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The Intertwined Relationship of Stress and Sleep Quality of Undergraduate Students During the COVID-19 Pandemic

Jordan Nguyen
University of Central Florida

THE INTERTWINED RELATIONSHIP OF STRESS AND SLEEP QUALITY OF UNDERGRADUATE STUDENTS DURING THE COVID-19 PANDEMIC

by

JORDAN NGUYEN

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ABSTRACT

This study aims to examine the relationship between stress and sleep of undergraduate students during the course of the COVID-19 pandemic. The possibly correlational relationship between these two parameters was determined with respect to how this population was faring during recent times, two years into the pandemic. The study also served to examine how this relationship changed over time based on three time frames: before the pandemic, during the advent of the lockdown (March 2020-May 2020), and during recent times. A survey was developed to collect data from the undergraduate participants for correlation and regression analysis to determine the relationship between stress and sleep quality as well as how the relationship has changed over time. In addition to questions pertaining to the subjective stress levels and subjective sleep quality of the respondents, questions adapted from the Pittsburgh Sleep Quality Index (PSQI) were used to serve as an objective measure of sleep quality. The survey was created through the Qualtrics online survey software and distributed through social media such as Reddit and Discord. The participant inclusion criteria included: 1) be a current undergraduate student at a university or community college, and 2) be at least the age of 18. One-hundred-four full responses were collected out of a total of 138 that began the survey. The results indicated a high prevalence of sleep problems among the participants, with the majority of them (58.65%) having poor sleep quality within the last month. A moderate negative correlation between stress levels and sleep quality was found as well. This was based upon a moderate positive correlation between subjective stress level, and PSQI score the month prior to participants taking the survey. However, stress was not a good predictor in determining sleep quality alone. Further, the results were inconclusive on how the relationship between stress and

sleep quality changed from before to during the duration of the lockdown. Overall, this study indicated the need to further research into how stress and other factors affect the sleep quality of not just undergraduate students but other populations susceptible to poor sleep.

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INTRODUCTION

Sleep is a fundamental physiological process ubiquitous to not just all humans but animals in general. It is defined "as a state of immobility with greatly reduced responsiveness." Sleep is distinguished from other states of reduced activity, including anesthesia or a coma, due to its rapid reversibility [1]. People have long struggled to understand the various facets regarding sleep, whether it be the process itself or the factors that influence it. One aspect of this is sleep quality. This is defined by how well a person can sleep at night. However, it is difficult to measure objectively due to the numerous parameters involved in determining quality. This includes the duration of sleep, how long it takes the individual to fall asleep, and subjective assessment [28]. Nonetheless, the Pittsburgh Sleep Quality Index (PSQI) has been developed that combines a number of these factors to determine an objective score to the sleep quality [28]. However, even this is not perfect due to the sheer quantity of variables that can play a role [2].

Sleep quality is of particular note because it has been declining recently due to changes brought about by the ongoing COVID-19 pandemic. However, a decline in quality of sleep has been an issue long before the outbreak [3]. Chronic sleep loss has already risen in modern times due to increasing economic and social demands [3]. In fact, sleepiness overtakes both drug use and alcohol as the most prevalent preventable cause of accidents regarding modes of transportation [4]. Yet, this loss of sleep is further compounded by changes brought about by the pandemic, with a significant proportion within the general populace with diminished sleep quality [4]. These rapid changes occurred due to the pandemic, including "an extended period of isolation, fear of infection, uncertainty, disappointment, insufficient supplies, and economic

damage [5].” Especially when combined, these factors can lead to a drastic increase in the stress one would typically experience from their life [5]. This is what may have led to the remarkable decrease in sleep quality in the wake of the pandemic. So, while various other elements play a role in determining sleep quality, including but not limited to physical activity, body mass index, and diet, the critical component with prominent influence, especially concerning COVID-19, would be one’s stress [6].

LITERATURE REVIEW

Stress and Glucocorticoids

As described by Dr George P. Chrousos, stress occurs when there is a “state of disharmony or threatened homeostasis” due to the presence of stressors that disrupt the normal balance in one’s life [7]. In response to said stressors, the body will elicit certain adaptive reactions which can be either generalized or directed to a particular stimulus. Further, the response may be either a behavioral adaptation or a physiological adaptation. Because of its necessity for survival as well as invariability in its presentation, there is a system precisely to coordinate the adaptations to these stressors. In particular, it revolves around the hypothalamic-pituitary-adrenal (HPA) axis, which acts to control the intensity of these adaptations [11].

The intensity of the responses is directly correlated with the novelty of the circumstances the subject experiences. Essentially, when the environment forces individuals into unpredictable situations beyond their control they will experience stronger reactions [8]. The unpredictability is denoted by an “absence of an anticipatory response” while the lack of control is marked by “a reduced recovery” in the physiological response [8]. It is noted that the speed of this recovery depends on the individual's previous experience with even a “single pre-exposure” being enough to increase the recovery significantly. Otherwise, the body will exhibit signs of stress for a longer duration of time. In fact, according to Dr. Richard S. Lazarus, “the most stressful condition is: no information, no control, and no prediction of upcoming events, with an uncertain feeling of threat [9].” The anxiety regarding the unfamiliarity of the stimulus will compound upon the typical amount of stress expected from it. As such, the physiological response to the said stimulus is expected also to be exaggerated.

