Sleep quality during the COVID-19 pandemic and High frequency- heart rate variability as a moderator: A longitudinal study

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Abstract

Sleep Quality during the COVID-19 Pandemic and High Frequency- Heart Rate Variability as a Moderator: A longitudinal Study

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A growing body of literature describes the effect of the confinement during the COVID-19 pandemic on sleep quality and duration. Sleep quality seems to be worsening during the confinement for vulnerable individuals, but seems to be improving for others with less rigid school and work schedules. High frequency heart rate variability (HF-HRV) has been conceptualized as a biomarker of vulnerability to stress-related sleep disturbances. The goal of this study was to investigate the effect the confinement on sleep quality, sleep efficiency, and sleep duration and to investigate HF-HRV as an individual difference in sleep reactivity to confinement. One hundred and fifty participants (M_{age} = 50.62, SD = 6.0) completed the Pittsburg Sleep Quality Index (PSQI) at the beginning of the confinement, about a month later, and at the end of confinement period of the first wave of the COVID-19 pandemic in Montreal, Canada. HF-HRV was collected few years prior to the onset of the pandemic. Results from hierarchical linear models demonstrated a curvilinear effect for sleep duration and sleep quality with poorer sleep quality and less sleep duration a month into confinement compared to the beginning of the confinement, followed by improved sleep quality and greater sleep duration during the deconfinement period; whereas sleep efficiency linearly decreased over time. Financial stress predicted between-person differences in PSQI scores at the beginning of the confinement, but HF-HRV did not predict within-person changes in PSQI scores. These results highlight the importance of providing sleep interventions to individuals and families affected by the pandemic.

TABLE OF CONTENTS

List of Tables

List of Figures

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On March 11th, 2020, the World Health Organization declared the novel coronavirus disease (COVID-19) a pandemic after declaring it a public health emergency of international concern on January 30, 2020 (World Health Organization, 2020). Due to the COVID-19 pandemic, confinement measures were put in place to limit the spread of the virus. Billions of people across Canada and the world were forced to stay at home. Individuals were obliged to work and teach their children from home, minimize or completely avoid social contact with individuals outside their household, maintain a 2 metres distance between individuals outside of home, limit non-essential travel, wash hands frequently using soap or alcohol-based disinfectant, practice proper cough and sneeze etiquette by covering mouth and nose with arm, and isolate if sick (Gouvernement du Quebec, 2020; Public Health Agency of Canada, 2020). Some individuals, such as health care workers, had to work for more hours under stressful situations while being exposed to the coronavirus. Even though confinement measures are important in reducing the spread of the virus, the resulting social isolation can be stressful to many individuals and contributes to negative emotional outcomes (Grossman et al., 2021; Jahrami, BaHammam, AlGahtani, et al., 2020; Wu & Wei, 2020).

When facing confinement measures due to COVID-19, sleep is an important factor to examine due to its many benefits for mental and physical health. For instance, sleep is very much involved in emotion regulation (Goldstein & Walker, 2014), and sleep loss is associated with impairments of attention, alertness, and memory and is also associated with subjective reports of irritability and emotional volatility (Horne, 1985). Accumulated sleep loss and restrictive sleep lead to an amplification of negative emotions, an increase in subjective reports of stress, anxiety, and anger in response to low-stress disruptive daytime experiences (Minkel et al., 2012; Zohar et al., 2005). Moreover, sleep enhances immune defences by altering inflammatory responses which promote host defences, and accordingly, sleep disturbances lead to increased inflammation at the expense of antiviral immune responses (Irwin, 2019). Hence, individuals with compromised sleep during the pandemic will be at a greater risk of developing long-term negative health outcomes, and might be more vulnerable to the SARS-Cov-2 virus infection the virus (Morin, Carrier, et al., 2020). Hence, the following literature review will focus on the impact of the confinement of the first wave of COVID-19 on sleep.

Since the beginning of the COVID-19 outbreak, researchers have conducted observational cross-sectional studies to examine sleep quality during lockdown where non-essential businesses were shut down and confinement measures, such as staying at home and keeping social distance, were mandated. These studies measured the sleep quality during confinement using self-reported surveys, which included validated and homemade questionnaires. Other researchers have explored the effect of the lockdown on sleep quality using longitudinal studies with pre-pandemic data, while other longitudinal studies explored how sleep changes over time during the pandemic. Examining the change in sleep quality across these different study designs is important to make proper inferences on the impact of the COVID-19 related confinement directives on sleep quality.

Sleep Timing

Sleep timing refers to the time an individual usually goes to bed (Harrex et al., 2018). In a cross-sectional Canadian sample of 5,500 individuals, Robillard and colleagues' (2021) identified three profiles of sleep-related behaviours during the COVID-19 pandemic using current and retrospective assessment: the first subgroup, the extended time in bed subgroup, characterized by no significant change in bedtime and significantly later wake-up times than before the pandemic, leading to a longer time in bed; the second subgroup is the reduced time in bed subgroup characterized by later bedtimes and earlier wake-up times, leading to a shorter time in bed and total sleep time; and the last subgroup is the delayed sleep subgroup characterized by later bedtimes and later wake-up times, leading to a small lengthening of time in bed and the prevalence of longer sleep onset latency. Even though over half of their sample had sleep difficulties during the pandemic, these data suggest that the pandemic may have heterogenous effects on sleep (Robillard et al., 2021).

In a longitudinal Spanish study that assessed sleep pattern changes in nursing students at pre- (January 2020) and during lockdown (April 2020), researchers found both bed time and wake-up time to be delayed during the lockdown (Romero-Blanco et al., 2020). A longitudinal Chinese study using crowdsourced smartphone-measures sleep data to examine sleep duration before (December 2019) and during confinement (January-March 2020) reported longer sleep during weekdays, but not weekends (P. H. Lee et al., 2020). In the United States, researchers assessed sleep duration during the confinement by asking participants to report on average, the hours of sleep they get in a 24h period. More individuals reported having shorter sleep (less than 7 hours of sleep a night) in 2020 than 2018 (40.7% vs. 34.0%, respectively), or exceeding the National Sleep Foundation's recommendations for sleep duration (greater than 9 hours of sleep a night) during the first month of the confinement when compared to a comparative sample (n = 19,000) who reported sleep duration before the pandemic, in 2018 (7.4% vs. 4.2%, respectively) (Hisler & Twenge, 2021). In another longitudinal study with a Chinese sample, participants who completed the PSQI at baseline (2019, before the pandemic) and during the pandemic reported increase in sleep duration, $M_{before} = 7.7$ vs. $M_{during} = 8.4$, $d_p = 0.64$ during the pandemic (Zheng et al., 2020). Thus, it seems that confinement has a heterogenous effect on sleep timing and duration, with longer sleep for some and shorter for others.

