THE ASSOCIATION BETWEEN SLEEP PATTERNS AND SINGING VOICE QUALITY DURING THE COVID-19 PANDEMIC

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This study investigated the associations between sleep patterns and singing voice quality in 231 adult singers of various skill levels across the United States. The four-part survey using a general questionnaire on demographics, musical background, vocal health, and three established survey instruments: the Pittsburgh Sleep Quality Index (PSQI), the Singing Voice Handicap Index-10 (SVHI-10), and the Epworth Sleepiness Scale (ESS) found that while scores were worse than normative values for the PSQI and the SVHI-10, a Pearson correlation between the two showed a moderate association. A linear regression also yielded that 8.9% of the variance in SVHI-10 scores could be predicted from PSQI scores. While further research is needed in this area, this study suggests that the amount of sleep needed for an optimal singing voice may be different from the amount needed to feel well-rested for some singers. Moreover, singers may overestimate the influence of sleep on their singing voices.

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CHAPTER 1

INTRODUCTION

1.1 Statement of the Problem

Many factors affect voice quality, including hydration, frequency and intensity of phonation, and drying medications, to name a few. Sleep is one primary factor affecting voice quality. Our awareness of the effects of sleep on human performance, in general, has developed over the decades. Numerous studies (Icht et al., 2020, Harger 2017, Bagnall et al., 2011) have specifically observed the effects of sleep deprivation, for instance, on the quality of speech; however, prior studies make no differentiation between speaking voice quality and singing voice quality. Given that recent studies are chronicling global sleep disturbances due to the pandemic, which affects occupational health, mental and physical health, and social interaction, what influence will these sleep disturbances have not just on speaking voice quality but on singing voice quality? This study attempts to contribute to recent conversations surrounding these topics.

1.2 Purpose of the Study

This study investigated the association between sleep patterns and singing voice quality since the COVID-19 pandemic began. Sleep patterns describe a person's wake times, nap times, bedtimes, and overall sleep disturbances and difficulties, or lack thereof, in falling asleep. This cross-sectional study included the assessment of singers' self-reported sleep patterns during the pandemic, self-perceived singing quality during the pandemic, and the associations between the singers' sleep patterns during the pandemic and singing voice quality.

Recent studies, referenced below, show that the COVID-19 pandemic is causing sleep disturbances. As we do not know how long this pandemic will last, if there will be future pandemics, or the ramifications of a post-pandemic society, observing that this study was developed and completed during the pandemic is relevant; however, the pandemic's direct influence on singing quality was not the focus of this study.

Therefore, this study is essential to contribute to the existing literature on the associations between sleep and singing quality by establishing a research record explicitly aimed at singers and providing an epidemiological snapshot of the COVID-19 pandemic's current impact on singers for posterity.

1.3 Research Questions

- What, if any, are the associations between sleep patterns and singing voice quality during the COVID-19 pandemic, and what is the strength and predictability of these possible associations?
- Does the participant's belief that sleep influences singing voice quality relate to their self-perception of their singing quality?
- What are the specific groups of interest among singers that may be most at risk?

1.4 Contributions

As I am unaware of any studies in the United States that investigate the relationship between sleep patterns and singing voice quality, this study serves as a precedent for further research.

1.5 Limitations

There were several limitations to this study. While several studies recommended using auditory perceptual evaluations with listeners blinded to the subject's sleep status, this was not feasible. I had no access to a sleep lab and the resources necessary to accommodate all variables and controls. For more detail about limitations and recommendations for further research, see Section 5.11 Limitations.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

The current pandemic has shown a negative influence on sleep patterns (Gupta et al., 2020). Several studies have reported a 1-2 hour disruption in the circadian rhythm of subjects (Cellini et al., 2020, p. 4; Javaheri & Javaheri, 2020, p. 1413). A circadian rhythm is a "natural, internal process that regulates the sleep-wake cycle and repeats on each rotation of the Earth roughly every 24 hours" (Circadian Rhythm: How An Inner Clock Connects Your Body With the Cosmos | Lifely, n.d.). Altena et al. (2020) found that activities relating to circadian rhythm such as mealtimes and sleep/wake times are governed by daylight. The bright light of daylight exposure produces more melatonin, a hormone within the human body that induces sleep. If bright light exposure throughout the day causes melatonin levels to increase over the course of the day, culminating at night, this would explain Borbely's theory on sleep pressure that Ravi Gupta cited in a similar study. In his study, Gupta cited that:

> Initiation and maintenance of sleep-wake cycles are explained by two-process models, whereby circadian factors and homeostatic factors constantly interact to induce and maintain sleep. This model posits that owing to circadian factors, humans have higher chances to fall asleep at night as we are designed to behave as a diurnal (as opposed to nocturnal) species by nature. Sleep pressure represents the homeostatic factor, which is proportional to the time awake. In other words, the longer the time awake, the higher the sleep pressure, and the higher the chances of falling asleep. Being a diurnal species, humans stay awake during the day and accumulate sleep pressure, which reaches maximum at night, where it interacts with circadian factors to induce sleep. (Gupta et al., 2020, p. 3)

Gupta found that home confinement can disrupt circadian rhythm and homeostatic processes, which refer to maintaining a stable internal environment for the body's numerous processes. Sleep is one such process, and a disruption of this process reduces the much-needed sleep pressure or the internal drive to go to sleep that pursues a prolonged phase of wakefulness.

This disturbance can partially be due to opportunities for longer morning sleep and daytime napping (Gupta et al., 2020, p. 12).

Perturbation in regular sleep patterns due to the pandemic is resulting in a self-reported general decline of sleep quality. Research is still pouring in about sleep disturbances amid the COVID-19 pandemic. Mandelkorn et al. (2021) published an article earlier this year reporting their review of responses from 3,062 participants from 49 different countries between March 26 and April 26, 2020, as a part of a two-part study. 40% of respondents reported decreased sleep quality compared to pre-pandemic sleep quality, 39% reported no change in sleep, and approximately 21% reported improved sleep. 58% of participants in Mandelkorn's study reported dissatisfaction with their current sleep patterns. As reported in a study by Altena et al. (2020) and other studies, women were listed as more likely to develop sleeping problems than men in Mandelkorn's study. The study was replicated with another 1,092 participants with similar results. This disruption is critical as sleep patterns are known to influence voice quality, as aforementioned.

Kenneth Wright Jr. et al. (2020, p. R797) compared sleep patterns among 139 university students (average age of 22) while the students were taking the same classes before the mandated quarantine (in-person) and after (online). Time in bed, which served as a surrogate for sleep duration, increased while "social jetlag" (the difference between the average time spent sleeping during the week and the average time spent sleeping on the weekend) decreased (Wright et al., 2020, p. R797). The percentage of participants that reported sleeping at least 7 hours increased from 84% to 92%, with results showing a trend in participants going to bed later and waking later (Wright et al., 2020, p. R798). Sleep duration is nonetheless only one component of a sleep pattern. As mentioned above, the Altena et al. (2020, p. 2) study made the critical distinction in their research that sleep duration, the actual time spent sleeping, not time in bed, does not necessarily denote sleep quality.

On the other end of the spectrum, one of the earliest studies, Bouhuys et al. (1990, p. 250), discovered a possible correlation between total sleep deprivation and a circadian organization of vocal parameters. Since then, numerous studies have expounded upon these correlations. Bagnall et al. (2011) used objective, auditory ratings by judges to explore how voice quality may be influenced by sleep deprivation. They discovered that voice quality was negatively impacted in subjects who were sleep deprived for 24 hours. Judges perceived the voices of sleep-deprived subjects as sounding "rougher, …less brilliant, …and more tired" (Bagnall et al., 2011, p. 448). As described by Bagnall et al. (2011, p. 448), the voice's luminosity is the acoustical description of the singer's formant, or "…ring" in the tone. Bagnall's study highlights that as brilliance comes in part from the contractions of laryngeal muscles and the contour of the vocal tract, it is not surprising that there is a concordant relationship between the two. This occurrence underscores that with fatigue, vocal or otherwise, the voice becomes "…less brilliant" (Bagnall et al., 2011, p. 448). Likewise, hoarseness among teachers was associated with a decrease in average sleep duration to 6 hours. This decrease in brilliance was similar to the general population in Bagnall's study; however, there was no definition as to the exact nature of these vocal quality changes.

2.2 Pandemic Studies

As we know, the COVID-19 pandemic started in China, and data collected from researchers on sleep disturbances in China serve as a baseline for further research globally. One of the earliest pandemic studies reviewed disruptions in 170 people who underwent 14-days of isolation in central China. Researchers used a self-assessment questionnaire to examine social capital, “the networks of relationships among people who live and work in a particular society, enabling that society to function effectively” (Social Capital, n.d.). Researchers used the Self-Rating Anxiety Scale (SAS), the Stanford Acute Stress Test, and the Pittsburgh Sleep Quality Index (PSQI) to evaluate sleep behaviors. The study showed that an increase in social capital reduced anxiety and stress, which improved sleep quality (Xiao et al., 2020). 5,461 individuals surveyed in China from February 5 to 23, 2020 reported insomnia, depression, anxiety, and stress which were found to be associated with a threat degree of COVID-19. Insomnia was worse for women, the youth, those residing near an epicenter of the pandemic, and those most susceptible to COVID-19 exposure or complications. Lin et al. (2021, pp. 3; 5) concluded that the public had developed poor sleep hygiene throughout the pandemic.

Li et al. (2020, p. 7) investigated sleep disturbances in 1,099 (55.8%) of their subjects, with a significant number of poor sleep quality associated with younger age, severe worry about COVID-19, and a more severe social interaction impact**.**

In a sample size that consisted of 70% females, Morin et al. (2021) found high rates of chronic sleep deprivation attributed to stress-related anxiety and depression (Morin & Carrier, 2021). A decline in sleep quality during the COVID-19 pandemic could also be due to prolonged periods of “social confinement” (Morin & Carrier, 2021, p. 346).

A study conducted on the epidemic in Hubei Province, China (939 individuals; 357 men and 582 women) found that emotions and behavior improved during a two-week period in February 2020, but sleep quality did not. The Hubei Province study used a self-reporting questionnaire (SRQ) to assess stress and sleep quality (PSQI). Subjects’ ages ranged from 18-24 (35.89%), 25-39 (35.57%), 65.92% of whom were university students (Yuan et al., 2020).

In a study of nursing students by Romero-Blanco et al. (2020), researchers assessed differences in the pre-pandemic and post-pandemic sleep quality of 207 nurses between February and April. The PSQI was used to assess sleep quality, with findings showing that the most affected aspects of sleep were latency (the measurement of time right before sleep,) duration, and quality. When stratified by group, the study found a more significant difference in women, underclassmen, those whose drink alcohol, subjects with "normal weight," and subjects residing with family (Romero-Blanco et al., 2020, 5222). The main inferences were that the students' sleep quality decreased during the quarantine, as analyzed by PSQI results showing worse scores in a majority of the seven components (Romero-Blanco et al., 2020, 5222).

An Italian study (Cellini et al., 2020) cited numerous times throughout 2020 echoed similar findings that there was a significant increase of poor sleepers from 40.5% to 52.4% over the pandemic. In addition, Cellini's study cited Altena et al. (2020) and Siversten et al. (2018), concurring that there was a disruption in nighttime sleep and a tendency towards young adults (18-35) to exhibit sleep problems in general. The assumption is that the pandemic is exacerbating these tendencies.

Not every pandemic study reported this, however. In another study (Zreik et al., 2020, p. 6), the majority of the mothers of 264 children of the ages of 6-72 months did not notice a change in their children's sleep patterns. Only a third of mothers observed variations in their children's sleep behavior (Zreik et al., 2020, p. 1). The study was inconclusive as to whether or not the pandemic was an adverse factor for a disruption in children's sleep patterns (Zreik et al., 2020, p. 6).