Physiologically speaking, a key component to the generalized stress response involves the release of glucocorticoids through the HPA axis. This process is done in a neuroendocrine manner. The hypothalamus releases corticotropin-releasing hormone (CRH) and arginine vasopressin (AVP) within the parvocellular neurons of the paraventricular nucleus [10]. The hypothalamus releases them at a basal rate. CRH travels through portal vessels to bind to their respective receptors on corticotroph cells in the anterior pituitary gland [10]. These cells will then release adrenocorticotropic hormone (ACTH) [11]. In turn, ACTH stimulates the Zona fasciculata layer of the adrenal cortex to release glucocorticoids [11]. The glucocorticoids are involved in modulating several functions, including cognition, metabolism, and immunity. In humans, the main glucocorticoid is cortisol.

Endogenous release of cortisol is correlated with the 24-hour circadian rhythm, with its release typically coinciding with the sleep-wake transition in the morning. The circadian rhythm is essentially the internal clock of the body that regulates the sleep-wake cycle [10]. Basically, cortisol is released at regular intervals throughout the day as dictated by this clock [10]. Though, the rate of glucocorticoid release can be amplified with exposure to stressors [10]. This includes both physiological stressors such as a disease state or emotional stressors like fear [10]. The neuroendocrine system will perceive these signals and activate the hypothalamus to release CRH beyond the basal rate [10]. In turn, this will lead to a higher concentration of glucocorticoids in circulation. The concentration of corticosteroid-binding globulin, the protein that 75% of cortisol in circulation typically binds to, is also decreased under stress [10]. This means that a larger proportion of cortisol is free and unbound, allowing it to bind to receptors more readily. Beyond

this, stress also impacts the levels of glucocorticoid receptors within the brain [12]. All of these factors will naturally lead to an amplified reaction of glucocorticoids in the presence of stress.

The Interdependent Relationship of Stress and Sleep

The suprachiasmatic nucleus of the hypothalamus act as the "master pacemaker" of the body in terms of regulating the circadian rhythm [13]. This includes maintaining the basal release of glucocorticoids as well as melatonin which help induce sleep [13]. However, the suprachiasmatic nucleus does not have sole control over the internal clock as other factors have influence [13]. This includes the levels of glucocorticoids which can vary based on the levels of stress currently being experienced [13]. Though, due to its regular endogenous release coinciding with the sleep-wake cycle, cortisol's release is seen as a "major internal synchronizer" of this circadian rhythm [13]. Glucocorticoids affect the daily rhythmicity of several peripheral organs as well as the central nervous system [13]. For this reason, alterations in glucocorticoid levels will have a detrimental effect on the sleep-wake cycle. In the case of individuals with Cushing's disease, resulting from chronic exposure to excess glucocorticoids, they experienced extended wake time as well as an increase in sleep latency [14]. This pattern would be experienced in healthy individuals as well, which indicates that these observations are linked to the levels of glucocorticoids.

Therefore, the increased glucocorticoid release from stress from outside forces will also disrupt the typical circadian rhythm. However, internal factors such as emotional state also play a role in generating stress [15]. Specifically, "stress-related worry and rumination" will manipulate the sensitive systems which control sleep [15]. There is a "cognitive-emotional" component in

which rumination and coping negatively affect sleep quality [15]. Essentially, the combination of external and internal stressors interrupts the standard regulation of the sleep-wake cycle.

Interestingly, sleep quality itself can affect the release of glucocorticoids by the HPA axis. This is expected based on the number of functions sleep serves for the individual. It has a restorative component because cellular components for many physiological processes are regenerated during sleep [16]. Further, sleep contributes to conserving energy due to the decrease in metabolism and energy consumption [16]. Interrupting these functions will inevitably prove detrimental to the body and generate stress leading to the neuroendocrine response [16].

In an experiment by Dr. P. Meerlo, rats exposed to chronic sleep deprivation experienced increased levels of both ACTH and glucocorticoids in circulation [11]. This observation was noted within a mere day of depriving the rats of sleep, and it continued throughout the seven days the experiment was conducted [11]. As long as the rats were exposed to the stressor, they continued to exhibit the physiological stress response. Dr. Stijin Massar experienced similar results in a study on human males [11]. The subjects who indicated poor sleep efficiency experienced exaggerated neuroendocrine reactions, meaning they had elevations in cortisol and blood pressure, another stress response marker [17]. Therefore, diminished sleep quality can act as a chronic stressor that further stimulates the HPA axis beyond the maintenance level. Essentially, sleep quality and stress display a bidirectional relationship in which an alteration of one will lead to a change in the other. A generalized stress response from an external stressor causes a diminishing of sleep quality. This, in turn, will lead to a further exaggerated stress response due to the lack of sleep. In other words, a feedback loop is generated that constantly compounds upon itself to the detriment of the body.

Beyond acting as a stressor itself, sleep deprivation has the capacity to amplify the stress response to other stressors. While a single night of sleep deprivation does not significantly impact how the body reacts to an outside stressor, chronic sleep deprivation has been shown to amplify the responsiveness to psychosocial challenges [18]. A higher cortisol level was noted in individuals with poor sleeping habits to an outside stressor than those who sleep well in response to the same stressor [18]. A study by Dr. Sarah M. Bassett demonstrated differential effects of sleep quality on salivary cortisol levels in response to the psychosocial stressor [19]. Specifically, the reactivity of the HPA axis was directly affected, which led to the observed increase in cortisol levels in poor sleepers [19]. Interestingly, there was a gender disparity in that men who reported lower sleep quality had more exaggerated stress responses than women who reported lower sleep quality [19]. In essence, diminished sleep quality not only elevates stress on its own, but it also amplifies the stress, and thereby responses, generated from other sources.