Sleep Efficiency

Sleep efficiency refers to the amount of total time in bed actually spent sleeping, and is calculated as sum of Stage N1, N2, N3, and REM sleep (total sleep time, TST) divided by the total time in bed (TIB, i.e., time span that begins with the initial attempt to fall asleep and ends when the individual finally wakes up or stops attempting to sleep), then multiplied by 100 to get a percentage (Palesh et al., 2014; Reed & Sacco, 2016; Shrivastava et al., 2014; Spielman et al., 1987). Sleep efficiency gives a sense of how well an individual slept, but it does not distinguish between frequent or brief episodes of wakefulness at night or long sleep latency. Hence, a low sleep efficiency percentage could result from long sleep latency, that is the duration of time an individual takes to fall asleep after lights are out (difficulties initiating sleep), and long sleep offset to lights (time that the individual awakens) with normal sleep quantity and quality. It could also result from awakenings during the night (total wake time after sleep onset in minutes) whether it be spent in or out of bed, or early morning awakenings, that is waking up earlier than desired and being unable to go back to sleep (Reed & Sacco, 2016; Palesh et al., 2014; Shrivastava et al., 2014; Spielman et al., 1987). Improvement in self efficiency is the gold standard for evaluating insomnia treatment efficacy and used to direct and implement sleep restriction therapy. Hence, we will be using research on insomnia symptoms as a proxy for sleep efficiency (Palesh et al., 2014; Reed & Sacco, 2016; Spielman et al., 1987).

Insomnia symptoms include one or more of the following: difficulties initiating sleep, problems staying asleep, or early morning awakenings (Morin, Jarrin, et al., 2020). In a recent meta-analysis that assessed sleep problems, defined as poor sleep quantity and quality, the pooled prevalence rate of sleep problems reported across studies using the Insomnia Severity

Index (ISI) among the general population was found to be 29.7% during the COVID-19 pandemic (Jahrami, BaHammam, Bragazzi, et al., 2020). In another meta-analysis that assessed sleep disturbances using a mix of clinical interviews, self- and clinician-rated screening tools/questionnaires found that the pooled prevalence of sleep disturbances, defined as sleep initiation or maintenance disorders, disorders of the sleep-wake schedule, poor sleep quality and/or other sleep impairments evaluated using interviews and questionnaires, was 34% during the COVID-19 pandemic. However, the pooled prevalence rate of sleep disturbances assessed by the ISI alone used by three studies was 43% (Deng et al., 2020). Individuals who have lower educational level, lower socioeconomic status (SES), worry more about being infected by the virus, are females, shift workers, health care workers, or isolated are at a greater risk of developing insomnia symptoms due to the confinement (Ferini-Strambi et al., 2020; Zhang et al., 2020).

A study of a representative sample of 1,005 participants of the French population found that 74% of participants reported having sleep problems, and 50% of them reported that these problems worsened since the lockdown, as assessed by a homemade sleep items (e.g., *Have you been having trouble sleeping in the past 8 days? If yes: Have these problems increased since the lockdown?*) (Beck et al., 2020). In a study conducted in China, researchers observed that 13.6% of participants developed new-onset insomnia, as assessed with a score over 7 on the ISI during the confinement, despite reporting prolonged time in bed and total sleep time assessed by homemade questions (Y. Li et al., 2020). Pinto and colleagues (2020) used a cross-sectional design to assess sleep difficulties, such as difficulties falling asleep, frequent awakenings during the night, and waking up too early in the morning, using the Jenkins Sleep Scale through a telephone survey in Portuguese respiratory patients during the lockdown from March to April

2020. Seventy percent of participants reported having at least one sleep difficulty, with unemployment during home confinement being the main predictor of sleep difficulties (Pinto et al., 2020). Another Chinese study investigated the sleep status at the third day of the 14 days of isolation in a sample of 14,500 participants with varying isolation status. The medically isolated population was defined as participants who were infected, suspected to be infected, had been exposed to infected or suspected to be infected with the coronavirus, or who have visited areas of high epidemic severity during the outbreak in February 2020 (Xue et al., 2020). Seventy six percent of the medically isolated sample reported difficulty falling asleep at least once over the past week and 79.5% reported having an early morning awakening at least once over the past week. These individuals had higher prevalence of sleep disturbances than both the non-medically isolated, those who reported self-isolating but did not meet the four conditions of medical isolation, and the control group, those who did not report isolating (Xue et al., 2020). A Canadian sample of 5,500 individuals completed the PSQI to identify changes in subjective sleep patterns, and clinically meaningful sleep difficulties was assessed using the Quick Inventory of Depressive Symptomology (QIDS-SR16) (defined by a score of at least two on the first item of QIDS-SR16 reflecting sleep initiation difficulties: "I take at least 30 minutes to fall asleep, more than half of the time," and a score of 3 on the second and third items of the QIDS-SR16 reflecting sleep maintenance difficulties and early morning awakenings, respectively: "I awaken more than once a night and stay awake for 20 minutes or more, more than half of the time" and "I awaken at least 1 hour before I need to, and can't go back to sleep") between early April and end of June 2020. About 33% of responders endorsed clinically meaningful difficulties in sleep initiation, 28% reported clinically meaningful difficulties in sleep maintenance, and 14% endorsed clinically meaningful early morning awakenings (Robillard et al., 2021).