Javaheri & Javaheri (2020) observed trouble in sleep latency and duration in patients regardless of their past record of insomnia. This disorder is known as "delayed sleep phase syndrome," in which a person's sleep is "delayed by two hours or more beyond what is considered an acceptable or conventional bedtime" (Javaheri & Javaheri, 2020, p. 1413; Delayed Sleep Phase Syndrome (DSPS), 2017). This challenge was attributed to increased anxiety levels, caffeine use, alcohol consumption, and blue light exposure (second to screen time). Daytime napping increased, as shown in prior studies. It is not uncommon for studies executed amid crises to show more instances of sleep problems, smoking, and drinking regardless of whether the population was under confinement (Balanzá-Martínez et al., 2021). Majumdar et al. (2020, p. 1192) studied sleep disruption effects on the mental health of 203 corporate sector professionals and 1,325 undergraduate and graduate students. They found that the COVID-19 pandemic lockdown "was associated with sleep disruption, depression, somatic pain, and other disturbances" and "stress from the pandemic also led to physical symptoms such as headaches, insomnia, digestive problems, hormonal imbalances, and fatigue" (Majumdar et al., 2020, p. 1192; 1196). Subjects generally expressed more lethargy and napping during the day compared to pre-lockdown periods (Majumdar et al., 2020, p. 1192).

2.3 Sleep Studies

Most recently, Icht et al. (2020, p. 489.e1) "used acoustical analyses to assess the effect of 24 hours of sleep deprivation on vocal parameters of young adults." They found that females had better voice quality (higher harmonic-to-noise ratio) when sleep-deprived than when following normal nocturnal sleep. To measure the effect of 24 hours of wakefulness on sleep quality, they examined the subject's "harmonic-to-noise ratio (HNR)." Simply put, a higher HNR would represent a more refined quality of voice. They surmised that these results might explain why some individuals, especially women, may perceive poorer voice quality after nocturnal sleep as opposed to being sleep deprived.

Icht et al. (2020, p. 489.e6) listed probable reasons why some individuals experience this phenomenon. One reason could be due to an overnight build-up of mucous on the membranes of the vocal folds resulting in swelling. Gastric acid reflux, sometimes called GERD, could also be linked to poorer voice quality following nocturnal sleep. Icht's study also listed dryness to the vocal folds from oral breathing while sleep for those who snore or sleep with their mouths mostly open. Lastly, the asynchronous vocal fold vibration that follows sleep may contribute to a temporary decrease in voice quality. These explanations may show why some people have clearer voices following sleep deprivation, namely, that sleep deprivation prevents these events from occurring. Nevertheless, since sleep is essential for the body to function properly, it can be implied that these effects would eventually become counterproductive if prolonged over time.

In closing, the study cited the necessity for future research using auditors blinded to the subjects' sleep status to increase validity (Icht et al., 2020, p. 489.e3). Remarkably, the study highlighted results from South Korean research that found sleep duration in addition to sleep deprivation to be a possible factor affecting voice quality. In essence, getting too much sleep could lead to dysphonia (hoarseness or abnormal voice quality) as well as sleep deprivation.

A prior cross-sectional study in South Korea (Cho et al., 2017, p. 2**)** investigated correlations between self-reported voice problems and hours of sleep in 17,806 adult subjects. "All participants reported voice problems (if present) and their daily average sleep duration using a self-reporting questionnaire." For the study, sleep duration was classified into five categories between 5 hours or less to more than 9 hours per day. There was a 6.8% prevalence of dysphonia in the sample (5.7% in males and 7.7% in females, respectively). Again, this finding supports similar studies that females may be at a higher risk for dysphonia following increased sleep duration.

Results showed that dysphonia was lowest in subjects that received 7-8 hours of sleep.

Cho et al. (2017, p.4) state, “After adjustment for covariates (age, sex, smoking status, alcohol consumption, regular exercise, low income, high-level education), a sleep duration of ≤ 5 h and a sleep duration of ≥ 9 h were significantly associated with dysphonia, compared to a sleep duration of 7h.” Males whose nightly sleep was less than 5 hours had a 1.69 probability to report voice problems in comparison to those whose nightly sleep was 7 hours, and males whose nightly sleep was more than 9 hours were twice as likely for self-reported dysphonia than those who slept at least 7 hours a night (Cho et al., p. 5). According to the study, sleeping too long or too short can have an adverse effect on voice quality (Cho et al., 2017, p. 5).

2.4 Auditory Perceptual Evaluations

Most of the studies referenced above-used self-assessment questionnaires to evaluate the study variables. One criticism of self-assessment surveys is that they are vulnerable to subjectivity. However, Jennifer Oates (2009) states that even objectively evaluative measures such as auditory-perceptual ratings, for instance, could have listener bias. Nevertheless, this factor does not make the evaluations ineffective.

As with Icht et al. (2020), Oates (2009, p. 52) noted, “Auditory-perceptual evaluation is the most commonly used clinical voice assessment method, and is often considered a gold standard for documentation of voice disorders.” She cautions, however, “….Perceptual evaluation has, however, been heavily criticized because it is subjective. As a result, listener reliability is not always adequate, and auditory-perceptual ratings can be confounded by factors such as the listener’s shifting internal standards, listener experience, type of rating scale used, and the voice sample being evaluated” (Oates, 2009, p. 52).

The most compelling argument Oates (2009, p. 52) made was that the voice is fundamentally a “perceptual phenomenon in response to an acoustic stimulus.” Therefore, all vocal evaluation of singing, whether it be a voice lesson, competition, performance, or otherwise, is susceptible to the listener's subjectivity. Objectivity is therefore rendered through an external assessment that is subject to subjectivity. Nevertheless, the subjectivity of voice and sleep quality self-assessments can still be a reliable indicator of a shift in patterns or possible disorder. The Pittsburgh Sleep Quality Index, for instance, was 89.6% effective in predicting a possible sleep disorder, according to Daniel Buysse et al. (1989, pp. 193; 205).

While there are plenty of studies conducted sleep deprivation and duration's effect on voice quality, none of the prior studies address singing voice quality, nor do the pandemic articles address the impact of sleep disturbances on the voice or the occupational health of singers, in general.

CHAPTER 3

METHODOLOGY

3.1 Participants

Participants for this study were a large and diverse group from over a dozen states across the United States recruited through Facebook and Instagram ads, personal posts, emails sent through Qualtrics to 539 accredited music schools, the National Association of Teachers of Singing (NATS) Texoma Region's Facebook group, the UNT College of Music Division of Vocal Studies faculty and students through Canvas, and snowball sampling. The target population was singers of any skill level that were at least 18 years of age.

3.2 Procedure

The method was modeled after current studies and included the development and deployment of a psychometrically robust online epidemiologic questionnaire designed to assess: demographics and general vocal health, singing-related occupational variables including employment patterns and musician identity, self-reported sleep patterns during the pandemic, and prevalence of self-perceived changes in singing voice quality. Social media analytics revealed that over 9,000 individuals were reached. The overall survey took approximately 7-12 minutes to complete. At the closing of the questionnaire, a total of 283 participants had responded. Of those, 231 completed the survey in its entirety, a completion rate of 82%. All participants signed the informed consent form notice. Data was collected through Qualtrics, and IP addresses were not recorded to protect the participants' identities. The study received Internal Review Board approval before distribution.

3.3 Assessment Tool

The four-part survey used a general questionnaire on demographics, musical background, vocal health, and three established survey instruments: the Pittsburgh Sleep Quality Index (PSQI), the Singing Voice Handicap Index-10 (SVHI-10), and the Epworth Sleepiness Scale (ESS).

3.3.1 Demographics, Musical Background, and Vocal Health

The first section of the overall survey (General Survey) included six questions on demographics and musical background and seven vocal health questions (see Table 4.1). Also, subjects were asked to rate the differences between their perceived sleep and singing voice quality on a bidirectional scale since the pandemic started. Lastly, subjects answered whether or not they believe that sleep quality influences singing quality.

3.3.2 Singing Voice Handicap Index-10 (SVHI-10)

The SVHI-10 is a survey of ten questions rated on a 5-point Likert scale (0 = *never*, 1 = *almost never*, 2 = *sometimes*, 3 = *almost always*, 4 = *always*) that ask the subject to describe their singing voice and the psychological impact if any, that their singing voice has on their overall self-certitude. Sobol et al. (2020) conducted a literature review to determine normative values for SVHI-10. After narrowing their search down to six published articles that employed the SVHI-10 in their studies, researchers determined that a normative value for a group of 528 singers was approximately an SVHI-10 score of 8.38 out of a possible maximum total of 40 points with confidence intervals between 7.43 to 9.34 (Sobol et al., 2020, p. 808.e28). Based on the population sample, this data further tells us that we have 95% assurance that singers' actual population would report somewhere between these confidence intervals. Anything above this would suggest an increasing level of vocal dysphonia though the following information would be needed to determine if this were an acute or chronic condition.

While objective modes of voice quality like auditory perceptual evaluations and cepstral peak prominence are considered the hallmarks for evaluating voice quality, a plethora of studies affirm the validity and reliability of self-assessments for voice and singing voice quality. Cohen et al. (2009) developed the original SVHI to discriminate dysphonic from healthy singers. After an evaluation, the survey was found to be valid, reliable for test-retestability, and internally consistent. The study's outcome showed 112 dysphonic and 129 non-dysphonic singers from various skill levels in a wide spectrum of genres. As expected, singers with voice disorders had poorer scores than their healthy counterparts. A Spearman correlation revealed a moderate relationship between SVHI and self-assessed singing voice problems, r = 0.63 (Cohen et al., 2009, p. 1868). The SVHI has since been translated into various languages across the globe.

Research has shown a difference in the evaluation of speech voice quality and singing voice quality. Jacobson et al. (1997) devised the VHI to assess subjective dysphonia in speech. Later this was reduced to the VHI-10. The difference between singers and non-singers was significant. Renk recalls prior studies attempting to explain this observation. When comparing 167 singers and 86 non-singers, Phyland et al. (1999, p. 603) found a higher likelihood for a voice disorder in singers. Murry et al. (2009) measured the differences in VHI scores between 35 singers and 35 non-singers. When the authors added questions about singing, singers reported more severe problems which led to the establishment of the SVHI, which was later shortened to the SVHI-10 to reduce the subject burden. Renk et al. (2017, pp. 383.e2-383.e3) found a significant difference between VHI-10 scores and SVHI-10 scores. Since singers were more sensitive to detecting problems with their voice when completing the VHI-10, the study highlights the importance of distinguishing between talking and singing in the analysis of voice quality as singers have specific needs not satisfied by standard tests (Renk et al., 2017, p. 383.e3). As numerous tests compare statistical and practical significances between the VHI-10 and the SVHI-10, I determined that it would not be necessary to include the VHI-10 test in this sample of singers.

3.3.3 Pittsburgh Sleep Quality Index (PSQI)

The PSQI assesses sleep quality and disturbances over a month using various scales that are later scored and converted to a 4-point Likert scale from 0-3 where 0 = *no difficulty* and 3 = *severe difficulty* based on compilations (described below). There are 19 self-assessment questions and five questions for partners or roommates to answer, which do not influence the score when a second observer is unavailable. The seven components that comprise the total score are: (1) Subjective Sleep Quality, (2) Sleep Latency, (3) Sleep Duration, (4) Habitual Sleep Efficiencies, (5) Sleep Disturbances, (6) Use of Sleeping Medication, and (7) Daytime Dysfunction.

