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DOES PERCEIVED LONELINESS AMONG OLDER ADULTS

PREDICT SLEEP QUALITY AND EXECUTIVE FUNCTIONING

DURING THE COVID-19 PANDEMIC?

By

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Abstract

Due to the COVID-19 pandemic, feelings of loneliness may have been exacerbated by social isolation mandates, especially among older adults. Previous studies show that loneliness is associated with poor sleep quality among older adults, as well as lower cognitive performance. While the associations between perceived loneliness, sleep problems, and poor cognitive functioning have been established independently, few studies focus on these associations in combination and in the context of the COVID-19 pandemic, particularly among older adults ages 60 and over. Thus, the present study aims to first examine the relationship between subjective sleep quality and cognitive functioning, and then investigate whether levels of perceived loneliness relates to subjective sleep quality and subjective cognitive functioning. Specific sleep quality components were also used as reference measures for subjective sleep quality. Older adult participants completed an online survey that assessed these components during the lockdown mandate, where subjective sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI) and executive function performance was self-evaluated using the BRIEF-A (The Behavior Rating Inventory of Executive Function–Adult Version™). Upon linear regression analyses, perceived loneliness was significantly correlated to perceived global executive functioning, but not significantly correlated to subjective sleep quality. Further research is needed to establish clear associations between reduced loneliness, improved sleep quality, and improved executive function, while evaluating the consequences of the COVID-19 pandemic on mental health and well-being. Emotional support in relationships may help to mitigate loneliness and developing sleep-based cognitive interventions may be especially beneficial for older adults.

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Introduction

Since the onset of quarantine and confinement during the COVID-19 pandemic, social isolation was encouraged to reduce the spread of the coronavirus. This was especially true for older adults who had to limit contact with others to avoid exposure to COVID-19, as they were one of the most vulnerable populations susceptible to developing severe illness globally (Berg-Weger et al., 2020; Grossman et al., 2020; Pires et al., 2021). Consequently, older adults may also have been at greater risk of experiencing feelings of loneliness due to social isolation (Müller et al., 2021; Shankar et al., 2013) congruent with aging-related role transitions, changes in health status, and societal views such as ageism (Smith et al., 2020). Therefore, on top of age-related physical and social changes, perceived loneliness among older adults was exacerbated as they became more at risk for social isolation by limiting physical interactions with others in order to protect themselves from COVID-19 exposure.

Loneliness is an important measure of subjective well-being among older adults (VanderWeele et al., 2012). Feelings of loneliness, or perceived loneliness, can be defined as the subjective feeling of isolation, not belonging, or lacking companionship, and as opposed to objective analyses of social isolation, the subjective distress of loneliness can be a more significant indicator of an individual's quality of life (Perissinotto et al., 2012). Also, in a recent study with German older adults, the subjective state of feeling lonely was weighed more heavily in relevance to limited socialization due to COVID-19 than the objective state of being isolated (Müller et al., 2021). Thus, feelings of isolation and individual impressions of loneliness are significant to understanding individual well-being.

Among older adults, loneliness is positively associated with lower cognitive function and sleep problems, respectively (Boss et al., 2015; Jia & Yuan, 2020). Although negative

associations have been established between loneliness and improved objective sleep quality and cognitive performance, simultaneous associations using subjective measures of sleep quality and executive function–in relation to perceived loneliness yielded inconsistent results, and remains unclear (Brewster et al., 2015; Yu et al., 2018). In addition, few studies focus on assessing these relationships among older adults using subjective measures during the COVID-19 pandemic. The goal of the present study is to link sleep quality with executive functioning, and investigate how perceived feelings of loneliness may relate to subjective sleep quality and executive functioning among older adults during the COVID-19 physical distancing mandate. Links between sleep quality, executive functioning, and loneliness have been established as follows:

Many studies link overall sleep quality with executive functioning such that higher sleep quality is positively correlated to higher executive functioning (Lo et al., 2014; Zavecz et al., 2020). Thus, it is important to define associations between specific parameters or components of sleep quality with specific domains of cognition (Brewster et al., 2015). The previous study concludes that while there was a relationship between decreased sleep quality in terms of objective sleep efficiency and worsened executive function; subjectively, there was no association; and overall, there were inconsistent relationships between cognition and specific sleep parameters. This literature emphasizes the significance in identifying certain sleep components to target for reducing the risk of cognitive change with aging.

