Introduction

Post Traumatic Stress Disorder (PTSD) is a psychological disorder that develops in people who have experienced a shocking dangerous event (US Department of Health and Human Services). PTSD is very common in Military Veterans of all services and from all types of trauma. Combat related PTSD stems from the trauma and events associated with combat deployments. Many Veterans who suffer from PTSD can be triggered by everyday things, such as cars backfiring to fireworks on the Fourth of July. As a combat veteran, and with friends and family who suffer from PTSD, I was very interested in its effect on sleep. The Army is funding multiple research efforts into sleep and its relation to soldier performance that my unit participated in. This helped to develop my initial research question: Does Post Traumatic Stress Disorder (PTSD) effect the quality/length of sleep in military Veterans? From this research question, I developed an initial hypothesis that PTSD degrades both the quality/length of sleep in the military veteran population with PTSD initially, but after a certain amount of time, sleep patterns return to normal.

The main goal of this research paper is to determine if there is a difference between healthy adults and those who have deployed to a combat environment in the military service. I will accomplish this by comparing the mean PSQI score from a healthy adult population with a mean PSQI score from a military combat veteran sample population.

Ideally, the results from this study and other researchers work could begin to help the military identify symptoms and severity levels of PTSD within the organization. Military members are far more likely to come forward about sleep issues than PTSD because the negative association with mental health issues so present in the military community does not carry over when discussing sleep.

Literature Review

There has been a large amount of research into the effects and relationship of Post Traumatic Stress Disorder (PTSD) and Sleep in not only military veterans, but other populations of people who are diagnosed with PTSD. The first article aims to look at the relationship between Post Traumatic Stress Disorder and sleep, more specifically the relationship between sleep quality being a negative indicator for the development of PTSD subsequently. This means that the study is attempting to prove that those who rate their sleep quality lower through the Pittsburgh Sleep Quality Index are more likely to develop PTSD in the future. From this 7-year study with 4 waves of data collection, scientists discovered that 142 (7.3%) of veterans developed PTSD over the 7-year period. They also determined that those who reported poor sleep during the first wave of data collection were 60% more likely to develop PTSD (Deviva). This article aims to prove that a poor Pittsburgh Sleep Quality Index score could serve as a predictor for Post Traumatic Stress Disorder as opposed to being a result from it.

Other indicators of poor sleep quality are prevalence of nightmares/terrors and insomnia. Much like the Pittsburgh Sleep Quality Index, there are measurement tools that assess the severity of these issues. Another research study focused on the association of PTSD with other sleep factors such as insomnia and nightmare in both prevalence and severity. This differs slightly from my research project in that they don't use the PSQI as a metric in their study. The study focused on 80 recent combat veterans with a mean age of 30 and had a subthreshold of PTSD. Their insomnia status and nightmare status were measured using the Insomnia Severity Index and the PTSD Checklist nightmare item respectively. From the study, it was determined that at baseline measurements, 74% of presented insomnia to varying degrees and 61% expressed having nightmares. The study concluded that both factors (insomnia and nightmares) were each strongly associated with the severity of PTSD. Furthermore, they determined that insomnia did not go away over time, and that it was a key indicator of ongoing,

untreated PTSD (Pigeon). These other indicators could potentially also work in conjunction with the Pittsburgh Sleep Quality Index and provide a more in depth analysis/linkage between sleep and PTSD.

Other studies have taken place that look at potential treatments of US Service Members and Veterans with traumatic brain injuries. These brain injuries are often commonly associated with post traumatic stress disorder and could potentially serve as an indicator as well. The purpose of one of these studies was to explore the use of hyperbaric oxygen (HBO2) as a treatment for military personnel with post concussive blast traumatic brain injuries (TBI) and assess/measure objective measures of sleep-wake disturbances. 71 military personnel were assessed using the PSQI, a sleep diary, sleep apnea tests, restless legs syndrome, cataplexy, and object actigraphic measures of sleep-wake. The study showed that personnel who were subjected to HBO2 treatment showed improvement in their PSQI sleep measures, although other sleep-wake measures showed no improvement over the testing period (Walker). The continued relationship between post traumatic stress and Pittsburgh Sleep Quality Index further validates my hypothesis.