Component 1 was computed by respondent's self-assessment of their sleep quality on a 4-point Likert scale. Component 2 was computed by creating a range of times to fall asleep (measured in minutes). The breakdown for this score was as follows: ≤ 15 minutes is a score of 0, 16-30 minutes is a score of 1, 31-60 minutes was a score of 2, and anything greater than 60 minutes was a score of 3. The score was combined with a score of frequency of the occurrences that the subject experienced this delayed sleep. Component 3 was computed by assigning scores to participants' assessments of their sleep duration. If hours slept was > 7, then a score of 0 was assigned. If participants slept approximately 6-7 hours, they were assigned a score of 1. If the reported time spent asleep was 5-6 hours, then a score of 2 was assigned. Finally, if the participant slept less than 5 hours, then a score of 3 was assigned. Component 4 was computed through a formula: (N of hours slept divided by N of hours slept in bed) x 100 to get the habitual sleep efficiency percentage. If the Habitual Sleep Efficiency percentage was > 85%, a score of 0 was assigned. If efficiency percentages fell between 75-84%, then a score of 1 was assigned. A score of 2 was assigned for percentages falling between 65-74%, and percentages greater than 65% were rated 3. For Component 5, first, scores were assigned for Questions 5b-5j on a 4-point Likert scale according to the scoring instructions in the PSQI (0 - Not during the past month, 1 - Less than once a week, 2 - Once or twice a week, and 3 - Three or more times a week). The total sleep disturbances were determined by assigning a score to the sum of Questions 5b through 5j pertaining to various types of sleep disturbances. If participants reported no sleep disturbances from Questions 5b-5j, they were assigned a score of 0. Totals from the composite score that fell between 1-9 were assigned a score of 1. Scores falling between 10-18 were assigned a score of 2, and totals that fell between 19-27 were assigned a score of 3. Component 6 was more straightforward. This component pertained to questions regarding the use of sleeping medications: Not during the past month (0), Less than once a week (1), Once or twice a week (2), Three or more times a week (3). Component 7 was computed by assigning scores to the sum of Questions 8 and 9. “An overall score greater than 5 indicates major difficulties in at least two components or moderate difficulties in more than three components” (Rocha & Behlau, 2018, p. 2). The higher the score is, the worse the sleeping patterns.

3.3.4 Epworth Sleepiness Scale ESS

The ESS contains eight scenarios involving the likelihood of dozing during daily activities. Excessive daytime sleepiness (EDS) is indicated by a global score above 10 (Rocha & Behlau, 2018, p. 2). The score breakdown is as follows: a score of 0-5 indicates lower normal daytime sleepiness (NDS), a score of 6-10 indicates higher NDS, a score of 11-12 indicates mild EDS, a score of 13-15 indicates moderate EDS, and a score of 16-24 indicates severe EDS (About the ESS – Epworth Sleepiness Scale, n.d.).

3.3.5 Data Analysis

Data were analyzed to compare interest groups and variables using descriptive statistics, parametric and nonparametric statistics, and association statistics employing the software Statistical Package for Social Sciences (SPSS-27). Normality of distribution was evaluated utilizing a histogram; however, since the number of participants was large enough ($n > 30$) and several statistical tests have been robust against normality violations when data showed a slight skewness kurtosis, the central tendency theorem was invoked. Thus, the data were treated as normal. I inspected box plots of each survey instruments' responses to check for significant outliers. Scatter plots were used to assess for linearity among data points.

Statistical significance between the SVHI-10, PSQI, and ESS scores was compared among demographic groups using an independent *t*-test if requirements were satisfied and a Mann-Whitney U test as an alternative. The strength of the association between perceived sleep quality and singing voice quality was tested using Pearson's correlation. For this research study, the correlation coefficient's value measured the effect size amongst variables for which an association, or lack thereof, was evaluated. A linear regression was also run to measure the predictability of sleep quality for singing quality.

When there were more than two groups to compare, e.g., race/ethnic background or age brackets, then a one-way ANOVA test or Kruskal Wallis test was run to analyze differences among and within groups. The sample's numbers were also compared to the mean scores and normative values for the SVHI-10, PSQI, and ESS using a one-sample *t*-test. Scores were taken from the Global cutoff scores for PSQI (≥ 5) and ESS (1-10), and SVHI-10 normative score (8.38) from a literature review conducted by Sobol et al (2020).

CHAPTER 4

RESULTS

4.1 General Survey

4.1.1 Demographics and Musical Background

For the various tests, it was necessary to identify which specific groups of interest were most at risk for self-assessed sleep problems and vocal problems. Table 4.1 shows the diversity of singers' demographics and musical qualifications.

Table 4.1

Demographics and Musical Background

	Group Statistics	%
Gender	Nonbinary	1.0
	Female	73.0
	Male	26.0
Age	18-30	52.8
	31-45	25.5
	46-60	13.4
	> 60	8.3
Race	Asian	2.2
	Black/African descent	37.2
	Hispanic	4.8
	Native American	0.4
	White/Caucasian	48.9
	Multiracial	5.6
	Other	0.9
Singer Skill Level	Elite Vocal Performer	29.0
	Graduate Student Singers	12.6
	Undergraduate Singers	36.8
	Amateur Singers	21.6
Voice Type	High Voice (Soprano/Tenor)	50.0
	Medium Voice (Mezzo-Soprano/Alto/Countertenor)	35.5
	Low Voice (Bass/Baritone)	13.0
	Uncertain	1.5

(table continues)

Group Statistics		%
Genre Primarily Taught/Performed	Classical (only)	36.8
	Classical & CCM	20.3
	Multiple CCM	13.4
	Gospel (only)	12.6
	Classical and MT	11.3
	One CCM Genre (only)	5.6

4.1.2 Vocal Health

The first section of the overall questionnaire (General Survey) asked participants a few questions about their overall vocal health. There were three areas of interest as it pertained to general vocal health: 1.) voice problems since the pandemic started, 2.) prior diagnoses related to vocal health at any period during the singer's life, 3.) any prior visit to an otolaryngologist or ear, nose, and throat doctor (ENT). When asked about their voice problems over the past year, participants were allowed to select multiple issues; therefore, the data reflects some overlap (See Table 4.2).

Table 4.2

Percentages of Voice Problems Since the Pandemic Started

Voice Problems	%	Mean	*SD*
"Loss of High Notes"	33.5	17.35	0.70
"Loss of Low Notes"	15.0	16.18	5.56
"Tired Voice"	67.4	13.68	6.10
"Weak Voice"	26.6	13.17	7.11
"Hoarse Voice"	24.9	12.50	6.72
"Loss of Ability to Speak or Sing Loudly"	3.5	19.63	4.53
"Loss of Ability to Speak or Sing Quietly"	0.9	5.00	5.66
"Voice Spasm"	2.6	16.17	8.23
"Effortful Voice"	18	8.00	6.24
"Other"	3.5	8.88	6.24
"None"	6.5	7.53	3.98

Of those who selected “Other,” 15 (6.5%) wrote in that they had experienced no voice problems over the past year. The rest of the written responses were either due to illness, loss of ability to speak or sing quietly, or some prior issue evaluated in subsequent questions of the general survey.

Respondents were asked if they had ever been diagnosed with one or more of the following diseases: respiratory allergies, asthma, laryngitis, sinus infection, vocal nodules, contact ulcers, gastrointestinal reflux acid disease (GERD) or other. Table 4.3 shows the number and percentages of singers that reported having a prior diagnosis.

Table 4.3

Frequency and Percentage of Reported Prior Diagnoses

Prior Diagnoses	*n*	%
No Prior Diagnosis	107	46.3
One Prior Diagnosis	61	26.4
Two Prior Diagnoses	37	16.0
Three or More Prior Diagnoses	26	11.3

When asked if they had ever visited an ENT for vocal-fold related issues, only 26.4% of the sample said yes. Moreover, when self-perceived singing voice quality and SVHI-10 scores were examined among those that reported having seen an ENT in the past for vocal fold-related issues, there was no statistical significance. Similar results were found when compared to reports of prior diagnoses (or lack thereof). The next section details the analysis of SVHI-10 scores as compared among self-perceived singing quality ratings and voice problems since the pandemic started.

4.2 Analysis of the SVHI-10

4.2.1 Scores by Voice Problems

A one-way ANOVA (Analysis of Variance) was run to determine if there were any differences in SVHI-10 scores and reported voice problems over the past year. Groups were categorized as shown in Table 4.2. Since group means were statistically different, I rejected the null hypothesis and accepted the alternative hypothesis. The null hypothesis states that no relationship exists between two variables and that any differences that do exist are by chance and do no not support the issue being investigated. It assumes that whatever the researcher hypothesized would happen, did not occur.

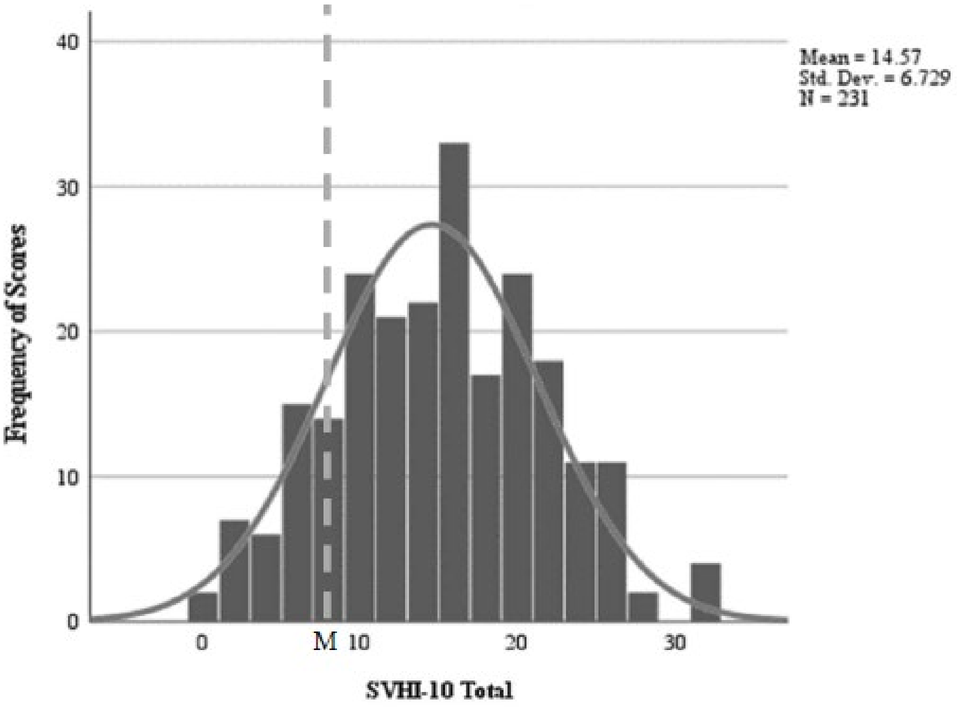
SVHI-10 scores were statistically different for some voice problems, $F(11, 220) = 5.940$, $p < .001$, $\eta^2 = 0.23$. (For reference, an η^2 of 0.01 indicates a small effect size or association. An η^2 of 0.06 indicates a moderate effect size, and an η^2 of 0.14 or greater indicates a large effect size). Table 4.2 shows the mean and standard deviation for each category of voice problems. Tukey post hoc analysis showed that the mean increase from "none" to "loss of high notes in my range" (9.81, 95% CI [4.18, 15.45]) was statistically significant ($p = .001$), as well as the increase from "none" to "loss of low notes in my range" (8.65, 95% CI [1.95, 15.34], $p = .002$), "none" to "tired voice" (6.14, 95% CI [0.44, 11.85], $p = .023$), and "none" to "ability to speak or sing loudly" (12.09, 95% CI [3.34, 20.85], $p = .001$). Additionally, there were mean increases between scores for "loss of high notes in my range" and "tired voice" (3.67, 95% CI [0.35, 6.99], $p = .016$) and "loss of high notes in my range" and "other voice problems not listed" (2.25, 95% CI [1.05, 15.45], $p = .011$), both statistically significant differences. Lastly, an increase in the mean differences between "loss of ability to speak or sing loudly" and "other voice problems not listed" (3.03, 95% CI [0.75, 20.75], $p = .023$) revealed a statistically significant difference. No other categories were statistically significant.