In addition to the sleep efficiency component of the PSQI, relationships between specific sleep parameters and cognitive performance have been established. In healthy older adults, cognitive decline is associated with decreased sleep efficiency, increased sleep latency or time taken to fall asleep, and short sleep duration (Brewster et al., 2015; Haimov & Shatil, 2013; Lo et al., 2014). Due to increased attention regarding the contribution of subjective sleep quality on

cognition in the past few decades, and based on the inconclusive evidence presented on the relationship between subjective sleep quality and cognitive performance, the present study investigates subjective sleep quality, in relation to overall executive functioning, as well as perceived loneliness (Brewster et al., 2015; Nebes et al., 2009; Zavecz et al., 2020).

Sleep quality is inversely related to both loneliness and social isolation, though these effects occur independently (Yu et al., 2018). In a study comparing subjective loneliness and sleep quality scores among identical twins, differences in loneliness were significantly associated with differences in sleep quality, where the lonely twin experienced significantly more sleep problems in terms of subjective sleep quality and daytime dysfunction (Matthew et al., 2017). The results of these findings suggest significant associations between loneliness and poor sleep quality, specifically subjective sleep quality for the present study. Additionally, longitudinal studies suggest that loneliness may affect health through short sleep as well as other sleep problems, illustrating that loneliness can affect specific sleep problems in both the short-term and long-term (Shankar, 2020). Using the UCLA Loneliness Scale to assess loneliness and the PSQI to assess sleep quality, a negative correlation was found between loneliness and sleep quality among Chinese rural older adults (Jia & Yuan, 2020).

Studies show links between sleep and the COVID-19 pandemic, associating sleep disorders such as sleep apnea with COVID-19-related aspects in young adults, but there is not a lot of original research focusing specifically on the older adult population in this regard (Pires et al., 2021). In the previous study, social isolation and home confinement due to the COVID-19 pandemic directly contributed to impact sleep, while loneliness additionally influenced sleep quality. This helps to illustrate that older adults experience sleep problems not only because they are socially isolated, but because they feel socially isolated (Cho et al., 2019). Although older

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adults may experience objective social isolation due to COVID-19, individuals can have worse

sleep quality symptoms when they experience subjective isolation in addition to objective social

isolation. Thus, it is postulated that loneliness is associated with sleep quality to some degree.

Decreased cognitive functioning is associated with increased loneliness (Boss et al.,

2015). In a longitudinal study involving older adults, linear regression analyses showed that there

was a relationship between isolation and poor cognitive performance, but also loneliness and

cognition, as well, where loneliness was associated with delayed and poorer immediate recall

(Shankar et al., 2013). Although relationships have been established between loneliness and

cognitive performance, it is still unclear as to what variables actually associate with subjective

executive functioning scores, which can provide valuable information about real-world

difficulties experienced by the individual (Brewster et al., 2015; Meltzer et al., 2017). In a study

among older adults with Autism Spectrum Disorder (ASD), patients were well aware of their

difficulties with daily executive functioning in agreement with their relatives, demonstrating the

clinical relevance of the BRIEF-A survey to assess executive function among older adults, as

well as those individuals with ASD (Davids et al., 2016).

During the lockdown and physical distancing period, individuals experienced mental

health and well-being consequences such as depression and loneliness. Associations have been

made between social isolation and loneliness with regard to decreased cognitive functioning, as

well as increased mortality, and increased risk of Alzheimer's Disease (Müller et al., 2021). In

the previous study, while there was no relationship between depressive symptoms and being

isolated but not feeling lonely, results showed significant associations between feeling lonely but

not being isolated, and being both lonely and isolated. Thus, perceived loneliness during the

COVID-19 pandemic may not only affect individual well-being in terms of cognitive function

performance, but can also be associated with mental health. Previous studies reinforce the

significance of using subjective analysis to measure executive functioning and predict

depression, as well as, the importance of studying the old age population because they were

heavily impacted by the pandemic (Boss et al., 2015; Cho et al., 2019; Müller et al., 2021).