Longitudinally, Salfi and colleagues (2020) assessed sleep quality and insomnia severity using the PSQI and the ISI, respectively across the course of confinement in an Italian sample. Individuals reported worse sleep disturbances as reported by higher values of ISI at the third week of confinement than at the eighth week of confinement (Salfi et al., 2020). A Chinese study of 2,009 undergraduate students assessed anxiety using the General Anxiety Disorder-7 and insomnia symptoms, using the ISI at baseline, from their first year of university which was two months after entering university, and during the lockdown in February 2020. These researchers found the prevalence rate of insomnia symptoms to be 12.5% before the lockdown which increased to 16.9% during the lockdown (Ge et al., 2020). Moreover, U.S. adults were asked to report the number of days in the past week they had (1) trouble falling asleep, (2) trouble staying asleep, and (3) waking up feeling rested in 2018 (prior to the pandemic) and a month into the confinement; the number of U.S. adults reporting difficulties falling and staying asleep nearly doubled a month into the confinement compared to pre-pandemic (Hisler & Twenge, 2021). In an Italian longitudinal study that examined changes in sleep during the confinement using the PSQI found that sleep efficiency, the ratio between time in bed and actual sleep time, was worse a month in the confinement than at deconfinement (Alfonsi et al., 2021). In sum, it seems that insomnia symptoms have increased and sleep efficiency has worsened during the pandemic based on retrospective accounts and longitudinal studies, and with time, these symptoms seem to be decreasing as individuals start adjusting to the new reality.

Perceived Sleep Quality

Perceived sleep quality is referred to the subjective meaning of good sleep which can refer to the subjective ease of waking up, clear-headedness and how rested, refreshed and restored one feels upon waking (Harvey et al., 2008). In a recent meta-analysis conducted by Jahrami and colleagues (2020), the prevalence of sleep problems, assessed using the PSQI alone in the general population and health care workers since the beginning of the pandemic, was found to be high at 39.6%. In another meta-analysis conducted by Deng and colleagues (2020) that assessed sleep disturbances using the PSQI alone in three studies found the pooled prevalence of sleep disturbances to be 19%. In a Chinese studies, medical staff reported poor sleep quality with an average PSQI value of 8.6, higher than that of the general Chinese population during the confinement, average PSQI of 7, d = .35 (Xiao et al., 2020a). Similarly, individuals who were isolating themselves from other individuals in the same household due to contracting the virus, and who were forced, by law, to stay in their own space such as their room, reported poor sleep quality, with an average score of 8.48 on the PSQI (Xiao et al., 2020b), compared to individuals who were not self-isolating. In a Canadian sample, 6% of the population reported clinically meaningful improvements in the global sleep quality of the PSQI during the pandemic (Robillard et al., 2021) where the prevalence of poor sleep quality among Canadians prior to the pandemic is around 50% (Rich et al., 2020).

This paragraph examines longitudinal studies with pre-pandemic data to examine the effect of the confinement on sleep quality. In a longitudinal study in a Chinese sample, participants who completed the PSQI at baseline (2019, before the pandemic) and during the pandemic reported increase in sleep duration, $M_{before} = 7.7$ vs. $M_{during} = 8.4$, $d_p = 0.64$ and 37% of participants reported poorer sleep quality during the pandemic (Zheng et al., 2020). The number of U.S. adults reporting days where they were not feeling rested was substantially greater in 2020, during confinement, than in 2018 (Hisler & Twenge, 2021). Researchers have also assessed sleep quality using a single item adapted from the PSQI a month into the lockdown in a

Scottish sample of 1,091 84-year olds from the Lothian Birth Cohort 1936 (Okely et al., 2021). In comparison to data taken between 2014 and 2017, sleep quality did not change significantly during the lockdown (Okely et al., 2021). In an American sample of 699 adults, researchers assessed sleep quality, measured by the PSQI, stress-related sleep disturbances, measured by the Ford Insomnia Response to Stress Test (FIRST), and daytime sleepiness, measured by the Stanford Sleepiness Scale, pre- (February 2020) and during lockdown (in late-March, 2 weeks of confinement) (Gao & Scullin, 2020). Participants also answered questions that focused on their COVID-19 experiences which include social interactions, increase in responsibility, adverse life impact, and an increase in worry or stress. Gao and Scullin (2020) found that on average non-shift workers' sleep health improved during the confinement which could be explained by the reduction in rigid work and school schedules, with only 25% of participants' PSQI scores worsened. Sleep quality was more likely to worsen if an individual had a higher FIRST score, if they are shift workers, if the pandemic had an adverse life impact, or if their workload or responsibilities increased due to the pandemic (Gao & Scullin, 2020). Thus, individuals who are most affected by the pandemic are reporting poor sleep quality during the pandemic in comparison to before whereas others', such as non-shift workers, sleep quality is not changing or improving during the pandemic.

In the following paragraph, longitudinal studies using data during the pandemic will be examined to understand the long-term effect of the confinement on trajectory of sleep quality with time. Longitudinally, Martinez-de-Quel and colleagues (2021) assessed sleep quality using the PSQI in Spanish university students two days after the state of emergency was issued and five days after these measures have eased. Participants reported higher sleep disturbances during the confinement (M= 7.2, SD= 3.9) than before the confinement (M= 6.2, SD= 3.5, d_p = .27)

(Martínez-de-Quel et al., 2021). However, another study that examined sleep quality, using the PSQI, of university students in Spain before the lockdown, 20 days, and 40 days after the lockdown was initiated, showed that sleep quality worsened during the confinement. Seventy percent of the sample showed poor sleep quality after 20 days, almost twice as much as before confinement (37%), and (68%) remains to show poor sleep quality at 40 days of confinement (Martínez-Lezaun et al., 2020). In another Spanish study, participants completed the PSQI at 2 weeks after exams (January 2020) and 4 weeks after the start of the lockdown (April 2020), where these students had not left their homes in a month (Romero-Blanco et al., 2020). The PSQI global score at the second timepoint increased from 5.51 to 6.42, $d_p = .3$, indicating worsening sleep quality during the lockdown. Despite an increase in the number of hours spent in bed, sleep efficiency, the ratio between time in bed and actual sleep time, declined during the lockdown as students took longer time to fall asleep (Romero-Blanco et al., 2020). Salfi and colleagues (2020) found that individuals reported worse sleep disturbances at the third week of confinement than at eighth week of confinement. In another Italian sample, PSQI global score decreased significantly at post-lockdown than during the lockdown, indicating improved sleep quality (Alfonsi et al., 2021). In another study of 50,000 adults residing in the United Kingdom, researchers explored the relationship between worries about adversity and experience of adversity due to the pandemic and quality of sleep, which was measured using a single item "over the past week, how has your sleep been," in the early weeks of lockdown in the United Kingdom. Participants completed the survey weekly from April 1st (one week after the lockdown commenced) to May 12th (Wright et al., 2020). These researchers found that greater number of experience of adversities and worries, especially worries about the inability to pay bills, accessing food or medication, and catching COVID-19 were associated with poorer sleep quality

(Wright et al., 2020). Thus, sleep difficulties are high at the beginning of the confinement and is associated with experience of adversities and worry during the pandemic, but seem to decrease as individuals become accustomed and adjust to the new lifestyle.