A potential issue with studying the military population when researching sleep quality is that as a whole population, PTSD diagnosis or not, the military does not do a good job teaching good sleep habits, or placing a large focus on healthy sleep. One such study aims to address the relationship between PTSD and sleep quality in veterans, specifically from Australian Vietnam Veterans. More specifically, it aims to determine if poor sleep quality is common to veterans in general or is relegated to those diagnosed with PTSD. In the study, 152 veterans were assessed, 87 of which were not diagnosed with PTSD. All those with PTSD 90% of those without PTSD self-reported sleep disturbance, showing that serious sleep problem are common across the veteran population, regardless of PTSD diagnosis. A main takeaway from this study was that further research in to sleep disorders in veterans with PTSD might be strengthened by paying attention to etiological role of deployments over the contribution of PTSD (Lewis). This article is useful because the sleep quality in all the participants was measured through the Pittsburgh Sleep Quality Index. It does show that results from military populations could have a potential skew to them, as the population could all have a much poorer baseline score than a healthy similar group.

Further linking the relationship between sleep quality and post traumatic stress disorder has been the subject of many other studies. The aim of one study in particular was to determine if the PSQI could be used as an indicator for PTSD in military veterans. Of the 22.6 million military veterans (2010), a health study reported that roughly 20% of Veterans Affairs patients met criteria to be diagnosed with PTSD. Due to institutional stigma within military communities, it is thought that the current pre/post health assessments required by Department of Defense personnel do not accurately portray the true health of patients. An anonymous survey on an Infantry Brigade Combat Team found that psychological issues were reported between 2 to 4 times more than on the named pre/post deployment assessment. From the sample of 119 veterans in this study, it was determined that the PSQI could predict PTSD in patients 74% of the time, meaning that the PSQI could pose as a more non-invasive assessment within veterans returning from a combat deployment to assess PTSD (Insana). This ties into my hypothesis but also shows that the relationship can go both ways. This is important moving forward, as it could help potentially diagnose PTSD more reliably while also avoiding the institutional stereotypes that are rampant in the military regarding mental health treatment.

Similar to the previous research, the goal of the study in another article was to use subset of participants from a larger study to examine whether preexisting daytime and nighttime sleep disturbances predict depression, PTSD and substance abuse use in US National Guard Soldiers deployed to Iraq. The difference between this study and the goal of my research project is the method in which they measured sleep quality. Instead of the PSQI, this study

used the Daytime and Nighttime Sleep Complaint Scale. They used this scale because the measures are slightly more independent from non-sleep-related constructs like PTSD. At the conclusion of the study, it was found that daytime and nighttime sleep complaints tended to be more strongly correlated with PTSD and depression than other predictor variables, especially as time went on. This strong correlation existed up to a period of two years. This article further solidifies the connection between sleep quality and PTSD (Koffel). It also shows that other measurement methods can be used to reliably assess sleep quality besides the Pittsburgh Sleep Quality Index.

Further solidifying this relationship, another study looked at measuring the level of PTSD experienced in combat veterans from both Iraq and Afghanistan and then looking at their PSQI scores. This article discusses a study which aimed to examine the severity and attempted to correlate sleep difficulties in a sample of treatment-seeking veterans from Operation Enduring Freedom and Operation Iraqi Freedom. A total of 167 veterans completed self-reporting measuring sleep quality, combat exposure, psychopathology, fear of loss of vigilance, cognitive coping strategies, and unit and post deployment social support within 1 year of returning from deployment. I am most interested in in the sleep quality measures, which were obtained through the Pittsburgh Sleep Quality Index. At the conclusion of the study, it was found that PSQI scores correlated positively with PTSD with an r value of 0.65 among the overall population. This further solidifies the relationship between sleep and PTSD in military veterans, especially those from Iraq and Afghanistan (Pietrzak). This data set and results are what I will be comparing the healthy data from the MMASH data set with, specifically the mean PSQI scores for the sample population of military veterans.

