Theta, Alpha, Beta, Sigma and Gamma). This analysis showed that both GWI and control groups had average topographies typical of those for men of this age (fig 1, rows 1 and 2, respectively).

Figure 1: All night NREM topography (n=9, top panel GWI subjects, lower panel Control subjects)



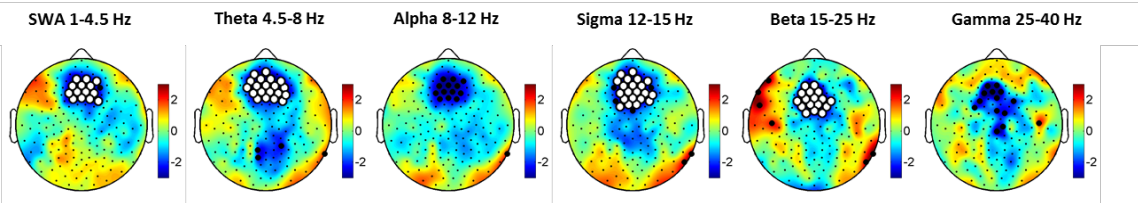
Visual examination of the absolute power comparisons between groups suggested that the GWI group had a reduction in low frequency power as suggested by the average all-night spectral data in the Gamma frequency band (Figure 2, image 6), although this effect was not significant.

Figure 2: Widespread increase in Gamma power (image 6)



After spatially normalizing each subject's topography within each frequency band, which reduces between-subject variability and removes the between group differences, we observed marked broad band-reduction in neural activity in a circumscribed region of frontal cortex in all stages of NREM sleep. Statistical nonparametric mapping (SnPM), a suprathereshold test which accounts for the multiple comparisons involved in testing all electrodes simultaneously, identified significant clusters in the SWA, Theta, Sigma and Beta bands (Figure 3: White dots). Uncorrected t-tests also identified significant groupings of reduced power in electrodes in the Alpha and Gamma bands. (Figure 3 black dots).

Figure 3: Normalized NREM all-night topography



It is now relatively well-established that sleep itself is not a global phenomenon, but occurs in a regional, often use-dependent manner.¹⁻³ One explanation for the daytime fatigue and cognitive impairments commonly reported in GWI may well be that these veterans undergo frontally specific sleep deprivation. In light of the central role sleep plays in learning and performance, a failure of sleep-related oscillations, particularly SWA, to encompass frontal areas would have deleterious impacts on short-term daytime function. Moreover, optimal sleep is not only critical for daytime learning and performance, but emerging evidence indicates that low frequency sleep slow-waves play a critical role in regulating cortical plasticity.⁴ An alternative, but related, interpretation of these data is that it is a reflection of neural injury in this cortical region, arising either as a consequence of long-term sleep loss or as a result of an unknown process related to Gulf-War participation. The notion that sleep pathology results in acute impairments of frontal lobe function has long-standing support, but more recent data suggests that detriments in sleep may ultimately impact the structural integrity of the frontal lobe. A recent volumetric analysis of Gulf-War veterans, adults with major depression and those with PTSD demonstrated reductions in frontal lobe volume associated specifically with poor sleep quality.⁵ Grey matter reductions in prefrontal cortex have been reported in patients with clinical

sleep disorders, including insomnia and cataplexy.⁶⁻⁸ A recent hdEEG analysis of obstructive sleep apnea in men of a similar age, identified a circumscribed reduction in neural activity over the posterior parietal cortex across all frequencies. Given that many neuroimaging modalities indicate the presence of neural injury the posterior cortex in patients with this disorder, the authors interpreted these data as offering further support of neural injury.⁹

We are in the process of correlating this functional deficit with temperature anomalies in this group of 9 subjects to determine if the effect may be related to alterations in the phase relationships between sleep and temperature rhythms. If so, this would support the notion that subjects with GWI are in a state of circadian misalignment, which could also account for many of the symptoms to the syndrome, including cognitive impairment, gastrointestinal distress and fatigue.

Key Research Accomplishments

Recruiting and data collection
Data processing
Some data analysis

Reportable Outcomes

Reportable outcomes have not yet occurred. We are currently in the data collection phase and data analysis phase. Some preliminary outcomes discussed above.

Conclusion

Although firm conclusions are premature, we have demonstrated that, despite the appearance of adequate nocturnal sleep, there are marked differences in the frontal profile of sleep in veterans of the Gulf-War relative to healthy control subjects. Whether this nighttime pattern of frontal disruption is a consequence of neural injury or if it is a reflection of poor quality sleep is unclear. Functionally, however, this distinction may ultimately be an arbitrary one. Long-term sleep disruption is associated with alterations in the structural integrity of the frontal cortex, alterations that may arise secondary to impairments in the plastic processes that are known to occur during sleep. Examinations of functional EEG activity during the daytime will help to clarify whether this is a 24-hour phenomenon. Regardless, this sleep-related deficit could surely explain some of the cognitive symptoms associated with GWI as well as related fatigue.

These findings offer some potential areas of future targeted treatments. Other potential contributors will continue to be assessed when they are analyzed (batched), such as cortisol and more melatonin.

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