Cross-sectional studies suggest a point-prevalence of insomnia disorder of about 30% based on the ISI, with insomnia symptoms being more prevalent in health care and shift workers. As for sleep quality, cross-sectional studies report a prevalence of poor sleep quality of about 40% using the PSQI. Longitudinal studies using pre-pandemic data suggest that sleep quality worsened during the pandemic, compared to pre-pandemic levels, showing a large effect using the validated PSQI. On the other hand, conflicting findings show that elderly's sleep quality did not change from periods of pre-confinement to during the confinement, but this conclusion should be interpreted with caution since sleep quality here was measured using a single item taken from the PSQI (Okely et al., 2021). In line with these findings, researchers have concluded that the rest of the population seem to have poorer sleep quality during the beginning of the confinement as measured by validated scales, but the effect is small. Longitudinal studies using data during the pandemic show that sleep quality and sleep efficiency worsened among individuals with financial problems, those who worry contracting the virus, or those who are isolated, despite an increase in sleep duration and time in bed. Research findings have shown that the prevalence rate of sleep disturbances was quite high (60-70%) at the beginning of the confinement (Martínez-Lezaun et al., 2020). However, empirical data shows that with time and as some of these individuals become accustomed to their new way of living, their sleep quality improves and their sleep difficulties start to decrease. Moreover, and contradictory to the evidence presented earlier, some longitudinal data show that the confinement has been beneficial to some individuals, such as students and those who are non-shift workers, where the loosening of rigid work hours and flexible school schedules have improved their sleep health, specifically their sleep quality, measured using the validated PSQI scale. Hence, it seems that there are quite conflicting findings that show 1) sleep quality worsens during the confinement with weaker evidence for the general public, 2) confinement will only have detrimental effects on an individual's sleep if the confinement has affected their life negatively and increased their worries and responsibilities, so 3) university students' sleep quality might improve during the confinement and that of elderly might not be affected. As such, the confinement seems to have a heterogenous effect on individuals' sleep quality.

Stress and Sleep

Stress, due to the confinement, may be associated with poor sleep quality (Reeth et al., 2000). Conceptual models of insomnia suggest that individuals with sleep disturbances experience increased physiological and cognitive-emotional arousal at rest and/or in response to stress that interfere with sleep onset and maintenance (Drake et al., 2014; Riemann et al., 2010). Laboratory studies have shown that exposure to acute laboratory stressors such as giving a speech (Hall et al., 2004) or watching aversive films (Bkeland et al., 1968) before sleep leads to delayed sleep onset latency, lower sleep efficiency. In an observational, longitudinal study, researchers assessed participants' sleep and stress levels over a span of 2 weeks through both objective and subjective measures (Winzeler et al., 2014). Participants were given an ambulatory wrist actigraphy that detects sleep-wake cycles to wear for 2 weeks and daily diaries and self-report measures to complete assessing sleep quality and daily stress. Participants completed subjective sleep quality question each morning after rising, and the Pre-sleep Arousal Scale and Daily Stress Inventory every evening before bedtime. Additionally, participants completed the

PSQI twice, once before the beginning of the study period and once at the end of the study period (Winzeler et al., 2014). In their study, participants who experienced high levels of daily stress reported experiencing high levels of somatic pre-sleep arousal and worse sleep quality. On days where these participants experienced above-average stress and cognitive arousal relative to their own mean, they reported worse subjective sleep quality (Winzeler et al., 2014). Morin and colleagues (2003) assessed sleep and stress for 3 weeks in a French-speaking sample of insomniacs and good sleepers. Global and retrospective measures of stress and coping were assessed by the Life Experience Survey, Perceived Stress Scale, and the Coping Inventory for Stressful Situations. Sleep and pre-sleep arousal was assessed through daily sleep diary and the Pre-Sleep Arousal Scale completed upon rising each morning, and daily stress was assessed by the Daily Stress Inventory completed before going to bed for a total of 3 weeks (Morin et al., 2003). Both insomniacs and good sleepers had comparable minor daily stressors; however, insomniacs experienced these stressors with a higher intensity, viewed their lives as more stressful, relied more on emotion-focused coming strategies, and reported higher levels of pre-sleep arousal than did good sleepers. Their findings also provide evidence of an association between daily stress and sleep that is mediated by pre-sleep arousal (Morin et al., 2003). Similarly, Åkerstedt and colleagues (2012) assessed sleep through the Karolinska sleep diary that participants completed upon awakening, and stress through rating their stress every three hours a day and answering an item that assessed their stress/worries at bedtime over a period of 6 weeks. The results indicate that participants who reported stress and worry at bedtime experienced poor sleep quality across 42 days, and that stress levels during the day affected sleep quality only if they were maintained up to bedtime (Åkerstedt et al., 2012). Thus, individuals experience poorer sleep at night if they had reported more stress than the usual during the precedent day and at bedtime (Åkerstedt et al., 2012; Morin et al., 2003; Winzeler et al., 2014).

There are different pathways through which the lockdown can lead to sleep problems. One explanation is that feelings of loneliness and perception of lacking a supportive network of individuals and the absence of social connectedness can promote an alert state, i.e., increase in stress, worry, hypervigilance, and rumination, in turn creating sleep difficulties (e.g., Cacioppo & Hawkley, 2009; Grossman et al., 2021; Kurina et al., 2011). Confinement involves a loss of usual routine, reduction in social and physical contact with others which may lead to boredom and frustration and may lead to sleep disturbances (Brooks et al., 2020; Shen et al., 2018). In a cross-sectional study, researchers have found that people have been using their electronic devices more, and are spending more time on social media to stay connected with others during the confinement than a week before (Cellini et al., 2020). On a behavioural level, using electronic devices especially before bedtime can induce a state of alertness and is linked to shorter sleep duration, longer sleep onset latency, and an unrestful sleep (Cellini et al., 2020; Hysing et al., 2013, 2015; Léger et al., 2020). Additionally, researchers have speculated that frustration and boredom may lead to the extensive use of electronic devices and social media, which could be problematic especially if the content exposed to is related to the pandemic, which might lead to greater fear and worry (Léger et al., 2020). Another pathway of developing sleep problems is through shifting one's circadian rhythm. During confinement, many individuals have shifted their schedules, as they are going to bed and waking up at later hours, and are less exposed to daylight, which may disrupt their circadian rhythm (Cellini et al., 2020; Morin, Carrier, et al., 2020; Zakay, 2014). These changes in lifestyle can disturb night-time sleep (Altena et al., 2020; Zakay, 2014).