4.2.2 Scores among Gender

There were 169 female, 59 male, and 3 nonbinary participants (*N* = 231). An independent-samples *t*-test was run to establish if there were differences in the SVHI-10 scores among females and males. Due to nonbinary singers accounting for approximately 1% of the sample size, comparisons for gender were assessed with males and females only. All variables tested in this study passed the test of assumptions. Additionally, using the central limit theorem, which states that "in probability theory... in many cases, when independent random variables are added, their properly normalized sum tends toward a normal distribution even if the original variables themselves are not normally distributed" and since the *t*-test is robust to abnormality, the data was treated as normal ($n > 30$) as shown in Figures 4.1, 4.2, and 4.3 (Central Limit Theorem - Encyclopedia of Mathematics, n.d.).

Figure 4.1

Frequency and Distribution of SVHI-10 for All Genders



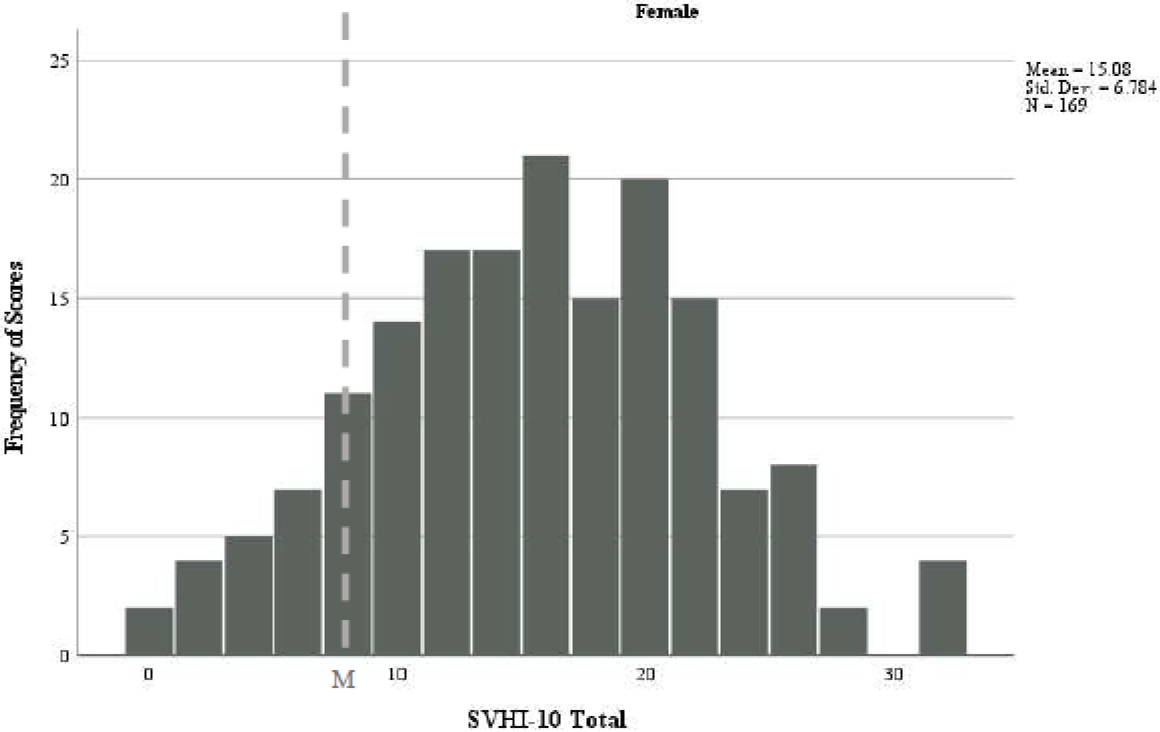
Note. The dotted, vertical line for "M" represents Sobol's "normative value" of 8.38 for the SVHI-10.

Figure 4.1 shows the normal distribution for the entire sample of singers in this study. The dotted line indicates the mean score for 528 singers taken from a literature review by Maria Sobol et al. (2020) where she and her colleagues attempted to establish normative values for the SVHI-10. In her review, the SVHI-10 mean score (*M*) was 8.38 which she referred to as the "normative value."

Figure 4.2 shows a normal distribution of scores for female singers in this study. The graph also shows that most SVHI-10 scores for female singers were above the "normative value" of 8.38, according to Sobol's recommendation (2020).

Figure 4.2

Frequency and Distribution of SVHI-10 Scores for Female Singers

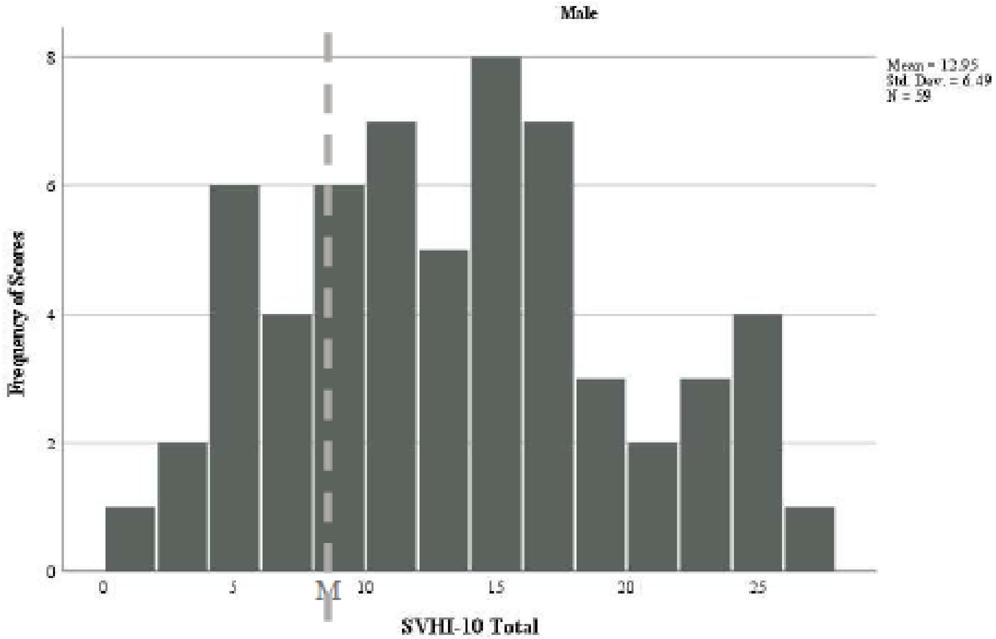


Note. The dotted vertical line for "M" represents Sobol's normative value" of 8.38 for the SVHI-10.

Figure 4.3 shows a normal distribution of scores for male singers in this study. It also shows that the majority of SVHI-10 scores for male singers were above Sobol's "normative value” of 8.38 as indicated by the dotted reference line.

Figure 4.3

Frequency and Distribution of SVHI-10 Scores for Male Singers



Note. The dotted vertical line for “M” represents Sobol’s normative value” of 8.38 for the SVHI-10.

For due diligence, tests were run using both parametric and nonparametric measures. Parametric tests require certain assumptions about a population sample’s parameters, specifically when it comes to its distribution. When these assumptions cannot be satisfied, nonparametric tests may be used as they are not as sensitive to outliers, violations in linearity, or normality of distribution.

In addition, outliers were winsorized to remove any chance of corrupting the sample. “Winsorizing or winsorization is the transformation of statistics by limiting extreme values in the statistical data to reduce the effect of possibly spurious outliers” (Winsorize: Definition, Examples in Easy Steps, 2020). The extreme scores did not represent the population’s average sample because the study was not intended to target singers with severe pre-existing voice or sleep disorders. Additionally, research shows that a prior vocal diagnosis is a predictor for future vocal disorders. After examining the two respondents' questions about their prior diagnoses and visits to an ENT, it was determined that there was enough information to infer that these two subjects were exceptions to the normal population of singers. For the SVHI-10, two of the singers had extreme scores of 34 and 35. These scores indicated a very severe voice disorder as the highest score possible on the SVHI-10 is 40. Therefore, these two scores were winsorized to the nearest highest score of 32. These outliers were examined by observation and inspection of a box plot.

SVHI-10 scores were normally distributed for females with a skewness of 0.022 (*SE* = 0.187) and kurtosis of -0.198 (*SE* = 0.371) and for males with a skewness of 0.239 (0.311) and kurtosis of -0.713 (*SE* = -0.613). Homogeneity of variances was assessed by Levene's test for equality of variances (p = .866). Females reported more voice issues over the past year (*M* = 15.08, *SD* = 6.78) than males (*M* = 12.95, *SD* = 6.49), a statistically significant difference (*M* = 2.13, 95% CI [0.13, 4.13], $t(226) = 2.10$, $p = .037$, $d = .32$. For Cohen's *d*, $d = .2$ [small effect size], $d = .5$ [medium effect size], and $d = .8$ or higher [large effect size]). Hence, the null hypothesis was rejected and the alternate hypothesis that women were slightly more affected by voice problems than men since the pandemic began was accepted.

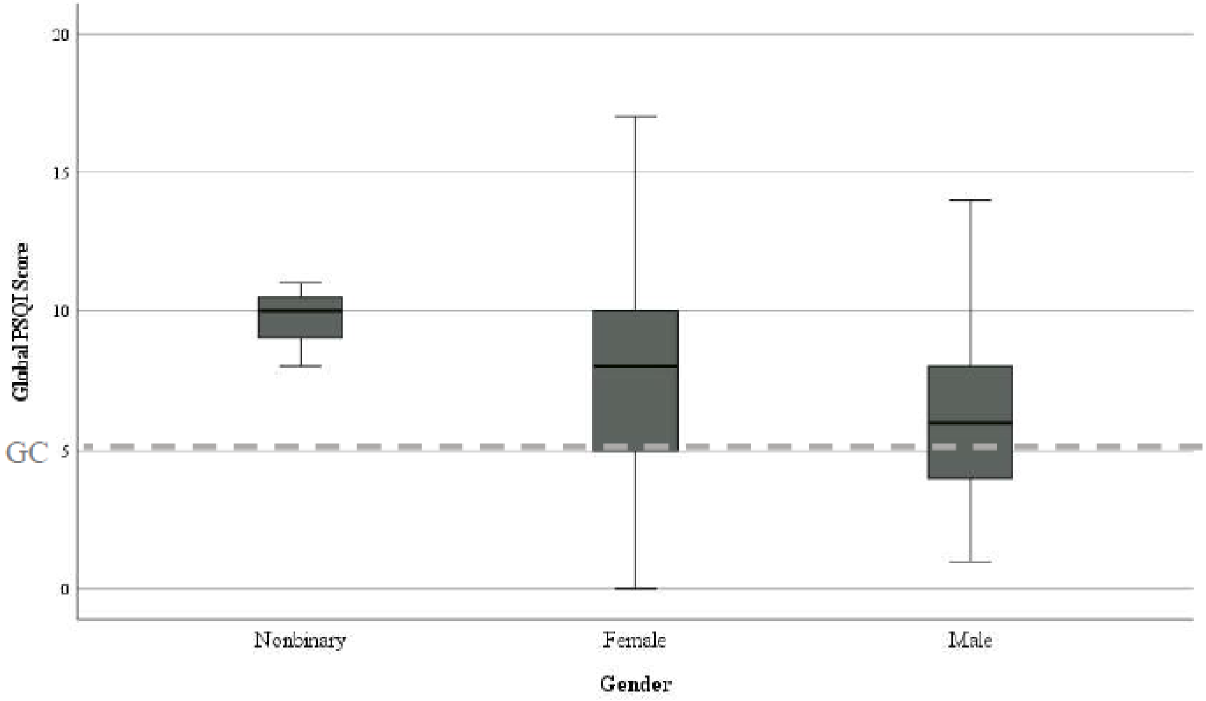
4.3 Analysis of PSQI Scores: Scores among Gender

As with the SVHI-10, an independent *t*-test was run to determine if there were differences among females and males in sleep quality over the last month. Two of the participants disclosed that they had severe sleeping disorders prior to the pandemic. Therefore, these two participants had extreme values for the PSQI that did not represent a normal sample of the population. These two singers had extreme scores of 16 and 18 (out of a possible 21) on the survey. These scores indicated the presence of a severe problem in at least two areas or a moderate sleep problem in at least three areas (Buysse et. al, 1989). Therefore, these two scores were winsorized to the nearest high score of 14. These outliers were examined by observation and inspection of a box plot.