COVID-19 and the Population of Interest

The COVID-19 pandemic proves to be an unprecedented time in terms of uncertainty and worry. Not only is the physical health of the populace in danger due to the spread of the virus, but their mental health is as well, even for individuals who never contract the disease [20]. The numerous stressors present during the outbreak include concern on how the pandemic is progressing, the financial struggles, social restrictions, and most importantly, the health of the individual and those close to them [20]. Of course, this is further compounded by the general unpredictability of the event [20]. This is also on top of any other responsibilities before the pandemic, such as work, school, or familial obligations. As such, it is not unexpected that 29.6% of 9074 individuals report stress, and 31.9% from 63,439 reported anxiety during the

pandemic[21]. These figures underscore the prevalence of stress among the general population, let alone groups more susceptible to increased stress.

Beyond stress, the pandemic has also had ramifications on sleep quality as well. In 2014, a study indicated that 29.8% of American soldiers in West Africa had sleeping problems in the wake of the Ebola outbreak [22]. This suggested possible issues regarding the soldiers adapting to the social isolation and quarantine [22]. A situation like this would be mirrored but on a larger scale due to the global level spread of COVID-19. The prevalence of insomnia among the general population was 30.5%. It increased to 38.4% when looking at healthcare workers specifically due to the stress accompanying their responsibilities and firsthand exposure to those with the virus [23]. Among those who reported insomnia, anxiety and stress were cited for poor sleep quality [23].

A particular population of concern regarding the effects of the pandemic is undergraduate students. Even prior to the lockdown, college students were under heavy stress [24]. In fact, the proportion of students diagnosed with a mental health condition increased from 22% to 36% from 2007 to 2017 [24]. Thus, it is not unexpected that college students will experience an exaggerated response to stressors from the pandemic relative to the general population. Younger people experience a higher level of anxiety and a lower locus of control relative to older individuals [25]. In addition to the challenges faced by the general population, they also had to contend with concern for their academic performance, the uncertainty of exam dates, and the difficulties of remote learning in general [25]. Further, students had difficulty coping with increased stress, which exacerbated the stress responses [25].

Not only are undergraduate students prone to stress, but they also experience poor sleep quality as well. Before the lockdown, sleep problems were already prevalent among college students, with more than half reporting poor sleep quality [26]. Attending college is a stressful experience with students dealing with the academic pressure and irregular schedules that may force them to stay up longer to do schoolwork if they want to succeed [26]. Frequent use of smartphones and nighttime media further compounds on this [26]. These issues are expected to be inflated due to the pandemic to result in a further loss of sleep quality.

PURPOSE

This study's purpose was to explore the relationship between stress and sleep quality for undergraduate students before and during the COVID-19 pandemic. Initially, the correlation between the subjective stress level of the students was compared to their PSQI score, which is a more objective measure of sleep quality within a month of taking it. It was expected that there will be an inverse relationship between these parameters considering that a higher PSQI score is more indicative of worse sleep quality. This is based off of the aforementioned effects stressors have on the body and sleep such as through the action of glucocorticoids.

There was a comparison between the subjective stress and subjective sleep quality for students before the pandemic, at the advent of the pandemic, and during recent times. Unfortunately, the PSQI is only able to quantify sleep quality within the last month meaning it was unable to be used for this comparison. As such, the subjective sleep quality as reported by the students was utilized. The prevalence of sleep issues as well as sources of stress within these time frames was analyzed. These time frames were chosen to reflect better how the stress levels, and thereby sleep quality, have changed due to the pandemic. The advent of the pandemic should see the highest amount of stress due to the rapid, unpredictable changes occurring and the most restrictive lockdown. Recent times should prove to be less stressful as restrictions loosened, people adjusted, and vaccinations increased.

At the moment, there is limited literature regarding sleep correlated to the pandemic [23]. It is vital that further awareness is generated in regards to the issue of sleep deprivation as well as the stressors which lead up to it. In particular, the increased level of glucocorticoids produced in

response to stress is quite relevant. Glucocorticoids have immunosuppressive properties by reducing the inflammation response [27]. This will make the body more susceptible to viral infections, namely COVID-19. As such, it is essential that further recognition of this key effect that the stress response elicits. Thereby, more solutions can be developed concerning stress that will lead to better health outcomes in the event of infection.

METHODS

Instrument

The survey used to collect data for this study incorporated original questions as well as adapting questions from the Pittsburgh Sleep Quality Index being a mix of multiple choice and write in questions. First, the participants were prompted with demographic questions regarding their age and sex as well as confirming that they are current undergraduate students. Following this, the participants responded with their perceived level of stress at the three time frames of interest: before the pandemic, the start of the lockdown, and within the last month. These were answered on a scale from one to ten. Optional write-in questions were also included that asked about what sources of stress arose or were alleviated as a result of the pandemic. These questions were included to provide context for the indicated stress levels. The next set asked respondents to provide their perceived sleep quality on a scale from one to ten in a similar vein to the perceived stress level. Afterward, the participants answered questions adapted from the PSQI. This index quantifies sleep quality through seven component scores which will add up to one global score. The seven components are subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Importantly, the PSQI is only limited to analyzing sleep quality within the prior month. As such, the questions only refer to how the participant sleeps within the month before taking the survey. It is reliable in distinguishing between good and poor sleepers with a kappa of 0.75 and p less than 0.001. Specifically, a global score of greater than 5 points is an indicator of poor sleep [28]. Of course, a higher score corresponds with worse sleep quality as well. The survey was administered in English. The survey contains no identifiable data and is anonymous with no names being

collected. A sample of the survey is provided in Appendix A. IRB approval for the protocol of this study is provided in Appendix B.

Target Population

The population of interest for this study was undergraduate students aged 18 or older. There also aimed to be a relatively even split between male and female participants. Besides this, there were no other parameters utilized to screen out participants.