Not all individuals will respond the same way to these stressors or develop sleep problems in response to stress. Individual differences exist in sleep-reactivity, i.e., the tendency to experience sleep disturbances following sleep challenges such as stress (Drake et al., 2011). Physiological arousal at rest, such as increase in heart rate, blood pressure, cortisol, and body temperature (Bonnet et al., 2014; Bonnet & Arand, 2010) and in response to stress (Massar et al., 2017) have been associated with the onset and maintenance of sleep disturbances. High frequency-heart rate variability (HF-HRV) has been conceptualized as a biomarker of vulnerability to stress-related sleep disturbances (Gouin et al., 2014). HF-HRV is a measure of variability in the time intervals between consecutive heart beats as a result of parasympathetic activity via the vagus nerve. Specifically, the heart is dually-innervated at the sinoatrial node of the heart by fast-acting inhibitory parasympathetic influence, maintaining an intrinsically slower heart rate, and by concomitant slower-acting excitatory sympathetic influence. Dominant parasympathetic influence at the heart is temporarily gated by inspiration, resulting in rapid fluctuations of its inhibitory effect and producing variations in timing of consecutive heart beats (Berntson et al., 1997).

Greater resting HF-HRV is conceptualized as a marker of stronger top-down inhibitory capacity of the prefrontal cortex and better ability to self-regulate, including better emotion regulation (Laborde et al., 2018). Resting HF-HRV has been considered a fairly stable trait-like biomarker for cardiovascular health, cognitive, and emotional functions (Bertsch et al., 2012; Brunoni et al., 2013; Z. Li et al., 2009). Individuals with low resting HF-HRV and excessive HF-HRV reactivity to emotional stressors were at increased risk for current and future sleep disturbances and insomnia disorder. Resting HF-HRV has been positively associated with sleep quality in cross-sectional studies (Castro-Diehl et al., 2016; Jackowska et al., 2012). In an experimental study in which good sleepers were exposed to stressors before bedtime across four different nights, those with low resting HF-HRV were more likely to experience sleep disturbances than those with high resting HF-HRV (Bonnet & Arand, 2003). In another study, mothers with lower resting HF-HRV were more susceptible to experiencing stress-related sleep disturbances in response to chronic stress than their counterparts with higher resting HF-HRV (da Estrela et al., 2020). Longitudinal studies have also shown that greater reductions in HF-HRV in response to stress during a low-stress baseline assessment predicted increases in sleep disturbances during a period of high academic stress (Gouin et al., 2015; MacNeil et al., 2017). Hence, individuals with lower resting HF-HRV and greater HF-HRV reactivity to stress are more vulnerable to stress-induced sleep disturbances.

When facing confinement measures due to COVID-19, sleep is an important factor to examine due to its many benefits for mental and physical health (Medic et al., 2017). To our knowledge, there seems to be a lack of longitudinal research that assess the effect of the confinement, a stressful period, on sleep while also examining HF-HRV as an individual difference in sleep reactivity to confinement. We hypothesize that sleep efficiency would improve over time, being the worst at the beginning of the confinement and then improving a month in and during the beginning of the deconfinement period when confinement measures became less strict. Sleep duration would also decrease with time, especially during the beginning of the deconfinement period as businesses start opening up and work schedules go back to normal. Accordingly, and with time, the total PSQI score would decrease with time as sleep quality starts improving. We also hypothesize that individuals who have lower resting HF-HRV would be at a higher risk of developing sleep problems and would report lower sleep quality and sleep efficiency, and higher sleep disturbances during confinement.

Methods

Participants

Participants were recruited from a sample of 222 participants who were involved in the Transition study at the Stress, Interpersonal Relationships, and Health laboratory of Concordia University. The transition study participants were mothers of adolescents who either have neurodevelopmental disorders (intellectual disability or autism spectrum disorder) or are typically developing adolescents. These participants had to be living within 50 kilometers of Concordia University and had to be speaking either French or English fluently. Participants were excluded from the transition study if they were pregnant or nursing, had a chronic medical condition that would alter physiological markers of stress (e.g., an individual undergoing chemotherapy or immunotherapy), used medication with anti-inflammatory properties on a regular basis, had a severe mental illness (such as schizophrenia, bipolar disorder, or substance use), or if they smoked. Some chronic medical conditions were accepted, and these include the following: hepatitis B, Irritable Bowel Syndrome (IBS), hypoglycemia, ADHD, asthma, sinusitis, anxiety, depression, fibromyalgia, hypothyroidism, hyperthyroidism, migraines, Chron's, celiac disease, hypertension, cholesterol, vertigo, glaucoma, and osteoarthritis.

Of the Transition study sample, 150 participants, i.e., 67% of the parent study agreed to participate in the current study: all participants were females, $M_{age} = 50.62$ ($SD = 6.0$), 50.7% were mothers of an adolescent with disability, 74% of them identified as White, 47% of the sample reported obtaining a Bachelor's degree or higher, and 24% reported having a chronic medical condition (e.g., heart or lung disease, hypertension, or diabetes). The COVID-19 study's participants were not significantly different than those who did not participate in the study across age $t(220)= -.26$, $p= .80$, ethnicity $t(220)= -.26$, $p= .79$, or education level $t(220)= 1.29$, $p=.20$. Twenty-two percent of the participants dropped out of the study before completing follow up assessments. These participants were not different than those who remained in the study on their demographic such as age $t(145)$= -e.08, $p= .94$, ethnicity $t(146)$= -.1.13, $p= .259$, education level $t(146)=.633$, $p=.528$, children with or without disability $t(148)= -.69$, $p= .49$, chronic health condition $t(146)= -1.24$, $p=.22$, or pre-pandemic Time 1 PSQI total score $t(136)= -.06$, $p= .95$.

Procedure

Participants received an invitation email to complete a survey about their psychological responses to the COVID-19 pandemic during the first week of confinement in March 2021. Once consent had been obtained, participants received a link to complete the survey. They were contacted again to complete the same survey at two other time-points: end of April and end of June, which marks a month into confinement and during the deconfinement period, respectively. At the end of April, confinement measures were still in place, while at the end of June, non-essential businesses such as restaurants, museums, and retail businesses had reopened, and face covering was made mandatory along with physical distancing measures (Rowe, 2020). At each assessment, participants had two weeks to complete the survey which included demographic questionnaires and the Pittsburgh Sleep Quality Index (PSQI). Participants were compensated $20 for each survey. Baseline HF-HRV was collected before the beginning of the pandemic from 2014-2018 in either the laboratory or at participants' homes.