Significance of the Present Study

Loneliness may further affect older adults due to the COVID-19 pandemic. By complying

to physical distancing restrictions and quarantine to limit exposure to the coronavirus, older

adults in the community are more at risk for social isolation and loneliness. This was especially

true for older adults already experiencing disconnectedness and loneliness prior to the

COVID-19 pandemic (Smith et al., 2020). According to the COVID-19 Social Connectivity

Paradox, older adults are especially prone to risk, because as levels of social interaction increase,

there is higher risk for COVID-19 infection; and with decreased social interaction levels, there is

higher risk for social isolation, limited connectivity, and impacted loneliness (Smith et al., 2020).

Therefore, it is important to mitigate risk for severe illness from infection, while also minimizing

risk for social isolation and loneliness to prevent detrimental outcomes regarding subjective

well-being and mental health, especially with older individuals as vulnerability increases with

aging populations.

The present study highlights the associations between perceived loneliness and subjective

sleep quality, as well as perceived loneliness and overall subjective executive functioning. By

examining the established relationship between sleep quality and cognitive functioning, the

relationships between these variables in respect to feelings of loneliness can be investigated.

Although it was found that both objective and subjective social isolation are associated with

sleep problems among older adults, literature concludes that many sleep problems experienced

by the older adult population may not only be attributed to being physically withdrawn from social networks, but can also be influenced by feeling socially isolated (Cho et al., 2019; Yu et al., 2018). Based on the relationship between sleep quality and cognitive functioning, perceived loneliness due to social isolation and home confinement may negatively impact subjective sleep quality and executive functioning among older adults.

Few studies focus on the concurrent relationships between loneliness, sleep quality, and executive functioning in the older adult population, specifically with consideration to well-being and mental health outcomes of the COVID-19 pandemic. Since perceived isolation, or loneliness, was associated with sleep problems, as well as lower cognitive function, loneliness may predict and lead to lower subjective well-being (Boss et al., 2015; Smith et al., 2020; VanderWeele et al., 2012; Yu et al., 2018). Thus, the present study aims to associate subjective sleep quality and subjective executive functioning, then predict both subjective sleep quality and executive functioning using subjective measures of loneliness, and finally provide additional context for subjective well-being among older adults in future studies.

Many studies and growing research demonstrate the individual links between components that contribute to individual well-being. It was originally anticipated that lower levels of perceived loneliness would be associated with higher subjective quality and higher overall executive functioning, where subjective sleep quality is also positively correlated to executive function. However, there is still no clear relationship established simultaneously between feelings of loneliness, subjective sleep quality, and executive functioning. Therefore, the significance of the present study encourages continuous emotional and social support to be provided for older adults during the COVID-19 pandemic and periods of social isolation in order to reduce feelings of loneliness, highlights the importance of quality sleep maintenance

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especially in regard to subjective sleep quality, and reinforces the value in identifying related sleep parameters for use in further research that may utilize sleep-based cognitive interventions.

Methodology

Participants

In the present study, participants included a total of 140 older adults ages 60 and over who resided in the Inland Empire (including the Riverside and San Bernardino Counties) (81.4% Female, 18.6% Male; M_{age} = 68.09, SD_{age} = 6.73). Four out of 144 individuals did not complete the study questionnaire and thus, have been omitted from the present study to maintain equal sample size across all measures. Additional inclusion criteria consisted of being fluent in English, retaining normal or corrected-to-normal vision, and having no prior history of mild cognitive impairment (MCI), dementia, or Alzheimer's Disease. Participants in the community completed an online survey during the COVID-19 pandemic. The survey included measures such as the Pittsburgh Sleep Quality Index (PSQI) to assess their sleep quality, the UCLA Loneliness Scale to measure perceived loneliness, and the BRIEF-A (The Behavior Rating Inventory of Executive Function–Adult Version™) to assess subjective executive functioning. A combination of these secondary measures were used for data analysis using IBM® SPSS® software.

Measures

The PSQI is a self-rated questionnaire used to measure sleep quality in clinical populations as well as research, and can assess whether individuals are considered good or poor sleepers based on the sum of their component scores (Buysse et al., 1989; Nebes et al., 2009). There are 7 components that make up the global PSQI score including: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleeping medication, and (7) daytime dysfunction, respectively. Each component

contains a range of 0 to 3 points, totaling to a global score of 0 to 21 points, where a higher global score indicates worse sleep quality. In the present study, component use of sleeping medication was excluded as a potential variable, and respective component scores of the PSQI increased as sleep quality increased. Items 1, 3, and 10 from the PSQI have been omitted from the assessments, so habitual sleep efficiency was also not analyzed. The focus of the present study was primarily on Component 1: subjective sleep quality, examining how individuals would rate their sleep quality overall during the past month from 0 (very good) to 10 (very bad).