Sampling Method

The survey was done through the Qualtrics online survey software. Anyone with a direct link to the survey will be able take the survey. However, the first question of the survey will screen out anyone who does not fit the target population. The link to the survey was disseminated through a variety of social media sites such as Discord, Reddit, or Facebook. It was also sent by participants to anyone else they knew who fit the criteria for the survey. Being an online survey, it was able to be done at any location at the leisure of the participant as long as they have the requisite device to take it. The survey was open from December 2021 to January 2022.

Statistical Analysis

Descriptive statistics were utilized in order to get a baseline understanding of the perceived stress level and perceived sleep quality of the participants during the main time frames. This was also done with the score generated from the PSQI. Following this, correlation analysis was performed between the perceived stress level of the participants during the month prior to the survey and their PSQI score. This will ascertain the relationship between the two

factors. Regression analysis was also performed using these parameters. This tested the predictive value and causality of perceived stress level on the PSQI score. The PSQI being an objective measure of sleep quality, should better illuminate the baseline relationship between the perceived stress of the individual and their sleep quality. Following this, correlation analysis was performed and associations made between the self-reported score on perceived stress and the perceived sleep quality score for each time frame. The coefficients obtained from the analysis of each time frame were compared to each other in order to understand how the relationship between stress and sleep quality changed throughout the pandemic. This was not compared to the ones obtained in the analysis using the PSQI as it is an objective measure of sleep quality instead of the subjective measure of perceived sleep quality. IBM SPSS software was used for correlation and regression analysis.

RESULTS

The purposes of the study were to ascertain the relationship between stress and sleep during the pandemic in addition to observing how this relationship changed between the time frames of interest: before the lockdown, during the lockdown (March-May 2020), as well as within the last month. Analysis of the first data set will address the relationship between stress and sleep during the pandemic during recent times. Comparisons and analysis of the three following data sets will address how this relationship had changed between the time frames.

Overview of the Respondents

The survey link was started by 147 individuals. One hundred thirty-eight of these participants met the inclusion criteria for the survey. However, only 104 respondents completed the entire survey. As such, these were the only participants who were part of the results to be analyzed. Not every participant answered every question. A couple of the questions had the purpose of providing context rather than to be analyzed such as what sources of stress came about as a result of the lockdown. The average age of the respondents was 21.06 years old with eighty of them being 18-22 which consistent with what one expects of a traditional college-aged undergraduate student. In regards to the gender breakdown, there was a very even split of 52 men to 52 women. Most of the responses were collected from students attending school in Florida, although some came from other states such as New York or Massachusetts. The survey was conducted from December 2021 to January 2022.

Based upon the open-ended responses, the common reasons cited for the marked increase in stress were the transition to online classes and working from home. General uncertainty in

regards to the future was also a commonly cited new source of stress in regards to the pandemic. This consisted of economic uncertainty as well as uncertainty in regards to the health of the participants and their family. There were not many sources of stress alleviated due to the pandemic. The only commonly cited source of stress alleviated was the need to commute due to the transition to online work and classes.

Relationship of Subjective Stress Level within the Last Month and PSQI Score

Table 1: Descriptive Statistics (PSQI)

	Mean	Standard Deviation	N
Pittsburgh Sleep Quality Index Score	6.8846	3.45655	104
Subjective Stress Level	6.3462	2.16669	104

The PSQI scores of the participants ranged from 1 to 18 out of 21 with an average of 6.8846. Also of note was that 61 or 58.65% of the 104 participants scored greater than a 5 on the PSQI.

Table 2: Correlations (PSQI)

		Subjective Stress Level	Pittsburgh Sleep Index
Subjective Stress Level	Pearson Correlation	1	.477**
	Sig. (2-tailed)		<.001
	N	104	104
Pittsburgh Quality Sleep Index Score	Pearson Correlation	.477**	1
	Sig. (2-tailed)	<.001	
	N	104	104
**. Correlation is significant at the 0.01 level (2-tailed).			

The Pearson Correlation Coefficient determined from the analysis was 0.477. The positive sign indicated that there was a positive relationship between subjective stress level and PSQI score. Given that the Pearson Correlation Coefficient ranges from 0 to 1, a magnitude of 0.447 indicates a relationship that is moderate in strength. The p-value for this analysis was less than 0.001. Using a significance level of 0.05, the correlation found here was statistically significant.

Table 3: Regression Coefficients (PSQI)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.053	.930		2.206	.030
	Subjective_Stress_Level	.761	.139	.477	5.485	<.001
a. Dependent Variable: Pittsburgh_Sleep_Index						