Measures

High frequency heart rate variability (HF-HRV) was measured during the 5-minute resting baseline. Electrodes were fitted on participants in a Lead II position by a trained research assistant. Electrocardiograph (ECG) data were acquired with a Mindware BioNex 8-slot chassis. Participants' heart-rate was recorded continuously at a sampling rate of 1000 Hz throughout the laboratory visit. ECG recordings were visually inspected to identify and correct recording artifacts and then analyzed using MindWare Analysis and CardioEdit softwares. HF-HRV was then calculated using Cardiobatch software, which employs Porges-Bohrer moving polynomial calculation method by applying a 0.12-0.40 Hz frequency band filter which isolates heart-rate variability tied to the typical adult respiration cycle (Cacioppo & Tassinary, 1990; Denver et al., 2007). HF-HRV values were calculated in 30-second epochs and averaged to compute a single HF-HRV at rest for each participant. Another method of calculating HF-HRV is using spectral frequency components of integrals of power spectrum density over specific bands, namely Fast Fourier Transform which applies a 0.15-0.40 Hz frequency band filter and its power spectra is calculated with the method of Welch Periodogram (Badilini et al., 1998, 2000).

Adjusted-Pittsburgh Sleep Quality Index (PSQI): sleep quality was measured using an 18-item scale that produce seven subscales including sleep quality, sleep duration, sleep latency, habitual sleep efficiency, sleep disturbance, use of sleep medications, and daytime dysfunction. The instructions were altered to the past week instead of the past month to capture changes in sleep quality during the confinement period. Each of these dimensions were scored from 0-3 producing a total score ranging from 0-21 with higher total score indicating worse sleep quality. The clinical cut-off score for significant poor sleep quality and presence of a sleep disorder is a global PSQI score greater than 5 (Buysse et al., 1989).

The PSQI is considered to be a subjective measurement of sleep quality. Subjective measures of sleep are self-assessments whereby individuals report their sleep that usually differs from actual sleep structure which can be measured objectively (Åkerstedt et al., 2002; Buysse et al., 1991; O'Donnell et al., 2009). Sleep diaries and single or multi-item sleep questionnaires, such as the PSQI, are the two commonly used instruments for subjective sleep assessment (Mallinson et al., 2019). Subjective reports of sleep quality are important in clinical settings as they help determine whether further screening is required for a diagnosis, to diagnose, and to determine treatment for the sleep complaint (Åkerstedt et al., 2002). Subjective measures are efficient, practical and address subjective sleep quality, and research has shown that these measures can be comparable to objective sleep measures among healthy adults; however participants, especially elderly and those with poor health might underestimate their total sleep time and sleep duration and are more likely to overestimate their night awakenings and sleep latency (Kushida et al., 2001; Mallinson et al., 2019; Sadeh, 2011). On the other hand, objective measures give a more accurate representation of sleep patterns. Sleep recordings at night, such as recordings of sleep architecture, the amount of wake during sleep, frequency and duration of awakenings, and total duration of sleep using polysomnography (PSG) or actigraphy are examples of objective sleep measurements (Kushida et al., 2001). However, in-lab sleep duration may not be the same as in-house sleep since PSG might interfere with sleep, and both PSG and wearables do not capture sleep quality, as the concept itself is subjective (Mallinson et al., 2019).

Adherence to Physical Distancing Measures: was assessed at the first timepoint by a homemade questionnaire including seven questions; *In the past week, to what extent have you been able to follow social distancing recommendations*: *Avoid direct contact when you greet someone, such as shaking hands, hugging or kissing the cheeks; In public, outside of home, standing 2 metres of other people; at any time, standing at least 2 metres away of people who sneeze or cough or seem sick; avoid social gathers with multiple individuals; minimizing contact with other people by staying at home; minimizing non-essential travels outside home; not having* *visitors.* The answers ranged from 1 to 5 with 1 being "almost always" and 5 "never." A mean of the following 7-items was created, and a higher number indicated less adherence to physical distancing measures; scores ranged from 1 to 3. Cronbach alpha for this measure is good at 0.71.

Other Covariates

The covariates that could explain the associations among the predictors (time and HF-HRV) and sleep and that are included in the current study include age, ethnicity (0 "White ethnicity" and 1 "other"), education level (0 "primary education," 1 "some high school," 2 "high school degree," 3 "completed CEGEP," 4 "some university education," 5 "undergraduate degree," 6 "Master's degree," 7 "Doctoral degree"), participants' health condition (*Do you have a chronic medical condition (e.g., heart or lung disease, hypertension, diabetes)?* 0 "yes" and 1 "no"), financial stress (*In the past week, how worried were you about your finances?* 0 "not at all," 1 "a little," 2 "some," 3 "a lot"), mothers of children with disability (0 "yes," and 1 "no"), and adherence to physical distancing measures. All of these variables are assessed using one question as part of the demographic questionnaire except for the adherence to physical distancing measures which was assessed by six questions. As individuals age, their sleep becomes more fragmented and sleep quality worsens (Fox et al., 2018; Madrid-Valero et al., 2017; Middelkoop et al., 1996). Low educational levels and non-white ethnicities are also associated with poor sleep quality (Patel et al., 2010; Zhang et al., 2020). Individuals reported poorer sleep quality in months of greater financial stress (Galambos et al., 2011), and those whose income has been reduced also reported poor sleep quality (Wright et al., 2020). Similarly, poor chronic health conditions and poor sleep quality are associated, and researchers point to a bidirectional relationship between sleep and chronic health conditions whereby chronic health conditions result in poor sleep quality and sleep disturbances can also contribute to the development of, or increase the severity of various medical and psychiatric conditions (Zee & Turek, 2006). Thus, individuals with chronic health conditions, income changes (reduction) and financial stress due to the pandemic are more likely to worry about catching the virus (Wright et al., 2020; Zee & Turek, 2006) and are in a more alert state, which may lead to greater sleep disturbances and poorer sleep quality. Similarly, caregiver stress and adherence to the physical distancing measures can be very stressful to individuals and can also lead to poor sleep quality (da Estrela et al., 2020; Gao et al., 2019; Giallonardo et al., 2020; Wright et al., 2020; Yu et al., 2018). However, the study included more moderators such as household income, COVID-19 restrictions that are impacting individuals, perception of or exposure to the virus, income change during COVID-19, alcohol and drug consumption, social contact, social support, marital status, and exercise.