The revised UCLA Loneliness Scale is composed of 20 questions that can be used to assess perceived loneliness, or loneliness as a distinct psychological experience (Russell et al., 1980). Each item was rated from 1 (strongly disagree) to 8 (strongly agree), to make up a global loneliness score between 20 and 140. In the present study, 9 out of 20 items such as "I feel in tune with the people around me" were reverse scored for analysis, so that each item was subtracted by 8, and higher scores related to increased feelings of loneliness experienced by the individual.

Subjective executive functioning measured by global BRIEF-A scores were analyzed in the present study to examine whether there was a direct relationship between subjective cognitive performance and perceived loneliness. The BRIEF-A questionnaire is also based on a self-informant report scale, measuring various domains of executive function, which can be utilized to understand the associations between specific domains of executive function and everyday behaviors for adults ages 18 to 90 (Roth et al., 2005). The BRIEF-A is divided into two indexes: Behavioral Regulation Index (BRI) and Metacognition Index (MI), in which subscales such as inhibit, shift, emotional control, and self-monitor make up the BRI; and MI comprises of subscales initiate, working memory, plan/organize, task monitor, and organization of materials.

Because individual items are less reliable relative to the scales, the present study includes a combination of 8 clinical scales, excluding emotional control, to consist of 65 questions that make up the BRIEF-A. This is called the global BRIEF-A score–a composite of the executive functioning scores for each scale. Participants rated each question from 1 (never) to 8 (very often), and global BRIEF-A scores for each participant were used for analysis.

Data Analysis

In order to assess the relationships between perceived loneliness with subjective sleep quality and cognitive functioning in older adults, individual simple linear regression analyses were performed. Descriptive statistics and bivariate correlations were collected for 3 individual linear regression analyses through SPSS®. Participants were first filtered by age so that the year of birth fits the inclusion criteria–before 1962, and only those who finished all three assessments were included in this study.

Bivariate correlations were conducted for regressions. Components of BRIEF-A Z-Scores were transformed into T-Scores and also compiled into a global BRIEF-A T-Score. Two-tailed correlations revealed that subjective sleep quality scores had small association with global executive functioning composite scores of the BRIEF-A. A significant, negative relationship was found at the 0.01-significance level for a 2-tailed distribution ($r = -.345$, $p = .000$). Bivariate correlation analyses also involved composite executive function scores using global BRIEF-A T-scores and variables created for other specific components of the PSQI such as sleep duration ($r = -.342$, $p < .001$), sleep latency ($r = .279$, $p = .001$), sleep disturbances ($r = .459$, $p < .001$), and daytime dysfunction ($r = -.145$, $p = .088$). There was no significant correlation between perceived loneliness and daytime dysfunction and associations that were significant were found at$\alpha = 0.01$.

By creating a variable using the reversed loneliness scores and adding up the total, global perceived loneliness scores can be associated with sleep quality. There was no significant correlation between perceived loneliness and subjective sleep quality (r = .034, p = .693), as well as between loneliness and each of the 5 specified PSQI components, having omitted habitual sleep efficiency and use of sleeping medication.

Linear regressions were performed between global scores of perceived loneliness and executive functioning. A two-tailed test revealed that perceived loneliness had a significant but small correlation to global executive functioning scores at α= 0.05 (r = .197, p = .020). Significant, weak correlations from loneliness scores to T-scores for BRIEF-A components shift and self-monitor were also found at the 0.05 level, while components plan/organize and task monitor were significantly correlated at levels whereα= 0.01.

Results

A linear regression model was used to assess the simultaneous relationships between subjective sleep quality and subjective executive functioning, perceived loneliness and subjective sleep quality, and perceived loneliness and subjective executive functioning. SPSS® analyses using measures such as the BRIEF-A, PSQI, and UCLA Loneliness Scale showed that there was a significant correlation between subjective sleep quality and composite executive function performance; no significant correlations between perceived loneliness and subjective sleep quality; and a significant correlation between perceived loneliness and executive functioning, as well as BRIEF-A components shift, self-monitor, plan/organize, and task monitor. The present study reaffirms that there is inconclusive evidence for association between loneliness and sleep quality, as well as loneliness and executive function performance, and posits the need for further studies to be implemented to define those subjective links with regard to social isolation.