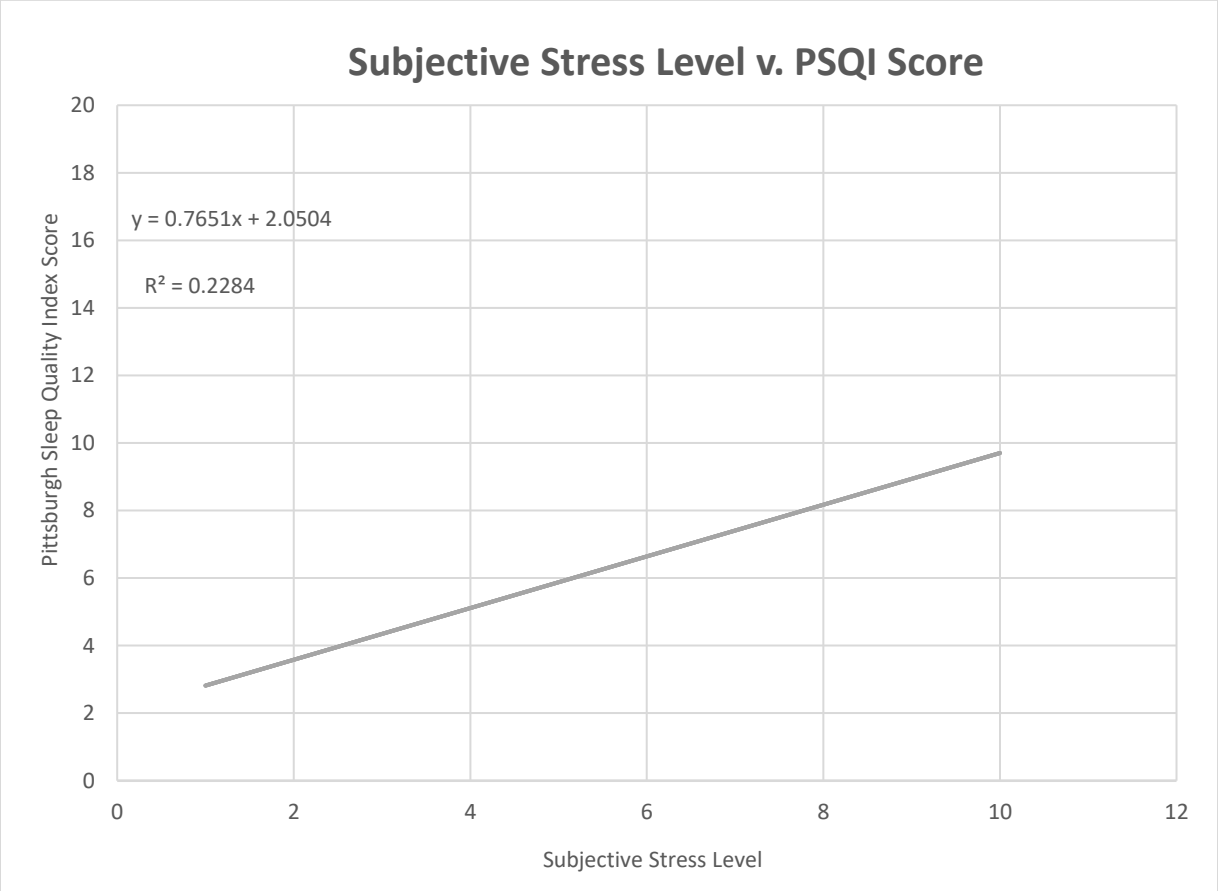

Figure 1:Linear Regression Relationship between Subjective Stress Level and PSQI Score

From the regression analysis, an equation for predicting the PSQI score from the perceived stress level was determined being $y = 0.7651x + 2.0504$ with an R^2 value of 0.2284 and p-value less than 0.001. The R^2 value was rather indicates how much of the variance in PSQI score was from variance in subjective stress level. As the R^2 value ranges from 0-1, this indicated that The regression found here was statistically significant.

Relationship of Subjective Stress Level and Subjective Sleep Before the Lockdown

Table 4: Descriptive Statistics (Before)

	Mean	Standard Deviation	N
Subjective Sleep Quality	6.3654	1.77391	104
Subjective Stress Level	5.5000	1.74601	104

Table 5: Correlations (Before)

		Subjective Stress Level	Subjective Sleep Quality
Subjective Stress Level	Pearson Correlation	1	-.166
	Sig. (2-tailed)		.092
	N	104	104
Subjective Sleep Quality	Pearson Correlation	-.166	1
	Sig. (2-tailed)	.092	
	N	104	104

The Pearson's Correlation Coefficient obtained was -0.166. This denotes a weak negative relationship between subjective stress level and subjective sleep quality. However, this is not statistically significant as the p-value is 0.092 which is greater than the significance level of 0.05.

Relationship of Subjective Stress Level and Subjective Sleep During the Lockdown (March-May 2020)

Table 6: Descriptive Statistics (During)

	Mean	Standard Deviation	N
Subjective Sleep Quality	6.4135	2.12982	104
Subjective Stress Level	6.3654	2.20352	104

Table 7: Correlations (During)

		Subjective Stress Level	Subjective Sleep Quality
Subjective Stress Level	Pearson Correlation	1	-.264**
	Sig. (2-tailed)		.007
	N	104	104
Subjective Sleep Quality	Pearson Correlation	-.264**	1
	Sig. (2-tailed)	.007	
	N	104	104

**. Correlation is significant at the 0.01 level (2-tailed).

The Pearson's Correlation Coefficient obtained was -0.264 which indicates that there was a weak negative relationship between subjective stress levels and subjective sleep quality during the start of the pandemic. This was statistically significant with a p-value of 0.007.

Relationship of Subjective Stress Level and Subjective Sleep Within the Last Month

Table 8: Descriptive Statistics (Last Month)

	Mean	Standard Deviation	N
Subjective Sleep Quality	6.0385	2.19851	104
Subjective Stress Level	6.3462	2.13734	104

Table 9: Correlations (Last Month)

		Subjective Stress Level	Subjective Sleep Quality
Subjective_Stress_Level	Pearson Correlation	1	-.401**
	Sig. (2-tailed)		<.001
	N	104	104
Subjective_Sleep_Quality	Pearson Correlation	-.401**	1
	Sig. (2-tailed)	<.001	
	N	104	104

**. Correlation is significant at the 0.01 level (2-tailed).

The Pearson's Correlation Coefficient obtained was -0.401. This indicates a moderate negative relationship between subjective stress levels and subjective sleep quality during the start of the pandemic. This was statistically significant with a p-value of less than 0.001.