Data Analysis

The independent variable of the current study is time across the confinement period (beginning of confinement, one month into confinement, and the end of the first confinement period), and the dependent variables are PSQI total score, sleep duration, and sleep efficiency. HF-HRV is the moderator in this study. Data was analyzed using hierarchical linear modeling (HLM), which not only captures how variables change over time, but also how these changes are associated with between and within-persons differences. These models are best used when the assumption of independence is violated, which is the case of repeated measures where data comes from the same individual over time (Shirtcliff & Essex, 2008). Unlike other statistical models, HLM does not require time-structured data, which means all cases are tested at the same intervals (Kline, 2011). This analysis would help understand how sleep quality, sleep duration, and sleep efficiency vary over time and the moderating role of HF-HRV while accounting for autoregressive effects. Main models included “Time” (Time 1 - beginning of confinement, Time

2 – about 4 weeks into confinement, and Time 3 - during deconfinement) as a predictor variable and PSQI scores as the dependent variable in Level 1. In this model, the intercept was centered at the beginning of the confinement and represents PSQI scores at Time 1. The time slope referred to the within person change in PSQI scores over time. HLM is similar to multiple regression analysis where it takes any covariates in the model and controls for their effects as it extracts the unique variance associated with each covariate. The two parameters (intercept and slope) thus become the outcome variables in the level 2 model, where they can be associated with the unique variance of a series of independent variables. As such, the level 2 model captures the between-person variability in the different parameters (intercept and slope) and examines what factors might account for this variability. Level 2 model included "HF-HRV" and study covariates (age, financial stress, education level, ethnicity, caregiver status, chronic health, and adherence to physical distancing measures). Both the study covariates and HF-HRV served as the stable between-person predictors over the course of the study predicting PSQI intercept at baseline. Cross-level interactions between the between-person variables and time were also examined. Significant interactions were interpreted using simple slope analyses. Preliminary data analysis indicated that there was no random effect for the slope; therefore, only the fixed effects for the slope were estimated. Missing data was handled by applying reduced maximum likelihood, and analyses were conducted with the PROC MIXED function in SAS version 9.3.

Results

Preliminary Analyses

Assumptions for repeated measures analyses were checked using visual inspection and statistical tests. The non-significant Mauchley's test with a Greenhouse-Geisser value of 0.979 and a Huynh-Feldt epsilon of 0.997, indicated that the assumption of sphericity was met.

Homogeneity of variance and homogeneity of covariance matrices assumptions were also met with a non-significant Levene's test and Box's test of equality of covariances, respectively. Upon visual inspection of the spread of the variables and examining Mahalanobis distance, no participants were considered to be outliers as they do not seem extreme relative to all other scores in the distribution. To check for normality, the spread of the dependent variables was visually inspected (subscales of the PSQI and the total scores across all three timepoints) using histograms and P-P plots. All variables were positively skewed and their Shapiro-Wilk test of normality was significant indicating a non-normal distribution. A log transformation was applied to normalize the distribution. However, when running the analyses with and without the log transformation, the same trends in the results were found. Hence, we decided to use the non-log transformed variables since they do not alter PSQI values and render the PSQI scores interpretable. A correlation matrix for the main variables of the study is presented in Table 1, and descriptive statistics for the main variables of the study are found in Table 2.

Main Analyses

PSQI Total Scores

The results of the HLM analyses are reported in Table 3. The PSQI total score intercept of the Level 1 model was significant, suggesting that the average PSQI total score at Time 1 was different from zero. The analysis also showed a non-significant linear effect for the within-person time slope, but a significant curvilinear effect for the within-person time slope indicating that PSQI total scores increase in scores from Time 1 to Time 2 followed by a decrease in scores from Time 2 to Time 3 (See Figure 1). HF-HRV values were not significantly associated with PSQI intercept. No significant effect of HF-HRV for the within-person PSQI total score slope was obtained, suggesting that within-person changes in PSQI total scores over time were not significantly associated with HF-HRV scores. Results indicated that of the covariates, only financial stress predicted the PSQI intercept with an estimate of 1.02. Participants who reported higher financial stress during the beginning of the pandemic had a higher PSQI total score at Time 1. However, financial stress did not predict changes in PSQI total scores over time.

PSQI Sleep Duration

The results of the HLM analyses for sleep duration are reported in Table 4. The PSQI sleep duration score intercept of the Level 1 model was significant, suggesting that the average PSQI sleep duration scores at Time 1 was different from zero. The analysis also showed a non-significant linear effect for the within-person time slope, but a significant curvilinear effect for the within-person time slope indicating that PSQI sleep duration scores increase in scores from Time 1 to Time 2 followed by a decrease in scores from Time 2 to Time 3 (See Figure 2). Similarly, HF-HRV values were not significantly associated with PSQI intercept. No significant effect of HF-HRV for the within-person PSQI sleep duration score slope was obtained, suggesting that within-person changes in PSQI sleep duration scores over time were not significantly associated with HF-HRV scores in the sample. Results indicated that of the covariates, only financial stress predicted the PSQI intercept with an estimate of 0.28. Participants who reported higher financial stress during the beginning of the pandemic had a higher sleep duration score, meaning that they had shorter sleep. However, financial stress did not predict changes in PSQI sleep duration scores over time.

PSQI Sleep Efficiency

The results of the HLM analyses for sleep efficiency are reported in Table 5. The PSQI sleep efficiency score intercept of the Level 1 model was significant, suggesting that the average PSQI sleep efficiency scores at Time 1 was different from zero. The analysis also showed a significant effect for the within-person time slope, indicating that PSQI sleep efficiency scores have a linear effect with an decrease in scores from Time 1 to Time 3 (See Figure 3). HF-HRV values were not significantly associated with PSQI intercept. No significant effect of HF-HRV for the within-person PSQI sleep efficiency score slope was obtained, suggesting that within-person changes in PSQI sleep efficiency scores over time were not significantly associated with HF-HRV scores. Results indicated that of the covariates, only financial stress predicted the PSQI sleep efficiency intercept with an estimate of 0.19. Participants who reported higher financial stress during the beginning of the pandemic had higher PSQI sleep efficiency scores. However, financial stress did not predict changes in PSQI total scores over time.