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Descriptive statistics in Table 1 show that among 140 older adults, subjective sleep quality was measured between a minimum of 1 and a maximum of 10 for the PSQI item, "During the past month, how would you rate your sleep quality overall? – slide the mark," where the mean was 6.83 with a standard deviation of 2.19. For overall executive functioning, the mean global score for the BRIEF-A among the participants was 46.84 ± 8.17. Overall perceived loneliness displayed a minimum global score of 61.68 and a maximum score of 93.65, where the mean was 74.36 ± 4.89.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
During the past month, how would you rate your sleep quality overall? – slide the mark	140	1.00	10.00	6.8286	2.19202
TBRIEF_Global_Functioning	140	39.92	88.45	46.8344	8.16993
Perceived_Loneliness_Global	140	61.68	93.65	74.3574	4.88683
Valid N (listwise)	140				

Table 1. Descriptive statistics displaying minimum and maximum scores, as well as respective means and standard deviations for subjective sleep quality, subjective overall executive functioning, and feelings of loneliness.

Relationship Between Sleep Quality and Executive Functioning

In order to perform two-tailed bivariate correlations, a scatter plot was first created to verify the linearity of the relationship between subjective sleep quality and executive functioning (Figure 1). The plot portrays that there may be a weak, negative relationship between subjective sleep quality (higher Component 1 PSQI scores) and global executive functioning (R^2 = .119), so simple linear regression was conducted after expressing the strength of association. The fitted regression model was: Global Executive Functioning = 55.62 - 1.29*(Subjective Sleep Quality).

The overall regression was statistically significant for a 95% confidence level or 5% significance level ($r = .345$, $F(1, 138) = 18.69$, $p < .001$). Subjective sleep quality significantly predicted global executive functioning among older adults during COVID-19 (= -.345, $t = -4.32$, $p < .001$). However, subjectively sleep quality was inversely associated with global executive functioning scores. As subjective sleep quality increased, global executive functioning scores decreased.
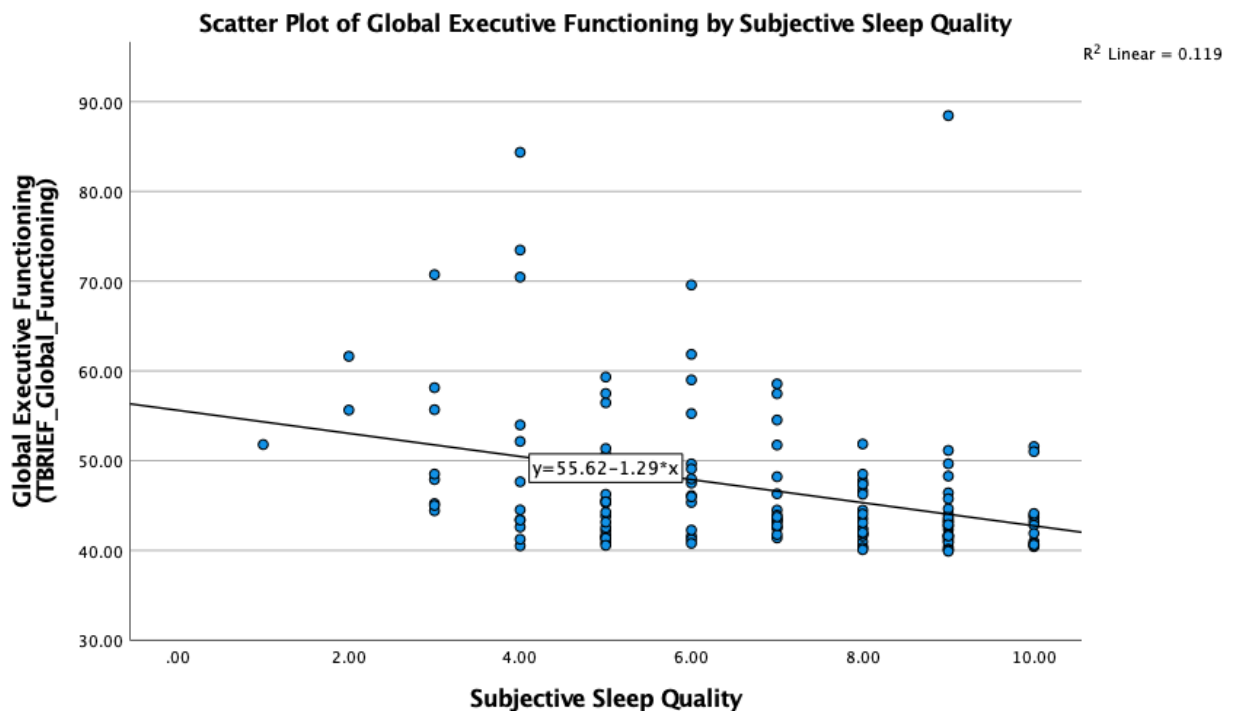