Subjective Stress and Sleep Levels Over Time

Table 10: General Trends

Time Frame	Subjective Stress Level*	Subjective Sleep Quality**
Before Lockdown	5.5000	6.3654
During Lockdown (March-May 2020)	6.3654	6.4135
Within the Last Month	6.3462	6.0385

*. Significant effect between before lockdown and during lockdown as well as within the last month ($F = 6.119$, $p < 0.005$) No significant effect between during lockdown and within last month ($F = 6.119$, $p = 0.881$)
**. No significant effect ($F = 1.055$, $p = 0.35$)

DISCUSSION

General Trends of Stress and Sleep

Regarding the perceived stress level noted by applicants, the average value was lowest before the advent of the lockdown at 5.5000. This was expected as the stressors that came about due to the pandemic had yet to be introduced. Though this value was still rather high given that the scale was out of 10. This meant that the value was closer to the higher end of the spectrum than the lower end. This exemplifies how undergraduate students were a particular population of interest when examining stress and its effects. As expected, the average perceived stress level increased to 6.3654 once the lockdown begun in March of 2020. This was expected because of the many changes in the lifestyles of the participants as well as fear of the looming new virus. Simple uncertainty of the future was also noted from what new regulations will be in place to whether or not the participant or one of their family members will get infected and the outcomes that may occur as a result. As mentioned before, this culminated in an exaggerated stress response that many of the participants had trouble coping with. Interestingly, the average perceived stress level decreased only slightly 6.3462 when respondents were asked about the last month. This goes against the assumption that modern times should have markedly lower stress. Even though people are vaccinated against the virus now and restrictions have loosened since the beginning of the lockdown, the disease is still rampant around the world. Further new strands have emerged such as Delta and Omicron which are both more transmissible than the original alpha strand [29]. With this in mind, it was logical that the amount of stress between March 2020 and now would not change as much due to the presence of these new stressors even though some old ones such as the regulations have been diminished. This is reaffirmed by the fact that there

was a significant effect observed when comparing the subjective stress level before the pandemic to both levels seen during the beginning of the lockdown as well as within recent times. There was also no significant effect seen when comparing subjective stress level during the start of the lockdown and within the last month. This corroborates the minimal change in average perceived stress level between the two time frames. Both of these time frames, during the beginning of the pandemic and now, are still notably regarded as more stressful by the participants than before the pandemic began.

In reference to the perceived sleep quality of the respondents, there was actually a marginal increase from 6.3654 to 6.4135 from before the pandemic to the beginning of the lockdown. This is contradictory to the expected outcome of a decrease in sleep quality once the lockdown began due to the notable increase in perceived stress of the participants between the two time frames. However, this could be explained by the transition to online classes and working from home that came about. Due to less of a need to commute or to show up to classes because of recorded lectures, this could allow for more opportunity to get quality sleep. This seems reasonable when taking the fact that the subjective sleep quality during the last month was lower than both of the other time frames at 6.0385 into account as well. By this time, regulations have been relaxed and people are commuting back to in-person classes again. With less opportunity to rest than at the start of the lockdown, it follows that the average sleep quality of the participants should decrease as well based upon the high stress levels at this time. There was also no significant effect observed between the time frames for subjective sleep quality. This indicated that the changes seen in perceived sleep quality of the participants was merely a trend.

From this, it can be seen that the change in subjective sleep quality over the three time frames was not very significant.

It was important to note that the accuracy of the data regarding the subjective stress levels and sleep quality from before the pandemic and during its beginning was impacted by the participants' perceptions of the past. Participants likely had different views of past events looking back on them now compared to when they were experiencing them. In regards to stress, it was likely they used how stressed they were during the past month as a baseline to compare to how stressed they were in the past. For example, fourth years now would have been second years before the pandemic started. Even if their coursework made it a stressful time for them then, they might not have indicated as such on the survey. As their classes now are generally more difficult and laborious than from two years ago, they may view their coursework from back then as easier than it was for them at the time. As such, they would respond with a lower subjective stress rating when recalling their experience for the survey now than if they were to answer the same question back then. Essentially, the perceptions of the respondents now in regards to their experience before and at the start of the pandemic was likely to be different from the actual experience.

Stress and the PSQI

While subjective sleep quality was a useful metric to generally gauge how well an individual sleeps based on how they feel about it, the score based upon the PSQI should better indicate how sleep quality is affected by stress. The PSQI scores of the participants ranged from 1 to 18 out of 21 with an average of 6.8846. Also of note was that 61 or 58.65% of the 104 participants scored greater than a 5. This is of importance because a global score of 6 or higher is

indicative of poor sleep quality. The majority of the participants in this survey had poor sleep quality based on this criterion as a result. This reaffirms the prevalence of sleep problems in the wake of the pandemic. On the other hand, the original PSQI study incorporated a control group of healthy sleepers that had an average score of 3.1154 with only 6 or 11.54% of the 52-person control group having a score greater than 5 [28]. There is a dramatic difference in sleep quality between the undergraduate respondents and the control group of health sleeps in the original study. A much higher percentage of the respondents to this survey had poor sleep at 58.65% compared to 11.54% of the control group. This further exemplifies undergraduates as a population of interest when examining the relationship between stress and sleep quality during the pandemic.

Correlation analysis was performed to determine the relationship between subjective stress levels out of ten and the PSQI score out of twenty-one during the last month since the participants took the survey. A Pearson's Correlation Coefficient of 0.477 was determined which indicated a statistically significant moderate positive correlation between subjective stress levels and PSQI scores (p-value<0.001). Regression analysis was also utilized to ascertain how good of a predictor subjective stress level was for the value of the PSQI score. The analysis yielded a positive line of best fit though the low R^2 value indicated that most of the changes in value of PSQI score was not attributable to changes in value of subjective stress levels. The positive rate of change of the equation of the line of best fit of the scatterplot produced corroborated the moderate positive correlation found previously. However, the low R^2 value does not make this a reliable model to determine PSQI score based on subjective stress level even if the regression

found was statistically significant (p-value<0.001) This indicated that the subjective stress level of the participant was a weak predictor for their PSQI score and by extension, sleep quality.