The total mean score for all genders was 7.35 (*SD* = 3.65). Scores were normally distributed for females with a skewness of 0.022 (*SE* = 0.187) and kurtosis of -0.198 (*SE* = 0.371) and for males with a skewness of 0.239 (*SE* = 0.311) and kurtosis of -0.713 (*SE* = -0.613). Homogeneity of variances was assessed by Levene's test for equality of variances (*p* = .733). Females reported more sleep issues over the last month (*M* = 7.62, *SD* = 3.70) than males (*M* = 6.44, *SD* = 6.44), a statistically significant difference (*M* = 1.18, 95% CI [0.10, 2.26], *t*(226) = 1.181, *p* = .033, *d* = .33).

Figure 4.4

PSQI Scores by Gender (after winsorization)



Note. The dotted, horizontal line represents the PSQI Global Cutoff Score (GC) of 5.

Figure 4.4 shows the box plot (also known as a box and whiskers plot) for PSQI scores among genders. The dotted line (M) at 5 represents the Global Cutoff Score for good sleep according to the author of the survey, Buysse (1989). The line bifurcating the box represents the median score for each gender. The first quartile extends from the base of the box to the minimum value. The second quartile extends from the base of the box to the median. The third quartile extends from the median to the top of the box, and the fourth quartile extends from the top of the box to the maximum value. The graph below shows that the median for female singers was ~7 with a minimum of 0 and a maximum of ~17. Male singers had a median of ~6 with a minimum of 1 and a maximum of ~14.

4.4 Analysis for the ESS

I ran an independent *t*-test to determine if there were differences among females and males in daytime sleepiness since the pandemic started. Similar to the other survey instruments, one extreme score for the ESS was winsorized due to a subject's self-disclosed sleeping disorder. For the ESS, one of the singers had an extreme score of 22 (out of a possible 24 points). This participant revealed earlier in the PSQI to having chronic insomnia, so this was to be expected. The score was winsorized to the nearest high score of 17. The outliers were examined by observation and inspection of a box plot, and a histogram was used to observe normality. ESS scores were normally distributed for females with a skewness of 0.376 (*SE* = 0.187) and kurtosis of 0.128 (*SE* = 0.371) and for males with a skewness of 0.562 (*SE* = 0.311) and kurtosis of -0.285 (*SE* = 0.613). Homogeneity of variances was assessed by Levene's test for equality of variances (*p* = .839). There was no statistical significance between scores of males and females for this survey. Female scores were still higher (*M* = 8.76, *SD* = 4.61) than male scores (*M* =

7.59, *SD* = 4.52) but no statistical significance between the difference of means (*M* = 1.17, 95% CI [-0.20, 2.54], *t*(226) = 1.687, *p* = .093, *d* = .25).

4.5 Influence of Sleep on Singing Voice Quality

In addition to completing the above instruments, singers were asked to answer whether they believed that sleep influences singing voice quality. Table 4.4 shows the group statistics for responses to this question along with the mean SVHI-10 score for each group. There was no statistical significance between groups (*M* = 1.905, 95% CI [-0.805, 4.615], *t*(229) = 1.385, *p* = .167, *d* = .28.

Table 4.4

Mean SVHI-10 Scores for the Influence of Sleep on Singing Voice Quality

	Sleep Q Influences Singing Q?	*n*	%	Mean	SD	Std. Error Mean
SVHI-10 Total	Yes	204	88.3	14.79	6.816	.477
	No	27	11.7	12.89	5.873	1.130

4.6 Sleep and Singing Voice Quality Since the Pandemic Started

Respondents were also asked to rate on a bidirectional scale (-50 to 50) their sleep and singing voice quality since the pandemic started. This bidirectionality was to assess the perceived degree of impact. Subsequently, ratings were divided into seven categories: much worse (a rating range of -50 to -35), moderately worse (-34 to -15), slightly worse (-14 to -1), no change (0 equaled 0), slightly better (1 to 14), moderately better (15 to 34), and much better (35 to 50). Next, these categories were consolidated into three major categories: worse, no change, and better (see Tables 4.5 and 4.6).

Table 4.5 shows seven categorical allocations of self-perceived sleep and singing voice quality ratings and the frequency and percentages of singers in each category. Table 4.6 further condenses Table 4.5 into three categories for sleep and singing voice respectively.

Table 4.5

Categorical Allocations of Perceived Sleep and Singing Quality Since the Pandemic Started

Quality Since the Pandemic Started		*n*	%
Sleep	Much Worse	44	19.0
	Moderately Worse	65	28.1
	Slightly Worse	33	14.3
	No Change	26	11.3
	Slightly Better	28	12.1
	Moderately Better	21	9.1
	Much Better	14	6.1
Singing	Much Worse	12	5.2
	Moderately Worse	40	17.3
	Slightly Worse	51	22.1
	No Change	24	10.4
	Slightly Better	46	19.9
	Moderately Better	35	15.2
	Much Better	23	10.0

Table 4.6

Three-Tiered Categorical Allocations of Self-Perceived Sleep and Singing Quality

Quality Since the Pandemic Started		*n*	%
Sleep	Worse	142	61.5
	No Change	26	11.3
	Better	63	27.3
Singing	Better	104	45.0
	No Change	24	10.4
	Worse	103	44.6

Figures 4.5 and 4.6 show the frequency and distribution of the raw ratings for self-assessed sleep and singing quality since the pandemic started. Figure 4.5 shows the graphical

depiction of Table 4.5 which states that 61.5% of singers ultimately rate their sleep worse since the pandemic started. As mentioned above, negative skewness is indicated by the long tail of the bell curve. Singing quality was normally distributed as shown in Figure 4.6 with a slight majority of scores (55.4%) showing either "no change" or "better."

Figure 4.5

Frequency and Distribution of Self-Assessed Sleep Quality Since the Pandemic Started

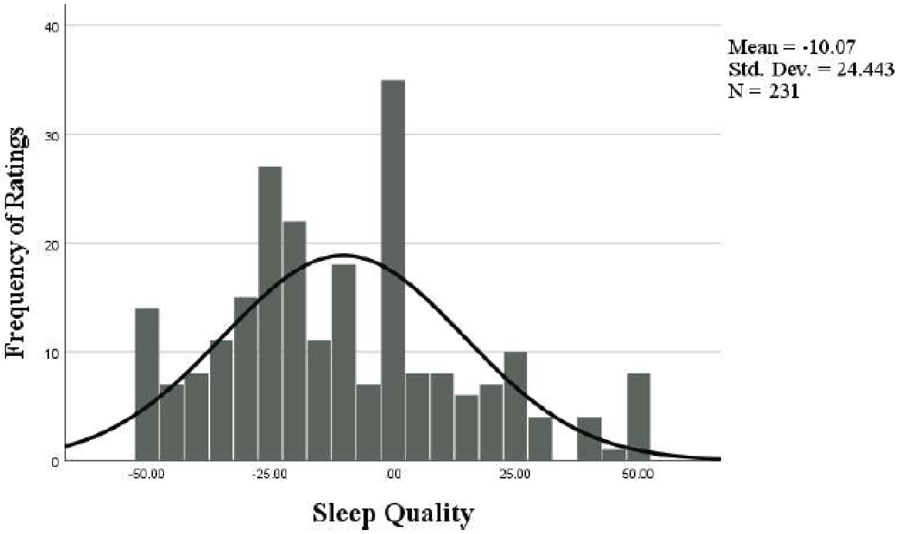


Figure 4.6

Frequency and Distribution of Self-Assessed Singing Voice Quality

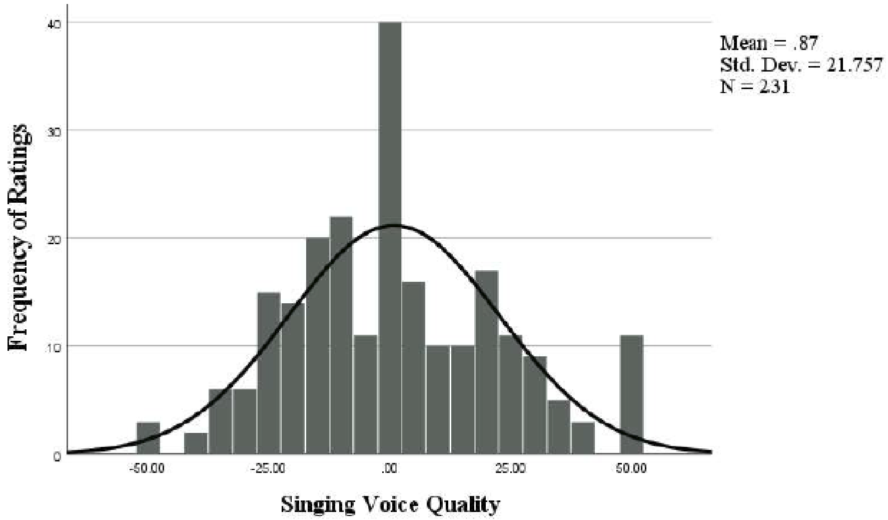
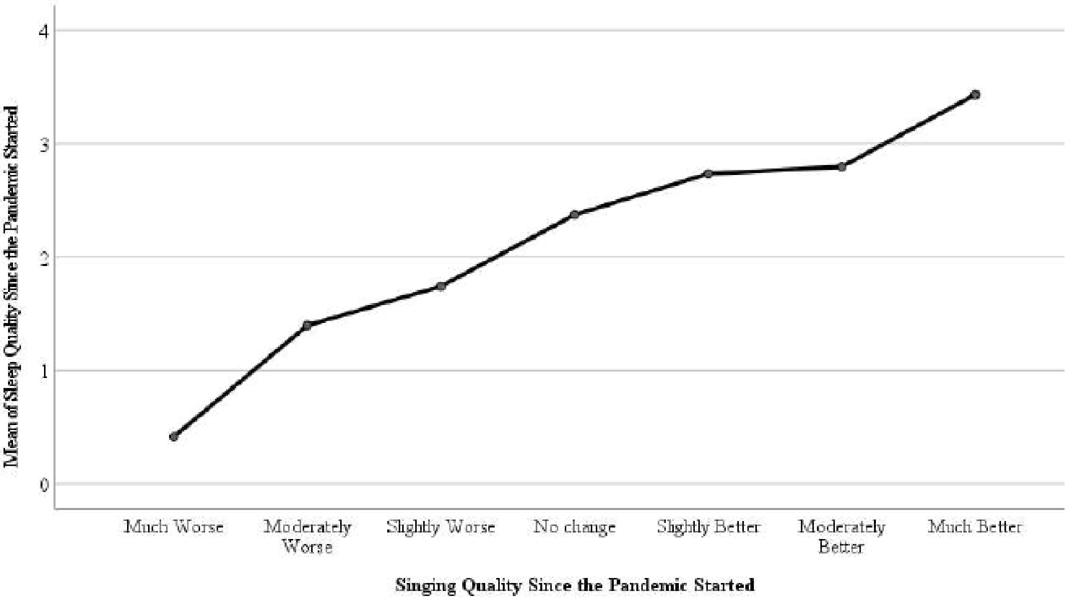


Figure 4.7 shows a monotonic relationship between the means of self-assessed singing quality and sleep quality. The mean plot in Figure 4.7 stops at 4 (slightly better) for sleep quality; however, Figure 4.8 shows what would happen if the graph were to continue to 5 (moderately better) and 6 (much better). Figure 4.8 shows that while the relationship between self-assessed sleep and singing quality starts to have a monotonic relationship (values increase in the same direction although not at, as sleep quality approaches "much better," the average ratings of self-assessed singing quality fall between 3 (no change) and 4 (slightly better). There was large association between perceived sleep quality and perceived singing quality since the pandemic started ($\eta^2 = 0.46$).