This next study studied a far larger population of military veterans, once again focusing on their sleep quality. Specifically, this article attempted to examine poor sleep, resilience, and psychological distress using questionnaires collected as part of the Study of Post-Deployment Mental Health in 1,118 US Military Veterans who had served since 9/11, had at least one overseas deployment, and were free from a mental health disorder for at least a month. Once again, the PSQI was determined to be the best measurement of sleep quality. This study used a linear regression to examine the relationship between PSQI Score and psychological distress (measured by the Global Symptom Index). The study concluded that over one-half of all the respondents were assessed to have met the criteria for poor overall sleep quality (PSQI > 5) with an average score of 7.17. This study further shows the positive correlation between sleep, and deployments, while not specifically discussing PTSD as either a cause or an effect of sleep quality (Hughes). This average score is indicative of poor sleep quality (greater than 6).

Another study related to using the PSQI as an indicator for PTSD actually focused on a female population. In this article, a study aims to examine the psychometric properties of the PSQI-A (Pittsburgh Sleep Quality Index Addendum for PTSD) in order to begin to characterize disruptive nocturnal behaviors (DNB) in a total of 169 women with PTSD and 63 healthy women. This study is unique when compared to others I have looked at because it doesn't focus solely on PTSD as a result from combat exposure in military veterans. Women in the PTSD group reported poorer overall sleep quality with an average score of 11.98, while women in the healthy group reported an average score of 4.98 on the PSQI. Not only were their PSQI scores higher, but they also suffered from more severe disruptive nocturnal behaviors than their healthy counterparts. The study concluded that the PSQI score of 4 served as a positive predictive value of 93% for discriminating participants with PTSD from those without (Germain).

Similar to the study on hypobaric treatment methods of treating concussive blast veterans, this article examines the effectiveness of different methods, mainly cognitive-behavioral therapies at treating sleep disturbance in PTSD subjects. The article compares the treatment effectiveness to pharmacologic treatments and determines that cognitive behavioral therapy is at least as effective in the short term and has more enduring beneficial effects. This study is important to my research project because it once again uses the PSQI to assess sleep

quality and relates it to PTSD exposure. The article concludes that a combination of CBT and traditional pharmacologic treatments are the most effective way to treat sleep disturbance in PTSD, but even then insomnia and nightmares are difficult to fully resolve in all patients (Schoenfeld).

Description of Data and Methods

The overall easiest and widely accepted method for measuring sleep quality is the Pittsburgh Sleep Quality Index (PSQI). The PSQI is a survey taken by the research subject and provides an overall score indicating the quality of sleep from the previous night. It consists of 19 self-rated questions and 5 questions rated by the bed partner or roommate (if one is available). Only self-rated questions are included in the scoring. The 19 self-rated items are combined to form seven "component" scores, each of which has a range of 0-3 points. In all cases, a score of "0" indicates no difficulty, while a score of "3" indicates severe difficulty. The seven component scores are then added to yield one "global" score, with a range of 0-21 points, "0" indicating no difficulty and "21 " indicating severe difficulties in all areas. This measurement is overall very useful as an initial indicator for sleep quality but does have some drawbacks. As with most surveys where the subject is assessing themselves, there is bound to be some biases within the results. As such, more sleep studies are using the PSQI in combination with live data from sensors worn during sleep.

The Multilevel Monitoring of Activity and Sleep in Healthy people (MMASH) is one of these datasets. It "provides 24 hours of continuous psycho-physiological data, that is, inter-beat intervals data, heart rate data, wrist accelerometry data, sleep quality index, physical activity (i.e., number of steps per second), psychological characteristics (e.g., anxiety status, stressful events, and emotion declaration), and sleep hormone levels for 22 participants" (Rossi 1). There is an incredible amount of very useful biological data within this data set and it is one of the only openly available datasets to provide heartbeat-to-heartbeat data in the long term and to link this data to psychological data as well. The portion of this data of interest to my research paper is the "Pittsburgh" variable. This is the subject PSQI score during the study. Because I was not able to acquire any PSQI data from the Veterans Affairs Office, I thought it would be interesting to compare the Sleep Quality of two different populations. The first population being the "Healthy People" from the MMASH dataset with the results from the longitudinal study conducted on 167 Operation Enduring Freedom (Afghanistan) and Operation Iraqi Freedom (Iraq) combat Veterans. Although I couldn't get the data, the results of the study on the Veterans would make an intriguing comparison.

It is also interesting to note, that all of the subjects in the MMASH data set were male. This will allow for an even better comparison, because the Afghanistan/Iraq Veteran sample was over 95% male. Further analysis into the comparison of the means would be useful, such as a two sample "t test" in order to determine if there is a true statistical difference in the means. Unfortunately, without access to the raw data from the Iraq/Afghanistan veteran sleep study, it is impossible to do a true comparison of means using the two sample t test.