The moderate positive correlation between the subjective stress level and PSQI score was expected. A higher PSQI score corresponded to worse sleep quality, meaning that there was an inverse relationship observed between subjective stress level and sleep quality. This was expected based on the known effects of the physiological response to stress such as with the elevated glucocorticoids. Unfortunately, the regression analysis indicated that the causal relationship between stress and sleep of the participants in the month before the survey was weak. This suggested that there is more to determining sleep quality than stress levels alone. For example, diet and physical activity are other components that play a role in determining the sleep quality [6]. So, while higher stress levels were associated with a higher PSQI score and lower sleep quality, this does not mean that stress will lead to poor sleep quality. Sleep is a multifaceted process with many factors at play that any singular factor like stress cannot be used as a predictor alone even if there is a moderately strong correlation.

The Changing Relationship of Stress and Sleep over the Lockdown

Aside from ascertaining the relationship between stress and sleep in general during the pandemic, this study also served to determine how this relationship changed throughout the course of the pandemic. As such, correlation analysis was done at each of the three time frames of interest between subjective stress level and subjective sleep quality. The PSQI was not utilized because it is only applicable to sleep quality within a month of taking it. Concerning the data in relation to before the pandemic, a Pearson's Correlation Coefficient of -0.166 was found with a ρ value of 0.092. Not only was the negative correlation observed in this time frame relatively

weak, but the high ρ value also signaled that this determination was not even statistically significant. As such, it was determined that there was little correlation between subjective stress levels and subjective sleep quality before the advent of the lockdown. On the other hand, the data corresponding to the start of the lockdown from March-May 2020 had a Pearson's Correlation Coefficient of -0.264 with a ρ value of 0.007 meaning this relationship was statistically significant. In contrast to the relationship seen before the pandemic, a correlation was able to be determined between stress and sleep quality. However, it is only a weak correlation due to the low magnitude of the Pearson's Correlation Coefficient. Regarding the relationship between perceived stress level and subjective sleep quality within the month before taking the survey, a Pearson's Correlation Coefficient of -0.401 with a ρ value of less than 0.001 was found, making this relationship statistically significant as well. This indicated that there was a moderate negative correlation between the two parameters for participants in recent times. The value of the coefficient in this case was also closest to the magnitude seen when observing the relationship between subjective stress level and the PSQI score which was 0.477.

As expected, there was a general negative correlation between subjective stress level and subjective sleep quality. This was expected based on the aforementioned effects that stress has on the various processes of the body such as sleep. However, this correlation was not consistent over the course of the pandemic. The relationship between the two parameters appeared to has strengthened over time. In particular, the correlation determined for the data before the pandemic was not even statistically significant. The correlation for the most recent time frame was also notably stronger than the other statistically significant correlation seen in the beginning of the lockdown. Given that the subjective stress level between the two time frames were of similar

value, it was unlikely that this factor alone was the cause for this discrepancy. Instead, it was possible that due to the sheer amount of time elapsed since the two early time frames of before the lockdown and at its advent, the participants did not accurately recall how stressed they were or how well they slept back then. It likely would have been easier for them to give a qualitative answer to the question rather than provide a quantitative answer using the scale from 1 to 10. This explanation would address how only the correlation observed for the data in recent times is not weak or insignificant. In essence, this study was inconclusive in how the relationship between stress and sleep quality changed before and during the course of the pandemic. Only speculative explanations can be made.

Limitations

A number of limitations to this study had been identified. One of the core limitations was the not using an objective measure for stress levels in contrast to the PSQI for quantifying sleep quality. In order to address this, stress levels should have been measured through cortisol levels found in saliva samples of the participants. However, this was not an option because of the next limitation of this study: two of the time frames of interest were nearly two years before the participants took the study. Optimally, cortisol levels of the saliva would be taken at all the time frames to act as a consistent objective measure. However, as this was not possible, the subjective stress level was used instead. This was also compared to the subjective sleep quality as noted by participants because the PSQI would have to be administered during the specified time frame in order to be accurate. This introduced a level of uncertainty into the study as the recollections of the respondent will likely be muddled considering they had to recall how they were doing from such a long time ago. Further, how the participants are doing in recent times may warp their

perceptions of how they were doing in the past. A further limitation found was that a question on the usage of coping mechanisms should have been included in the study. This is important because individuals who are able to cope with their high stress might be able to enjoy higher levels of sleep quality. Finally, the completion rate of the survey was not as high as it could have been given that only 104 of the 138 respondents who qualified to take survey completed it. While the open-ended questions for context were made optional to encourage full completion of the survey, it still may have been too long for some. Even if administering the survey online improves the reach of the survey, doing it in person should increase the proportion of participants who finish the survey upon starting.

Future Research

Further investigations should be done over the time frames of interest rather than rely on recollections of the respondents to increase validity and allow the usage of more objective means of collecting data. Beyond this, collecting more demographic data and contextual information of the respondents would help give a more concrete answer regarding the relationship between stress and sleep quality of the undergraduate student population. Speaking of which, the study would also benefit from being done on other population susceptible to high stress and poor sleep quality such as graduate students or health care workers. This can then be compared to the data found with the undergraduates to see if the correlation between high stress and poor sleep quality extend to beyond the population of interest of this study. Other factors that impact sleep quality should also be examined beyond stress such as with physical activity, diet, gender, and body type. It is simply imperative that more research be done on the factors that can affect sleep during the pandemic based on the currently limited amount of literature on the topic [23]. By

looking at the populations of interest that are susceptible to poor sleep and examining the factors that lead to this bad sleep quality, one can take preventative measures. Poor sleep quality may lead to exaggerated responses to stress which will in turn lead to a worse immune response in the event of infection. Essentially, to improve the health outcomes of these individuals in these unprecedented times of uncertainty, further research must be done.