Figure 1. Scatter plot with fitted line to visualize potential correlation between subjective sleep quality and global executive functioning among older adults ages 60 and over. The coefficient of determination, R^2, is equal to 0.119 and N = 140.

In addition, significant correlations were found between global executive functioning and individual components of the PSQI such as sleep duration, sleep disturbances, and sleep latency, excluding daytime dysfunction, using independent regression analyses. Between sleep duration and executive functioning, the overall regression was statistically significant ($r = .342$, $R^2 = .117$, $F(1, 138) = 18.23$, $p < .001$). Sleep duration ($M = 6.77$, $SD = 1.24$) significantly predicted global

executive functioning scores (β = -.342, t = -4.27, p < .001). Sleep latency (M = 30.34, SD = 28.61) showed low association to executive function performance (r = .279, R^2 = .071, F(1, 138) = 11.69, p = .001) and significantly predicted global executive functioning scores (β = .279, t = 3.42, p = .001). Sleep disturbances (M = 7.64, SD = 4.66) had a significant, moderate correlation with global executive functioning scores (r = .459, R^2 = .210, F(1, 138) = 36.74, p < .001) and significantly predicted them (β = .459, t = 6.06, p < .001). Daytime dysfunction (M = 7.62, SD = 2.07) did not significantly predict global executive functioning scores (β = -.145, t = -1.72, p = .088).

Relationship Between Loneliness and Sleep Quality

Simple linear regression was used to see if there was a relationship between sleep quality and loneliness. Results showed that for 140 older adult participants, subjective sleep quality was not significantly correlated to perceived loneliness (r = .034, R^2 = .001, F(1, 138) = .156, p = .693). The fitted regression equation was: Subjective Sleep Quality = 5.71 + 0.02*(Perceived Loneliness). Perceived loneliness did not significantly predict subjective sleep quality scores (β = .034, t = .395, p = .693). When simple linear regressions were performed to see if there was a relationship between loneliness and other specific components of the PSQI, there were no significant results.

Relationship Between Loneliness and Executive Functioning

A simple linear regression model was used to assess how loneliness and executive functioning are related to each other, where perceived loneliness is the predictor and global executive functioning is the outcome variable. A weak, significant association was found where loneliness was positively correlated to executive functioning (r = .197, R^2 = .039, F(1, 138) = 5.58, p = .020). The fitted regression equation was: Global Executive Functioning = 22.32 +