Analysis

With the Data Analysis Program "R Studio," I was able to import the individual user information from the MMASH Data Set. I then joined the user data information with the sleep study data and created my final data frame which included 22 observations (users) with 25 different variables, the most important being the "Pittsburgh" column with the individual PSQI

Scores of the healthy person. Through the "Mosaic" package in R, I was able to calculate cursory summary statistics of the PSQI Scores for all subjects. The data was as follows:

Min	Q1	Median	Q3	Max	Mean	SD	N	Missing
2	4	5	7	9	5.318182	1.985336	22	0

From this data, it is clear that the average PSQI score for the "healthy" people was roughly 5.3. From the PSQI instructions, any number below 6 was indicative of healthy, quality sleep. The average adult in this sample was within this range. The median was also 5, meaning that the sample was normally distributed. I validated this normal distribution with a qq plot using the "GGPlot" package.


qq plot of PSQI
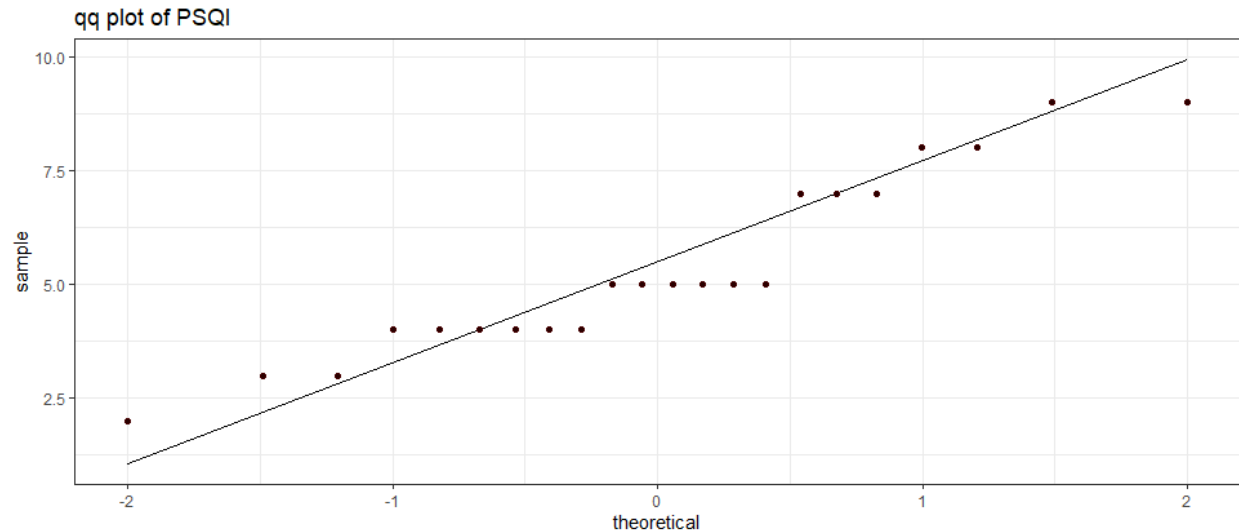
Another method of verifying the normal distribution of a data set is through the Shapiro Wilks Normality Test. Through R, we receive a p-value of 0.05828. Because this value is greater than 0.05, we can reject the null hypothesis and accept the alternative that the distribution of Pittsburgh Sleep Quality Index scores is normal. Because this distribution is normal, we can then compare the means from this data set and the 167 military veterans data set.

A few other plots of interest were the density plot and the histogram to look at the distribution of Pittsburgh Sleep Quality Index scores for the MMASH data set. These two graphs further illustrate the data's bell curve sitting in normal Pittsburgh Sleep Quality Index scores of less-than 6. On the density plot, the peak of the curve sits between 4 and 6, showing the center of the distribution is within the "healthy" range for PSQI scores. The histograms shows the same. From the histogram, we can also see that there is a slight right skew, potentially due to the outlier scores of 9.