Figure 4.7

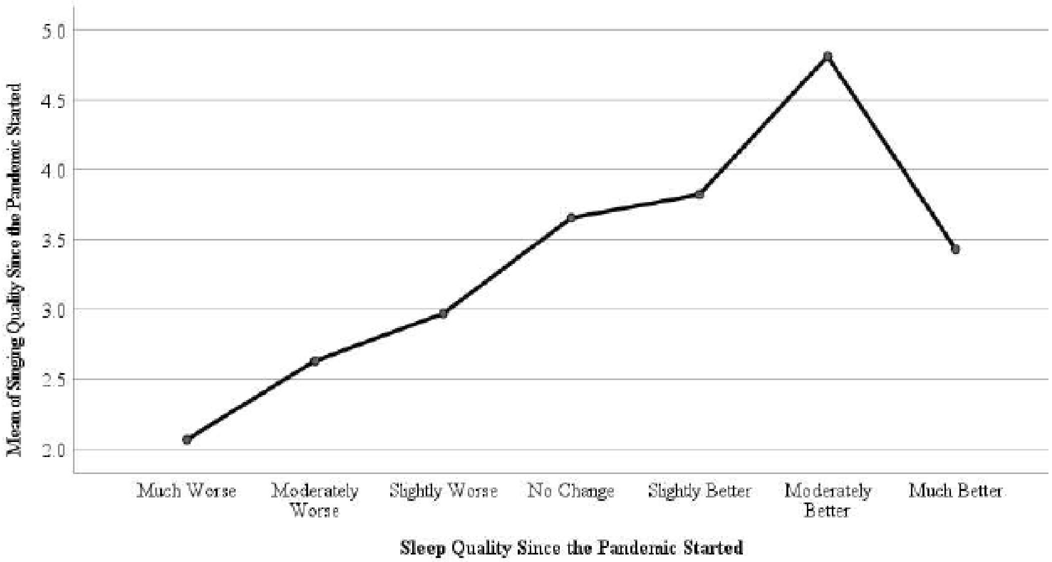
Mean Plots of Self-Perceived Singing Quality Compared to Self-Perceived Sleep Quality



Note. Vertical axis: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no change, 4 = slightly better.

Figure 4.8

Mean Plots of Self-Perceived Sleep Quality Compared to Self-Perceived Singing Voice Quality

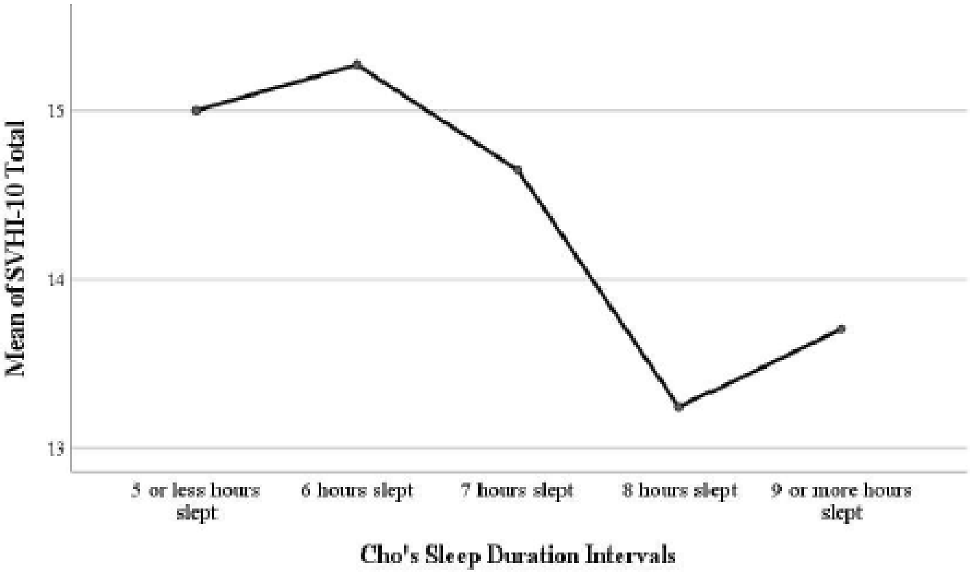


Note. Vertical axis: 2 = slightly worse, 3 = no change, 4 = slightly better, 5 = moderately better.

4.7 Cho's Sleep Duration and Singing Quality

Figure 4.9

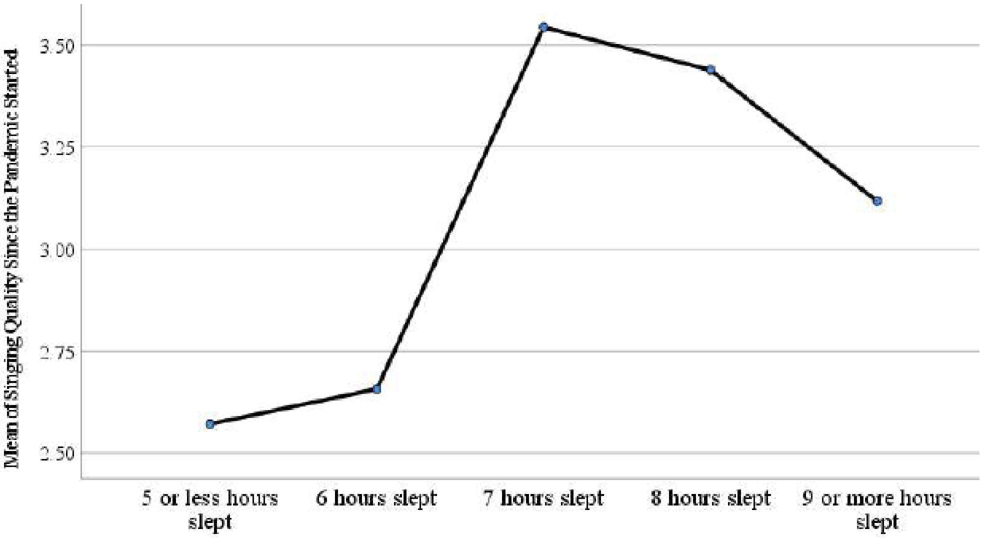
Mean Plot of SVHI-10 Scores and Cho's Sleep Duration Intervals



Note. Vertical axis: 2.5 - 2.99 = slightly worse, 3.0 - 3.99 = no change.

Figure 4.10

Mean Plots of Singing Quality Ratings and Cho's Sleep Duration Intervals



Note. Vertical axis: 2.5 - 2.99 = slightly worse, 3.0 - 3.99 = no change.

Figure 4.9 and 4.10 show the mean plots for singing quality and SVHI-10 scores compared against Cho's Sleep Duration Intervals (Cho et al., 2020). A one-way ANOVA yielded no statistical significance for SVHI-10 scores among Cho's sleep duration levels. Although, there was a statistical difference in the ratings of singing voice quality between 6 hours slept and 7 hours slept ($p < .004$), a medium effect size ($\eta^2 = 0.07$).

4.8 One Sample *t*-Tests

4.8.1 SVHI-10 Scores

I ran a one sample *t*-test to investigate the differences between the general singing population's self-assessment of singing voice quality and our sample. The mean score for our sample of singers (*M* = 14.57, *SD* = 6.73) was much higher than the normative values reported (*M* = 8.38), a statistically significant difference (*M* = 6.19, 95% CI [5.32, 7.06], *t*(230) = 13.98, *p* = .001, *d* = .92).

4.8.2 PSQI Scores

A one sample *t*-test was run to investigate the differences between normative values for self-assessment of sleep quality and our sample. The mean score for our sample of singers (*M* = 7.35, *SD* = 3.65) was slightly higher than the global cutoff score of 5, a statistically significant difference (*M* = 2.35, 95% CI [1.87, 2.82], *t*(230) = 9.76, *p* = .001, *d* = .64). I did not run a one sample *t*-test for ESS as our sample's scores were within normative values.

4.9 Correlations

To measure the effect size, I ran a Pearson's correlation for SVHI-10 and PSQI. A small correlation was found between self-assessment of singing voice quality and self-reported sleep patterns over the past month, *r* = .31. The correlation between singing voice quality and sleepiness was smaller, *r* = .26. A third Pearson's correlation was run to test the strength of the relationship between daytime sleepiness and sleep patterns among the sample. There was a small relationship between singer PSQI totals and ESS scores, *r* = .23.

Table 4.7

Correlations for Variables of Interest

Variables	1	2	3	4	5
1. Sleep Quality	-				
2. Singer PSQI Total	-.44**	-			
3.Singing Quality	.42**	-.26**	-		
4. SVHI-10 Total	-.16*	.31**	-.27	-	
5. ESS Total	-.19**	.23**	-.06	.26**	-

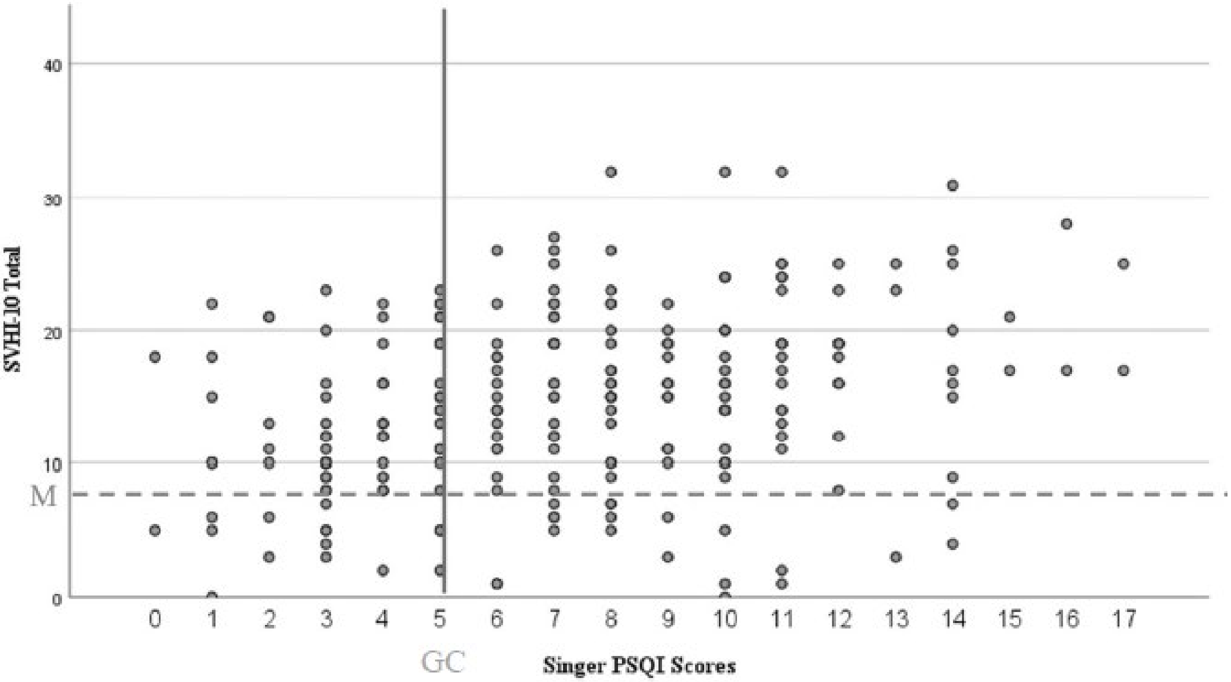
Note. A correlation coefficient (*r*) of .1 represents a small correlation. An *r* of .3 represents a moderate correlation, and an r of .5 or higher represents a large correlation. *Correlation is significant at the .05 level (2-tailed). **Correlation is significant at the .01 level (2-tailed). **p* < .05, ***p* < .001

Figure 4.11 shows the graphical representation of the correlation between SVHI-10 and

PSQI scores. The upper right quadrant shows data points for singers who had worse SVHI-10 and PSQI scores. The lower left quadrant shows singers who had scores that fell within "normative values" for SVHI-10 scores and lower than the PSQI Global Cutoff Score (considered a good score). The lower right quadrant shows scores for singers who had worse sleep (higher PSQI scores) and SVHI-10 scores that fell below the "normative value" of 8.38. The upper left quadrant shows data points for singers who had good sleep quality (a PSQI score of 5 or lower) and higher than normative values for SVHI-10.