0.33*(Perceived Loneliness). Figure 2 depicts a normal probability plot of residual distribution, where there is a slight skew from normal distribution shown in the P-P plot. It was found that perceived loneliness can significantly predict executive function performance (β = .197, t = 2.36, p = .020).
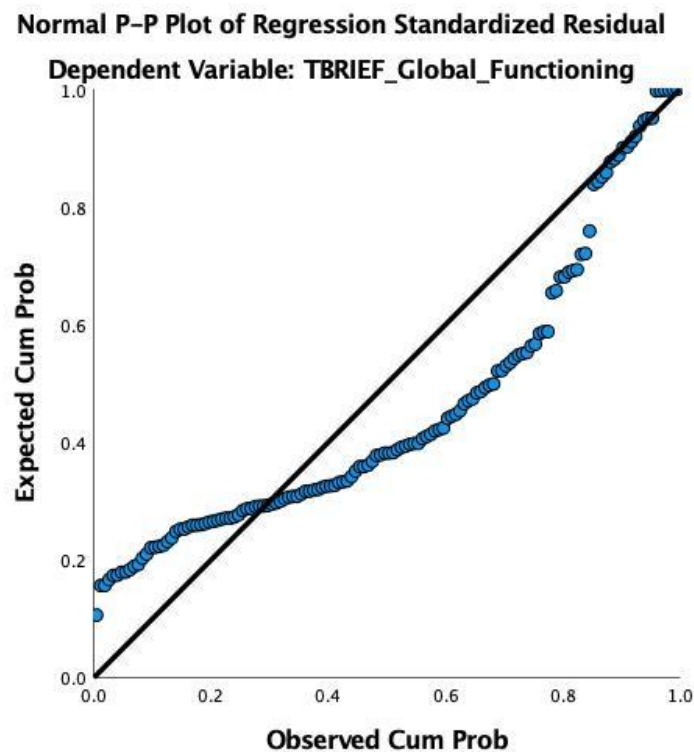

Figure 2. Simple linear regression normal probability plot showing approximate distribution of the data set, where the predictor variable is perceived loneliness and the outcome variable is global executive functioning. High probability density is observed near the center of the distribution.

Upon testing associations between perceived loneliness and specific components of the BRIEF-A, components shift (*M* = 46.47, *SD* = 7.65), self-monitor (*M* = 47.81, *SD* = 8.19), plan/organize (*M* = 47.38, *SD* = 8.54), and task monitor (*M* = 47.18, *SD* = 7.93) had independent significant correlations with global perceived loneliness at levels where α= 0.05. Feelings of loneliness were best correlated to the shift component (β = .281, t = 3.44, p = .001), then self-monitor (β = .236, t = 2.86, p = .005), then plan/organize (β = .204, t = 2.45, p = .016), and

then task monitor (β = .187, t = 2.24, p = .027). On the other hand, there was no significant association between global scores measuring feelings of loneliness and T-scores for BRIEF-A components inhibit (*M* = 47.01, *SD* = 8.46), initiate (*M* = 46.74, *SD* = 7.70), working memory (*M* = 47.29, *SD* = 8.64), organization of materials (*M* = 47.76, *SD* = 7.68) at α= 0.01. Components inhibit (β = .162, t = 1.93, p = .056), initiate (β = .122, t = 1.45, p = .151), working memory (β = .164, t = 1.95, p = .053), and organization of materials (β = .118, t = 1.40, p = .165) were not significantly predicted by by perceived loneliness at the chosen alpha level.

Discussion

Of the 5 PSQI components tested, subjective sleep quality, sleep duration, sleep latency, and sleep disturbances had small, significant associations to overall executive functioning. Sleep disturbances had the strongest association out of the components tested (r = .459), followed by subjective sleep quality (r = .345). Analysis shows that subjective sleep quality is a significant predictor of executive functioning. However, these results should be read with caution because the negative association between global executive function scores and subjective sleep quality scores is contrary to literature, where some studies found no association and some research shows positive correlation (Brewster et al., 2015; Meltzer et al., 2017; Zavecz et al., 2020). In addition, subjective sleep quality, duration, latency, and disturbances were significant but not effective predictors of executive function performance.

The present study shows that there was no significant relationship between feelings of loneliness and sleep quality, including subjective sleep quality, among older adults during the COVID-19 pandemic. In young adults, subjective sleep quality and daytime dysfunction were associated with perceived loneliness (Matthew et al., 2017). Thus, further research can be

implemented to clarify inconsistencies in the relationship between subjective sleep quality, as well as specific sleep components, with perceived loneliness for older adults in the community.

Lastly, the implications of these findings show that perceived loneliness was significantly correlated to executive functioning. However, this association was very low, and Figure 2 portrays that there is a deviation among residuals toward the center of the plot. Relationships were established between feelings of loneliness and specific components of the BRIEF-A, where components shift, self-monitor, plan/organize, and task monitor portrayed significant associations to global loneliness scores.