Density Plot of PSQI Score

Histogram Plot of PSQI Score
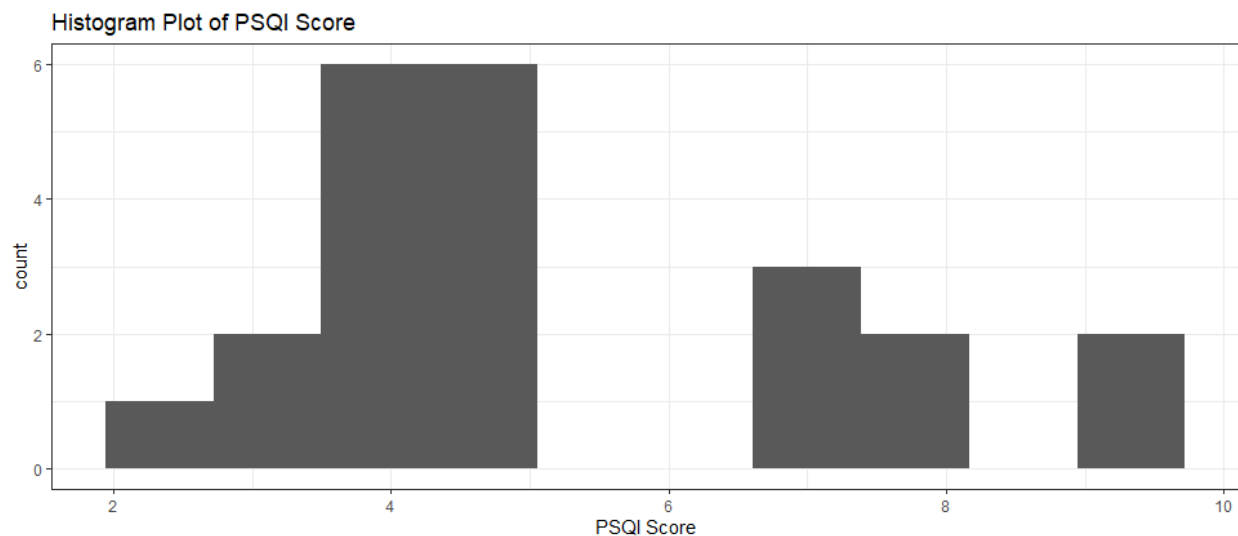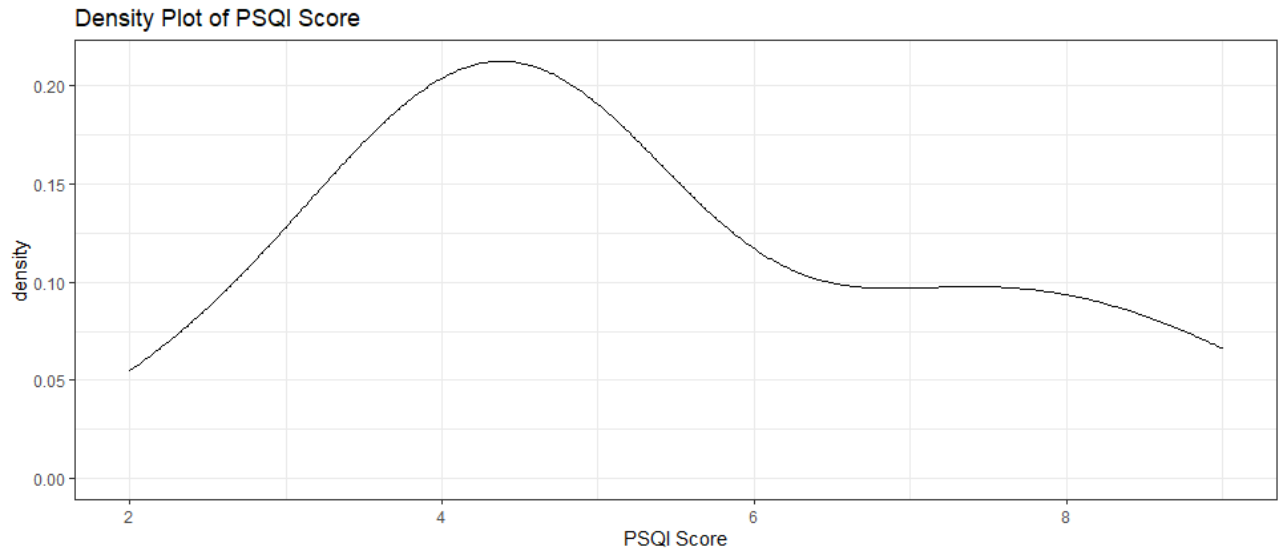
After confirming the distribution and gleaning summary statistics from the data set, I was interested in other factors in the study that may affect Pittsburgh Sleep Quality Index score, although this was originally not part of the research project. The two other variables of interest were "Age" and "Daily_Stress." The stress variable "is a 58-item self-reported measure which allows people to indicate stressful events that they engaged in in the last 24 h. In addition, participants have to indicate the magnitudes of the stressful events engaged in during the past days on a Likert scale from 1 (occurred but was not stressful) to 7 (caused me to panic). Daily_stress gives a score between 0 and 406, where the higher the values, the higher the frequency and magnitude of the stressful events perceived during the day" (Rossi 3). While this stress score may not be equivalent to the stressors of Post Traumatic Stress Disorder, I was interested to see if it served as an indicator within this study. The first step in this was determining correlation coefficients for the two variables of age and daily stress. The correlation coefficient for daily stress is 0.06 and the correlation coefficient for age was -.08. These are both very low correlation coefficients meaning that there is not a very strong strength of relationship between these variables and Pittsburgh Sleep Quality Index scores. Below are the