Figure 4.11

Scatterplot of SVHI-10 Score and Singer PSQI Scores

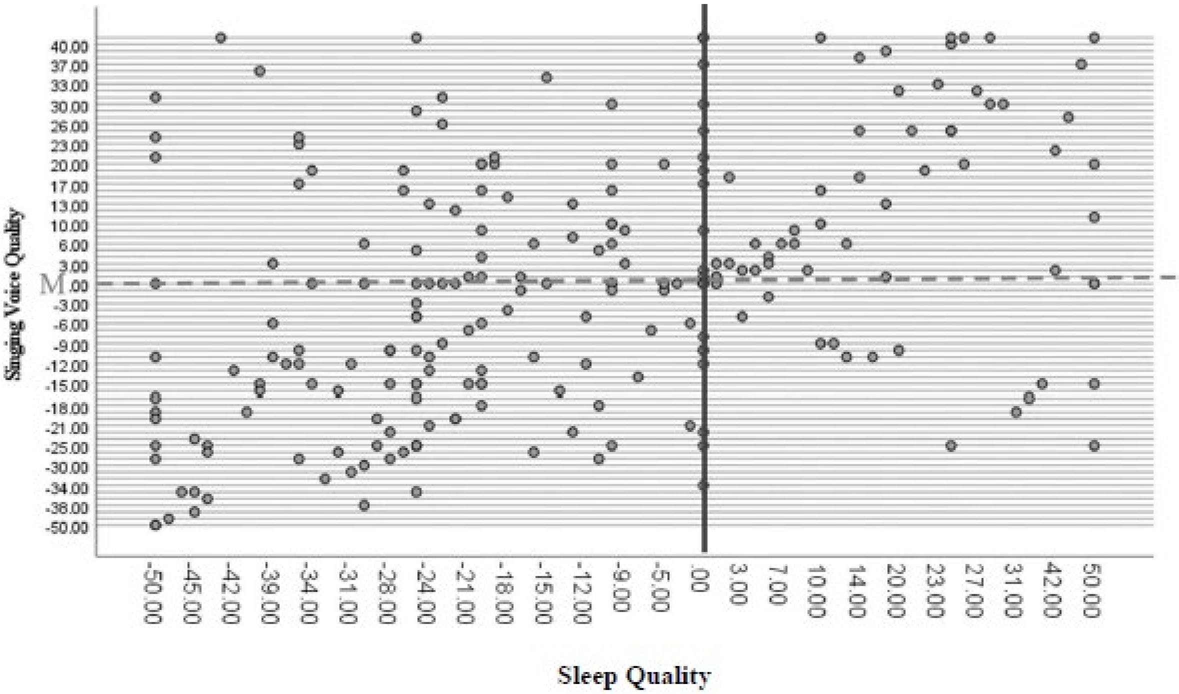


Note. The horizontal, dotted line represents the mean score (M) or "normative value" for the SVHI-10. The vertical, solid line represents the Global Cutoff Score (GC) for the PSQI.

Figure 4.12 shows the raw data for sleep and singing quality ratings. The upper right quadrant shows data points for singers who had better perceived sleep and singing quality since the pandemic. The lower left quadrant shows data points for singers who had worse perceived sleep and singing quality. The upper left quadrant shows singers' ratings who had better singing quality but worse sleep while the lower right quadrant shows singers' ratings who had better sleep quality but worse singing quality.

Figure 4.12

Scatterplot of Singing Voice Quality Ratings by Sleep Quality Ratings



Note. The horizontal dotted line bifurcates the graph for singing quality into better and worse hemispheres at the No Change value of 0. The vertical solid line bifurcates the graph for sleep quality into better and worse hemispheres at the No Change value of 0.

For singers who rated "No Change" for sleep quality, the solid reference line shows their self-perceived singing quality prior to the pandemic and can be used as a point of comparison.

4.10 Linear Regression

4.10.1 PSQI and SVHI-10

A bivariate regression was conducted to examine how well PSQI scores could predict SVHI-10. The regression equation for predicting SVHI-10 score from PSQI was ŷ = 10.448 +

0.561x, where x = the singer's PSQI score. The adjusted R^2 for this equation was .089; that is, 8.9% of the variance in SVHI-10 scores was predictable from PSQI scores, a moderate relationship (Cohen 1988). Per the prediction equation, for every 1 point of increase in PSQI scores, SVHI-10 score will increase by 0.561 points.

4.10.2 Self-Perceived Sleep and Singing Quality Ratings

The relationship between sleep and singing quality was positive and linear and did not reveal any outliers. To evaluate how self-perceived sleep quality ratings could be a predictor for self-perceived singing quality ratings, a bivariate regression was conducted, the equation for which was $\hat{y} = 4.595 + 0.370x$, where x = the singer's self-perceived sleep quality rating. The adjusted R^2 for this equation was 0.169 meaning 16.9% of the variance in ratings of self-perceived singing quality was predictable from sleep ratings, a medium effect size (Cohen 1988). According to the prediction equation, for every 1 point of increase of the sleep rating, the singing rating will increase by 0.370 points.

CHAPTER 5

CONCLUSION

5.1 General Survey

5.1.1 Demographics and Musical Background

While our sample needed to represent a culturally diverse group of singers from around the country, it is notable to mention that there were almost no statistical differences in any tested variable among race, singer skill level, voice type, or genre primarily taught or performed. The only reliably significant difference between groups of interest was between male and female singers.

In numerous singing studies, scientists have conducted research that omits or underrepresents certain races or genders due to lack of effective recruitment or oversight. These singers may have different experiences necessary to shape the full scope of knowledge in an area. For example, we know that females tend to have poorer sleep quality and singing voice quality than males. However, as gender expression becomes more commonplace, we are still learning how speech and singing voice quality affect non-gender-conforming individuals. Only three singers identified as nonbinary in the study, which is not a large enough sample size to make any significant conclusions. Further research is needed with a larger sample of gender nonconforming and transgender individuals to determine an accurate risk level.

5.1.2 Vocal Health

While the literature suggests that a prior voice problem is a predictor for a future voice problem, the data did not determine any statistical significance between subjects with prior diagnoses and SVHI-10 scores. This finding may be explained because having severe or recurring voice disorders would severely limit a singer’s ability to perform. If this sample truly represents a normal population of singers, one would not expect an overabundance of severe singing voice handicaps.

5.2 Analysis of SVHI-10

5.2.1 Scores by Voice Problems

The greatest degree of change was between those who reported no voice problems since the pandemic started and those who reported a loss of ability to speak or singing loudly (see Section 4.2.1 Scores by Voice Problems). The analysis revealed a very high association between voice problems since the pandemic started and scores of the SVHI-10. Moreover, singers who reported a loss of high or low notes in their range or who reported loss of the ability to speak or sing loudly were most likely to have higher SVHI-10 scores, suggesting a greater degree of impact.

5.2.2 Scores among Gender

Females were more likely to report singing voice problems than male singers. This finding corroborates the current literature on this topic (Rocha & Behlau, 2018, p. 6). Further research should be conducted to determine exactly why female singers are at a higher predisposition for singing voice problems.

5.3 Analysis of PSQI Scores: Scores among Gender

Similar implications for PSQI scores were found for females, as were found in the SVHI-10 analysis and again, future research should expound on the cause of these differences.

5.4 Analysis of ESS

The results for the analysis of ESS Scores suggest that daytime sleepiness affects singers the same across genders.

5.5 Influence of Sleep on Singing Voice Quality

In a study on the impact of sleep disorders on speaking voice quality, Rocha & Behlau (2018, p. 7) stated, “There was a difference between the VHI-10 and the influence that sleep has on the voice. It was observed that the higher the perception of the influence of sleep on voice, the higher the VHI-10 score and, therefore, the greater the chance of a voice handicap.” Rocha & Behlau’s study (2018, p. 6) also reported that persons who believe that sleep has a minimal influence on the voice are 1.43 times less prone for a voice disorder than persons who believe the influence of sleep on the voice to be significant.

In contrast, the current study found no statistical differences between the perception of the influence that sleep has on the singing voice and the severity of self-assessed sleep or singing quality. In this study, singers did not perceive their voices to be better or worse simply because they believed or did not believe the influence that sleep had on the singing voice. This outcome was also true for SVHI-10 scores. These results help authenticate the validity of other findings as some opponents of subjective measures of assessment criticize the influence that one’s beliefs may have on the outcome of a survey. Yet, it is difficult to draw significant conclusions about the results without more objective measures to cross examine these findings. Future research could assess if the influence of sleep on speaking or singing voice quality correlates to auditory perceptual ratings, cepstral peak prominence, or diagnosed voice disorders.

5.6 Sleep and Singing Voice Quality Since the Pandemic Started

Figures 4.7 and 4.8 comparing self-perceived singing and sleep quality since the pandemic began, show some interesting findings. For most data points, the scores follow a monotonic relationship. As one variable increases or decreases, the other increases or decreases in the same direction, though not necessarily at the same rate as in a linear relationship. Most singers' ratings fell into this monotonic category. While results indicated that there was a large association between self-perceived sleep and singing quality as indicated by the eta squared, these results must be carefully interpreted. The range of change is a very small window, as shown in Figure 4.7. While the singing voice quality ratings did increase with the improvement of sleep quality, the intervals of increase themselves were minuscule and often the change was within the range of one categorical allocation. 55.4% of singers reported better or no change for singing quality, although 61.5% reported worse sleep quality.

For singers with poor singing voice quality and good sleep patterns, it is reasonable to surmise that either a current or prior voice problem or another non-sleep-related factor influenced singing voice quality. This finding could also support recent articles that found a possible correlation between getting too much sleep and voice problems (Cho et al., 2017, p. 3). In short, for most singers whose sleep quality was worse since the pandemic started, their perceived singing quality was between slightly worse and no change. A moderately better perceived sleep quality matched almost perfectly with a moderately better perceived singing quality; however, singers who reported much better sleep quality tended to notice a minimal change in their overall singing voice quality.

5.7 Cho's Sleep Duration and Singing Quality

One most notable observation from the literature was from Icht et al. (2020), whose study showed that females had a higher harmonic-to-noise ratio (HNR) when sleep deprived. Tone quality will sound duller in some female voices after too much sleep and will take longer to "rejuvenate" (Icht et al., 2020, p. 489.e6). In Cho's study, researchers found that getting more than 9 hours of sleep was also a predictor and factor for vocal dysphonia (Cho et al., 2017, p. 6). If this is true for singers, it could explain why some singers reported poor sleep since the pandemic started but did not notice a change in singing quality.

When examining Component 3 of the PSQI (Sleep Duration) in the current study, singers whose sleep duration was < 5 hours per night reported a higher dissatisfaction with their singing voice quality since the pandemic started which is consistent with Cho's study; however, sleep duration did not seem to be a factor for singing voice handicap (SVHI-10 scores). Component 3 does not, however, differentiate between > 7 hours of sleep and > 9 hours of sleep. For Component 3, the cutoff value for "good sleep" was only > 7 hours. Cho's study suggests that a minority of those that get more than 9 hours of sleep may experience a level of dysphonia similar to those who were sleep-deprived. The results of the current study suggest that those who had 5 or less hours of sleep experienced voice issues that were no different than those who got 9 or more hours of sleep. Using Cho's sleep duration intervals did reveal differences between scores of singers who got 6 or 7 hours of sleep. Sleep varies for everyone, but singers may need to identify their golden hours of sleep for vocal optimization. These golden hours are the amount of sleep needed for optimal singing voice quality which may be different for some singers than the amount of sleep preferred or needed to feel well-rested. Obviously, further research is needed to shed light on these findings.

Moreover, for subjects in which singing voice quality was good despite poor sleep patterns, it affirms what research summarizes about sleep duration, i.e., some people, due to their genetic dispositions, may thrive vocally with much less sleep than others.