Although the preliminary findings of this study suggest various significant associations, there are several limitations to this research that should be considered. Subjective sleep quality was not an effective predictor of subjective executive functioning, and subjective executive functioning was not an effective predictor of perceived loneliness. It was originally predicted that with higher subjective sleep quality, or other PSQI component scores, participants would have higher overall executive functioning scores. Upon analyses, some of these associations were negative, indicating that some components may not have been reversed or sized to scale relative to the other components. Another source of error could be that not all of the components of the PSQI were included in the present study, creating high risk for bias among specific components tested. For instance, it would be easier to observe accurate main and interaction effects when reference can be made relative to participants' actual global PSQI scores. Also, although the BRIEF-A is a valid measure of subjective executive function performance, the BRIEF-A only minimally represents objective executive functioning scores when observed by performance-based measures (Meltzer et al., 2017).

Another limitation to this study is that associations between perceived loneliness, subjective sleep quality, and executive functioning were only assessed during the COVID-19 pandemic. Thus, associations were not compared between the consecutive waves of the COVID-19 pandemic, where there may have been an early or delayed impact. If this study were to be completed again, these associations should be assessed before the start of social isolation, during, as well as after this time period to control for the contribution of social isolation on loneliness, sleep quality, and executive functioning. Additional filters could have been included in the study to control for covariates that might affect the subjective variables in question such as depressive symptoms, medical conditions, employment status, and living situation. Much larger sample sizes should also be utilized for analysis to control for gender and demographics in order to produce more accurate results. Finally, only subjective measures were used in the present study. The use of both subjective and objective measures of sleep quality and executive functioning domains are encouraged to be able to compare them and have a better understanding of their discrepancies (Brewster et al., 2015; Cho et al., 2019; Yu et al., 2018).

In order to reduce loneliness, insomnia, and other sleep problems in older adults during the COVID-19 pandemic, it is important for older adults to practice physical distancing while minimizing social isolation, and for social and emotional support to be provided for their mental health and well-being (Berg-Weger et al., 2020; Pires et al., 2021). If the COVID-19 pandemic returns, maintaining quality sleep, staying connected and engaging in social interactions within safety measures, as well as increasing emotional support in relationships may help to mitigate loneliness and especially benefit older adults. It may also be helpful for older adults to participate in sleep-based cognitive interventions. Future studies can observe associations among loneliness and executive functioning by pairing those who participated in the intervention and those who

did not participate but participated in filling out the assessments. Scores can also be compared throughout the COVID-19 pandemic to investigate whether older adults' engagement in cognitively-stimulating activities prior to quarantine predicts their objective and subjective sleep quality, during or after the pandemic.

Sleep-based cognitive interventions may be beneficial for older adults to engage in social activities and further research to establish clear associations between subjective feelings of loneliness, subjective executive functioning, and subjective sleep quality (Jia & Yuan, 2020). Cognitive training interventions can help to not only associate these factors, but can also help to provide comparisons between objective and subjective measures, while also resulting in individual improvements in sleep quality and cognitive function performance (Haimov & Shatil, 2013). Older adults who participated in an intense learning intervention prior to the COVID-19 pandemic learned multiple new skills simultaneously and obtained increased levels of cognitive abilities in terms of improved working memory, cognitive control, and episodic memory relative to their baseline scores, in comparison to the group who did not participate in the intervention (Leanos et al., 2020). Of the 140 participants included in the present study, 43 older adults were part of this cognitive learning intervention prior to the COVID-19 pandemic. Secondary analyses of sleep quality and loneliness may be potentially significant for objective and subjective measures of executive functioning through sleep-based cognitive interventions and learning interventions, especially for older adults during the COVID-19 pandemic.

Conclusion

The significance of the present study portrays that it is important to reduce levels of loneliness in older adults, especially at times of social isolation such as quarantine during the COVID-19 pandemic (Berg-Weger et al., 2020; Grossman et al., 2021; Smith et al., 2020). In

order to promote the mental health and well-being of these individuals, it is important to understand loneliness and sleep quality, and loneliness and executive function. Although there is a fundamental association between subjective sleep quality and executive function, this relationship was not confirmed in the present study. Nonetheless, previous studies show the significance in understanding these parameters to investigate feelings of loneliness. There was no significant relationship between feelings of loneliness and subjective sleep quality, however, there was a small, significant association between feelings of loneliness and subjective executive functioning. It can be impactful for future research to design cognitive interventions to assess subjective variables such as perceived loneliness and subjective sleep quality in relation to objective scores, and for the surrounding community to engage in building emotionally-supportive relationships with older adults.

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