two scatter plots for the two variables as well as linear model lines showing the lack of relationship between the two potential explanatory variables daily stress and age.
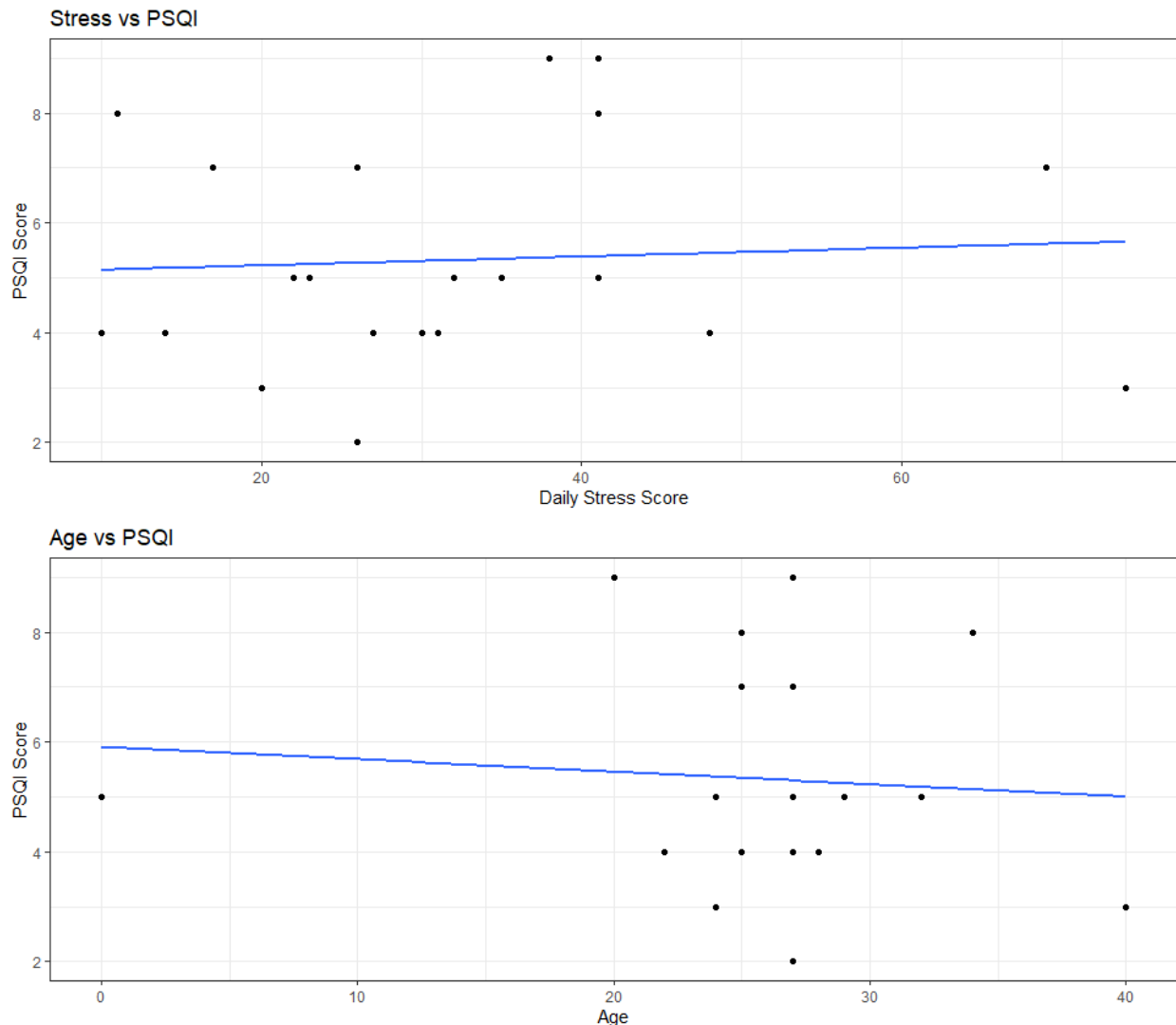
These two graphs clearly demonstrate the lack of a linear relationship between the two explanatory variables and Pittsburgh Sleep Quality index score within this data set. I believe that further exploration into this data set could involve data transformation to see if that helped create a stronger correlation between the explanatory and response variables. Some transformations could include logarithmic transformations of the explanatory and response variables. It would also be useful to look at building a multivariate model using some of the additional biological data available in the MMASH data set. Two variables of interest that could be used are STAI-Y 1 and STAI-Y 2, which are anxiety factors that could potentially influence or be tied to PTSD.