5.8 One Sample *t*-Test

The one sample *t*-tests show that our sample was significantly different from normative values for the SVHI-10 and PSQI. In short, singing voice quality and sleep patterns were higher than normative values for SVHI-10 and PSQI scores for singers since the pandemic started. The normative value for the SVHI-10, according to Sobol et al. (2020), is the mean score taken from a compiled sample of 528 singers. In this case, implications may be drawn from comparing an SVHI-10 to the mean score of this compilation of singers. In general, a higher SVHI-10 score represents a higher degree of handicap. In contrast, the PSQI has a definitive Global Cutoff score of 5. Anything above this score shows a progressive deviation from the normal population and an indication of worse sleep patterns. It is likely that singers in the current study were affected by factors relating to the pandemic and that this may have influenced their sleep or singing voice quality. Since ESS scores were within the normal range of 0-10, daytime sleepiness for this sample was the same as before the pandemic as suggested by the data.

5.9 Correlations

Though the literature suggests that there is a relationship between prior diagnoses and future issues, there was surprisingly no correlation between prior diagnoses and current voice problems. This is not to say that these problems do not exist, but further research is needed to retest these singing populations' associations.

Prior research highlighted that singers have different needs and are more sensitive to their singing voice than the needs of their speaking voice. What remained to be examined was the strength of the association between sleep patterns and singing voice quality. The correlations between sleep and singing voice quality as assessed by the PSQI and SVHI-10 scores showed a medium correlation. While this outcome was expected, the measure of the correlation between the two was much smaller than anticipated. Sleep clearly has an influence on the singing voice, but a controlled experiment or multiple regression could be done in the future changing various factors affecting the voice to determine what has the largest impact. This outcome could again explain why some individuals are able to have good singing voice quality without having good sleep patterns.

As it pertained to the ESS, it was notable that there was no relationship between singing voice quality and sleepiness which is plausible as studies are reporting an increase in daytime napping and later wake times since the start of the pandemic (Javaheri & Javaheri, 2020, p. 1413). Since ESS scores were within the normal range of 0-10, there was no need to compare the means of this study's scores to the global cutoff. This finding suggests, that while sleep patterns were overall worse for singers, daytime sleepiness was the same as global scores before the pandemic started.

There was a moderate negative correlation between Sleep Quality and Singer PSQI Total as expected. A higher perceived sleep quality should result in a lower degree of sleep disruption. There was a moderate correlation between sleep and singing quality. This result indicates that for most singers, a better sleep quality meant either better singing or no change from prior to the pandemic. There was a moderate correlation between SVHI-10 scores and PSQI scores. This outcome indicates that while sleep patterns were certainly influencing singing voice quality, they did not have a large sway. Additionally, experimental research or a longitudinal study could lead to which factors most influence singing quality. The moderate correlation could also be a result of some singers' seemingly robust resistance to the influence of poor sleep patterns on their singing voice quality.

5.10 Bivariate Linear Regression

After determining that there was in fact a moderate correlation between SVHI-10 scores and PSQI scores, the linear regression showed the degree to which a PSQI score could be a predictor for an SVHI-10 score. The data showed that at least 8.9% of the variance in SVHI-10 scores was predictable from PSQI scores. Though a moderate association, the practical application for this degree of prediction is at best, vaguely insightful. What factor most influences the singing voice? Further research should attempt to answer this question. Similar results were found for sleep and singing quality with 16.9% of the variance in self-perceived singing quality ratings being predicted by self-perceived sleep quality ratings. This discovery could mean that singers believe sleep has a greater influence on their singing voices than it actually does.

5.11 Limitations

There were several limitations to this study.

Limitation 1: Due to the survey's extensive length, questions were omitted to reduce participant burden. As a result, several questions that could have shed light on other personal or environmental influences were not included. For example, we did not ask the singers if they had lost work due to the pandemic, if they had contracted COVID, or if they had lost a loved one due to COVID-19-related issues. This omission was done in an intentional effort not to create emotional stress while completing the survey.

Limitation 2: While research shows that auditory perceptual evaluations, cepstral peak prominence, and other objective means of evaluations were preferred, this was not feasible due to my status as a student, the pandemic, and lack of funding. In addition, there was no access to a sleep lab. To keep the study manageable, a survey was the best method to collect data.

Limitation 3: Due to the pandemic, participation in the study was limited to an online survey.

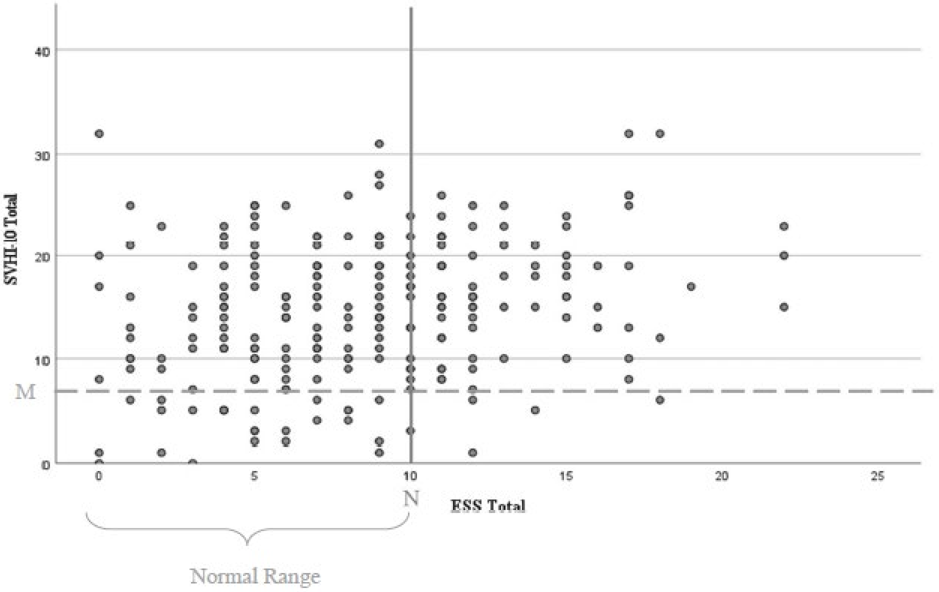
Limitation 4: I did not differentiate between transgender and cisgender on the questionnaire, which may have caused some confusion. Gender, in this case, was treated as self-identified, just as race. While other studies only give males or females the option, there is no way for them to differentiate if a transgender person marks a cisgender sex. Therefore, this should not confound the results so that they could not be compared to other data.

APPENDIX

SCATTERPLOTS OF CORRELATIONS

Figure A.1

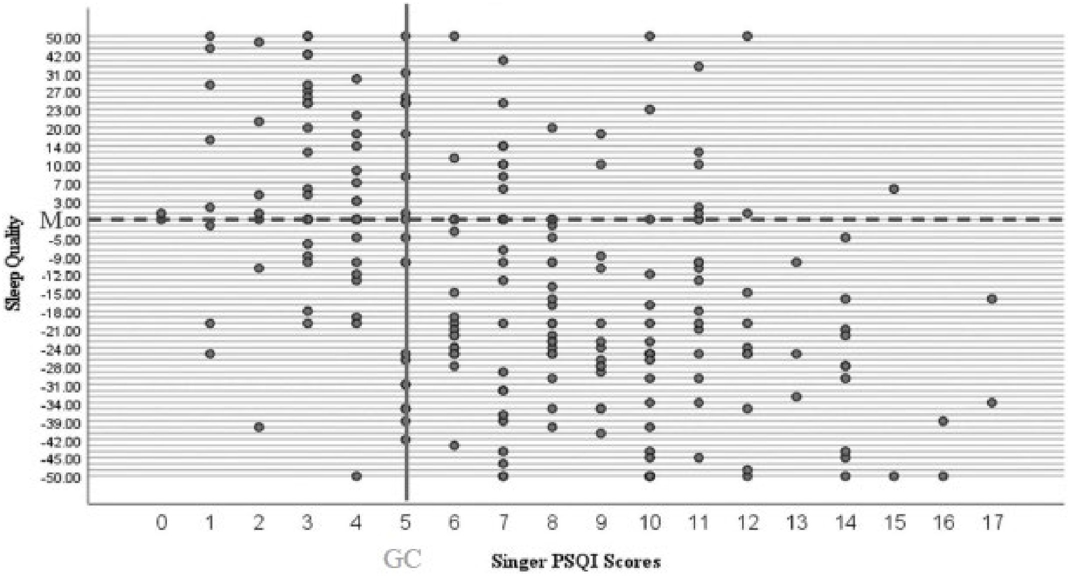
Scatterplot of SVHI-10 Score and ESS Score Totals



Note. The horizontal, dotted line (M) shows Sobol's "normative value" (approximately at 8.38) for the SVHI-10. The vertical, solid line represents the normal range (0 to 10) for the ESS.

Figure A.2

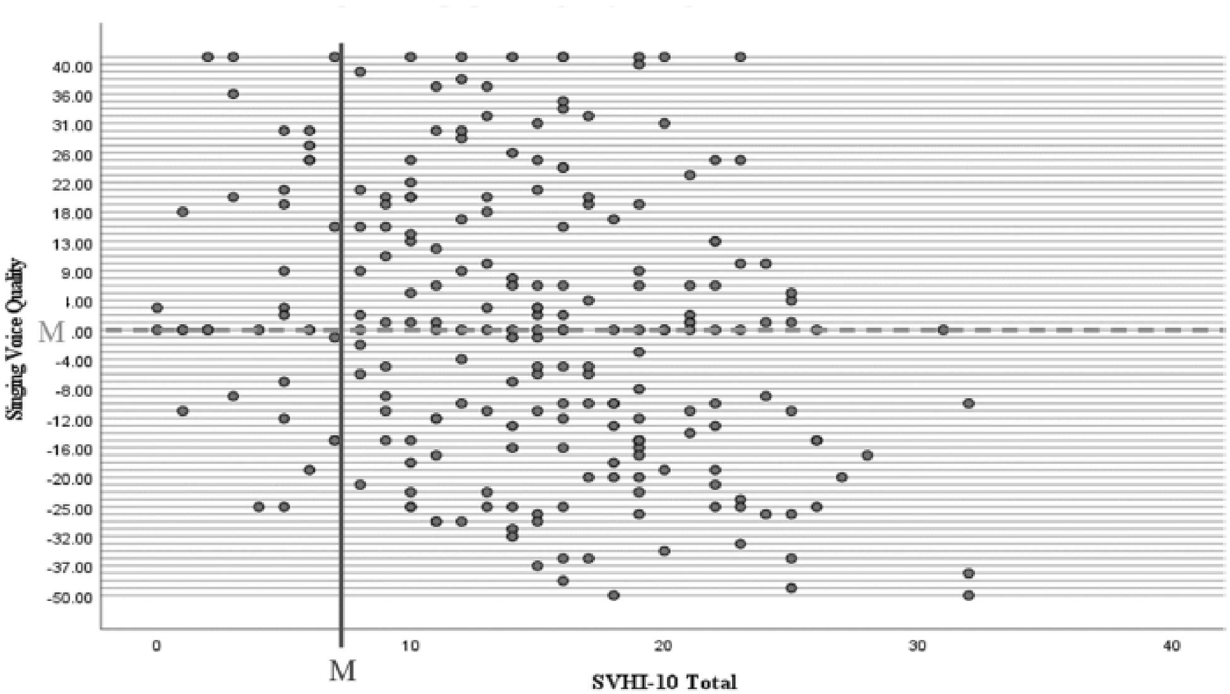
Scatterplot of Sleep Quality by Singer PSQI Scores



Note. The horizontal, dotted line bifurcates the graph for sleep quality into better and worse hemispheres at the No Change rating of 0. The vertical solid line bifurcates the graph for the PSQI into better and worse hemispheres at the Global Cutoff score of 5.

Figure A.3

Scatterplot of Singing Voice Quality Ratings and SVHI-10 Score Total



Note. The horizontal dotted line bifurcates the graph for singing quality into better and worse hemispheres at the No Change rating of 0. The vertical solid line M shows the "normative value" (approximately at 8.38) for the SVHI-10.

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