APPENDIX A: SURVEY SAMPLE

Explanation of Research:

Title of Project: The Intertwined Relationship of Stress and Sleep Quality of Undergraduate Students during the COVID-19 Pandemic

Principal Investigator: Robert Borgon

Other Investigators: Jordan Nguyen

You are being invited to take part in a research study. Whether you take part is up to you.

The purpose of this research is to analyze and study the relationship between stress and sleep quality in Undergraduate students before and during the COVID-19 pandemic.

You will be participating in a questionnaire. First, you will answer questions in regards to demographics such as your age and sex. After this, you will be asked questions regarding how stressed you felt before the pandemic, during the beginning of the lockdown, and during recent times. You will also be asked questions regarding your sleep quality during those times. Once this is done, you will answer more detailed questions on sleeping habits in the past month.

The expected duration of this questionnaire is approximately five minutes.

Your participation in this study is voluntary. You are free to withdraw your consent and discontinue participation in this study at any time without prejudice or penalty. Your decision to participate or not participate in this study will in no way affect your relationship with UCF, including continued enrollment, grades, employment or your relationship with the individuals who may have an interest in this study.

No private or identifiable information will be collected during this study. You must be 18 years of age or older to take part in this research study. You must also be a current undergraduate student at a community college or 4-year university.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints: Jordan Nguyen, Undergraduate Student, College of Medicine (407) 432-8034 or Dr. Robert Borgon, Faculty Supervisor, Burnett School of Biomedical Sciences at (407) 823-5798 or by email at Robert.Borgon@ucf.edu.

IRB contact about your rights in this study or to report a complaint: If you have questions about your rights as a research participant, or have concerns about the conduct of this study, please contact Institutional Review Board (IRB), University of Central Florida, Office of Research, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901, or email irb@ucf.edu.

Demographics:

Are you a current undergraduate student at a community college or 4-year university?

What is your gender?

Male

Female

Other

What is your age?

Perceived Stress Scale:

On a scale of 1-10, how would you rate how stressed you generally felt

…..before the start of the pandemic

…..at the beginning of the lockdown (March-May 2020)

…..within the last month

What new sources of stress arose because of the pandemic and are they still affecting you as of now? (Open-ended)

Were any sources of stress before the pandemic alleviated because of the pandemic? If so, what are they? Are they back now? (Open-ended)

Perceived Sleep Quality Scale:

On a scale of 1-10, how would you rate your general daily sleep quality

…..before the start of the pandemic

…..at the beginning of the lockdown (March-May 2020)

…..within the last month

Pittsburgh Sleep Quality Index

The following questions relate to your sleeping habits within the past month specifically.

1. During the past month, when have you usually gone to bed?

   Usual Bed Time: _____

2. During the past month, how long (in minutes) does it usually take you to fall asleep each night?

   Number of Minutes: _____

3. During the past month, when have you usually gotten up in the morning?

   Usual Getting Up Time: _____

4. During the past month, how many hours of actual sleep did you get at night?

   Number Hours of Sleep: _____

5. During the past month, how often have you had trouble sleeping because you…

   a. …cannot get to sleep within 30 minutes?

      ☐ Not during the past month.

      ☐ Less Than Once a Week

      ☐ Once or Twice a Week

☐ More Than Three Times a Week

b. …wake up in the middle of the night or early morning

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

c. …have to use the bathroom

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

d. …cannot breath comfortably

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

e. …cough or snore loudly

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

f. …feel too cold

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

g. …feel too hot

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

h. …have bad dreams

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

i. …have pain

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

6. During the past month, how would you rate your sleep quality overall?

☐ Very Good

☐ Fairly Good

☐ Fairly Bad

☐ Very Bad

7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?

☐ Not during the past month.

☐ Less Than Once a Week

☐ Once or Twice a Week

☐ More Than Three Times a Week

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

    ☐ Not during the past month.

    ☐ Less Than Once a Week

    ☐ Once or Twice a Week

    ☐ More Than Three Times a Week

9. During the past month, how much of a problem has it been to keep up enough enthusiasm to get things done?

    ☐ No Problem at all

    ☐ Only a very slight problem

    ☐ Somewhat of a problem

    ☐ A very big prob

APPENDIX B: IRB APPROVAL LETTER

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

EXEMPTION DETERMINATION

December 14, 2021

Dear Robert Borgon:

On 12/14/2021, the IRB determined the following submission to be human subjects research that is exempt from regulation:

Type of Review:	Initial Study, Category 2(i)
Title:	The Intertwined Relationship of Stress and Sleep Quality of Undergraduate Students during the COVID-19 Pandemic
Investigator:	Robert Borgon
IRB ID:	STUDY00003716
Funding:	None
Grant ID:	None
Documents Reviewed:	• HRP-254-FORM Explanation of Research.pdf, Category: Consent Form; • HRP-255-FORM - Request for Exemption.docx, Category: IRB Protocol; • Social Media Script.docx, Category: Recruitment Materials; • SurveySample.docx, Category: Survey / Questionnaire

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made, and there are questions about whether these changes affect the exempt status of the human research, please submit a modification request to the IRB. Guidance on submitting Modifications and Administrative Check-in are detailed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Katie Kilgore
Designated Reviewer

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