Conclusion / Results of Analysis

Sleep quality and post-traumatic stress disorder are clearly linked in the way I initially hypothesized. Overall, the healthy population from the MMASH sample had an average PSQI score of 5.31, which is considered healthy, superior quality sleep. When compared to the study of 167 Iraq/Afghanistan combat veterans, it is easy to see the difference. The study of the

Iraq/Afghanistan determined that the mean PSQI score of their sample population was 11.25. This average is significantly higher. In fact, the maximum value from the MMASH data set was only 9, which is lower than the average from the combat veteran population. This only solidifies the hypothesis that veterans who suffer from PTSD have poorer quality sleep than people who have not been exposed to combat and the stressors that come with it. The study on the military veterans was also unique in that it also attempted to quantify the level of PTSD in each of the subjects through measurement of their PTSD symptom severity. PSQI was found to have a strong correlation with this variable ($r = 0.65$) meaning that as PTSD symptom severity increased, the PSQI score also increased, indicating a degradation in the quality of sleep.

There are many opportunities to further expound on my research and other observational studies as well. The MMASH data set is unique in its comprehensive approach to sleep measurement. A potential opportunity would be to use the same measurement techniques used in that study on a unit preparing to deploy to a combat zone. Since the deployment population remains generally the same from the start to the end of the deployment, it would be interesting to see how the biological measurements change over the course of a deployment, especially as they relate to sleep. PSQI questionnaires could be administered weekly to members of the deployed unit, and changes could be analyzed real time from back in the United States. I believe that there would be an upward trend in the PSQI scores as the deployed time increases, with that upward trend continuing well into redeployment. This trend would continue because redeployment is generally just as stressful as the actual deployment.

Another potential opportunity for further research into the MMASH data set would be to conduct a regression analysis using more of the data. With the heartbeat-to-heartbeat data, there is a massive amount of information for each of the study participants. By beginning to build a linear model using multivariate regression, it would be possible to predict PSQI score using the biological data. This would be interesting and helpful because there are currently studies with the military in which entire formations of over 600 service members are wearing these "wearables" similar to the ones used to collect the MMASH data. A regression model would help to confirm / deny their ability to predict PSQI, and in turn predict post traumatic stress disorder in service members.

The true usefulness of the PSQI as an indicator of post traumatic stress disorder lies with its innocuousness. Like previously mentioned, most military service members are not likely to report post traumatic stress disorder symptoms on post deployment health surveys. This is due to social and institutional norms and stereotypes within the military. There is a severe negative connotation association with reporting mental health issues in the military. Most soldiers are unwilling to report them especially when their names are associated with the survey. A study found that military service members were far more likely to report mental health symptoms when their names are not associated with the results. The PSQI could help solve this problem because there isn't the same negative association with poor sleep as there is with mental health issues like PTSD. The military could potentially begin to use the PSQI as a predictor of PTSD, which would allow for earlier recognition of the symptoms as well as potential earlier treatment. This would great improve the health and readiness of soldiers returning from deployments, and would allow commanders in the military to more fully understand the readiness and capabilities of their formations.

References

DeViva, J. C., McCarthy, E., Southwick, S. M., Tsai, J., & Pietrzak, R. H. (2021). The impact of sleep quality on the incidence of PTSD: Results from a 7-year, nationally representative, prospective cohort of U.S. military veterans. *Journal of Anxiety Disorders*, *81*, 1–6. https://doi.org/10.1016/j.janxdis.2021.102413

Germain, A., Hall, M., Krakow, B., Katherine Shear, M., & Buysse, D. J. (2005). A brief sleep scale for posttraumatic stress disorder: Pittsburgh sleep quality index addendum for PTSD. *Journal of Anxiety Disorders*, *19*(2), 233–244. https://doi.org/10.1016/j.janxdis.2004.02.001

Hughes, J. M., Ulmer, C. S., Hastings, S. N., Gierisch, J. M., Mid-Atlantic VA MIRECC Workgroup, & Howard, M. O. (2018). Sleep, resilience, and psychological distress in United States Military Veterans. *Military Psychology*, *30*(5), 404–414. https://doi.org/10.1080/08995605.2018.1478551

Insana, S. P., Hall, M., Buysse, D. J., & Germain, A. (2013). Validation of the Pittsburgh sleep quality index addendum for posttraumatic stress disorder (PSQI-A) in U.S. male military veterans. *Journal of Traumatic Stress*, *26*(2), 192–200. https://doi.org/10.1002/jts.21793

Koffel, E., Polusny, M. A., Arbisi, P. A., & Erbes, C. R. (2013). Pre-deployment daytime and Nighttime Sleep Complaints as predictors of post-deployment PTSD and depression in National Guard troops. *Journal of Anxiety Disorders*, *27*(5), 512–519. https://doi.org/10.1016/j.janxdis.2013.07.003

Lewis, V., Creamer, M., & Failla, S. (2009). Is Poor Sleep in Veterans a Function of Post-Traumatic Stress Disorder? *Military Medicine*, *174*(9), 548–551.

Pietrzak, R. H., Morgan, C. A., & Southwick, S. M. (2010). Sleep quality in treatment-seeking veterans of Operations Enduring Freedom and iraqi freedom: The role of cognitive coping strategies and unit cohesion. *Journal of Psychosomatic Research*, *69*(5), 441–448. https://doi.org/10.1016/j.jpsychores.2010.07.002

Pigeon, W. R., Campbell, C. E., Possemato, K., & Ouimette, P. (2013). Longitudinal relationships of insomnia, nightmares, and PTSD severity in recent combat veterans. *Journal of Psychosomatic Research*, *75*(6), 546–550. https://doi.org/10.1016/j.jpsychores.2013.09.004

Rossi, A., Da Pozzo, E., Menicagli, D., Tremolanti, C., Priami, C., Sîrbu, A., Clifton, D. A., Martini, C., & Morelli, D. (2020). A public dataset of 24-H multi-levels psycho-physiological responses in young healthy adults. *Data*, *5*(4), 15. https://doi.org/10.3390/data5040091

Schoenfeld, F. B., DeViva, J. C., & Manber, R. (2012). Treatment of sleep disturbances in posttraumatic stress disorder: A Review. *The Journal of Rehabilitation Research and Development*, *49*(5), 729–752. https://doi.org/10.1682/jrrd.2011.09.0164

U.S. Department of Health and Human Services. (n.d.). *Post-traumatic stress disorder*. National Institute of Mental Health. Retrieved December 16, 2021, from https://www.nimh.nih.gov/health/topics/post-traumatic-stress-disorder-ptsd

Walker, J. M., Mulatya, C., Herbert, D., Wilson, S. H., Lindblad, A. S., & Weaver, L. K. (2018). Sleep assessment in a randomized trial of hyperbaric oxygen in U.S. service members with post concussive mild traumatic brain injury compared to normal controls. *Sleep Medicine*, *51*, 66–79.