Discussion

The goal of this study was to examine the effect of confinement during the first wave of the COVID-19 pandemic on sleep quality, sleep efficiency, and sleep duration and to investigate HF-HRV as an individual difference in sleep reactivity to confinement. Overall, participants reported poor sleep quality with 84.2% of them scoring above the PSQI clinical cut-off at Time 1. The longitudinal analyses showed a curvilinear change of the total PSQI score over time; from Time 1 to Time 2, sleep quality worsened, then from Time 2 to Time 3, sleep quality improved and was better than at the beginning of the confinement at Time 1. Similarly, the results showed a curvilinear change over time of sleep duration scores as sleep duration shortened from Time 1 to Time 2, but then became longer again from Time 2 to Time 3. Finally, results indicated a linear decrease in sleep efficiency scores as sleep efficiency improved over time. However, these changes in total sleep score, sleep duration, and sleep efficiency were not associated with HF-HRV. Furthermore, results indicated that financial stress predicted PSQI total scores, sleep duration, and sleep efficiency at baseline, where higher financial was associated with poorer sleep quality. Financial stress was not associated with change in PSQI scores over time. Hence, participants show overall poor sleep quality, but have demonstrated improvement over time, at the deconfinement period.

We hypothesized that sleep duration score would decrease linearly with time, meaning participants will have longer sleep about 4 weeks into confinement and even longer sleep at deconfinement. However, we found that participants had shorter sleep 4 weeks into confinement as their sleep duration score increased, and then had longer sleep at deconfinement as their score decreased. Contrary to our findings, a longitudinal study in the U.S. found that on average, individuals, especially students and non-shift workers, were sleeping longer during the confinement than before. They attributed their findings to the relaxed school and work schedules during confinement as work from home orders were instituted; this relaxation of schedules may allow for greater sleep opportunity and longer sleep duration especially among young individuals with later sleep schedules, which had frequently conflicted with work and school schedules prior to the pandemic (Gao & Scullin, 2020). The inconsistency of findings can be attributed to the different samples, Gao and Scullin's findings come from U.S. adults with a mean age of 38.04, whereas our sample consists of mothers and caregivers with a mean age of 50.62. In another longitudinal study using crowdsourced smartphone-measured sleep data to examine sleep duration before (December 2019) and during confinement (January-March 2020), Chinese adults had an average of 20 minutes longer sleep on weekdays, and maintained a similar sleep duration on weekends during the beginning of the confinement, compared to before the pandemic (P. H. Lee et al., 2020). However, this study assessed the effect of the confinement on sleep only in the beginning of the pandemic, and most of participants were working from home and were not required to work at scheduled hours (Alfonsi et al., 2021; P. H. Lee et al., 2020; Zheng et al., 2020). Another panel study of over 2,000 adults from the United States assessed sleep patterns during the confinement by asking participants to report the number of days in the past week they had (1) trouble falling asleep, (2) trouble staying asleep, and (3) waking up feeling rested, and to report on average, the hours of sleep they get in a 24h period. More individuals reported having shorter sleep (less than 7 hours of sleep a night) in 2020 than 2018 (40.7% vs. 34.0%, respectively), or exceeding the National Sleep Foundation's recommendations for sleep duration (greater than 9 hours of sleep a night) during the first month of the confinement when compared to a comparative sample, (n = 19,000) who reported sleep duration before the pandemic, in 2018 (7.4% vs. 4.2%, respectively). Thus, more individuals reported shorter sleep duration during the confinement than longer sleep duration, 40.7% vs. 7.4%, respectively (Hisler & Twenge, 2021). Hence, these findings are consistent with our findings whereby more individuals reported shorter sleep duration a month in the confinement than before. Additionally, studies have found that individuals who were not sleep restricted prior to the pandemic and who were already obtaining a healthy amount of sleep are unlikely to experience longer sleep duration during the pandemic. These individuals may respond to the increased sleep opportunity by spending more time lingering in bed in the morning which might reduce their sleep drive accumulation resulting in lighter sleep of shorter duration (Kutana & Lau, 2020).

We hypothesized that sleep efficiency would improve over time. Results showed that sleep efficiency scores linearly decrease from the beginning of the confinement to the deconfinement period suggesting improvement of sleep efficiency over time. In the aforementioned study, the number of U.S. adults experiencing any difficulties falling asleep and staying asleep nearly doubled from 2018 to 2020, a month into confinement (Hisler & Twenge, 2021). A previous longitudinal study found that nursing students reported worse sleep efficiency during the confinement than prior to it (Romero-Blanco et al., 2020). Furthermore, another longitudinal study examined changes in sleep during the confinement using the PSQI in an Italian adult sample. Their findings show that sleep efficiency was worse a month in the confinement than at deconfinement (Alfonsi et al., 2021). These findings suggest that sleep efficiency is the worst during the confinement, but then improves with time and into the deconfinement. Thus, the findings are in line with our results that show a linear decrease in sleep efficiency scores, indicating improvement over time.

Sleep duration is the longest at Time 1 with an average of 7.27 hours a night, and then gradually shortens with time to reach 6.97 hours a night at Time 3 (see Table 2). Additionally, at Time 1, individuals are going to bed later and waking up earlier than Time 2. A month into the confinement, individuals are sleeping at almost the same time as the deconfinement period, but are waking up the latest. However, sleep efficiency is the worst at Time 1, and then improves with time. It seems that individuals are spending more time in bed at Time 1 and are having difficulties falling asleep, maintaining asleep, or early awakenings. Eventually with time, these difficulties are fading as individuals' sleep efficiency improves into deconfinement. Confinement entails atypical work schedules which disrupt waketime and bedtime, engaging less in social and leisure activities, exercising less with closed facilities, and being less exposed to daylight since time outside is reduced– all of which affect the circadian timing system with the alteration of the aforementioned time cues (Morin, Carrier, et al., 2020). Research on sleep and circadian rhythm show that individuals who were temporally isolated from the outside world for several consecutive days had desynchronized sleep schedules with the outside world, however their endogenous clock remained close to 25-hours (Aschoff et al., 1971; Revell & Eastman, 2005).

This desynchronization due to atypical work schedules is a risk factor for sleep disturbances and sleep loss and exacerbates sleep problems (Morin, Carrier, et al., 2020).

We also hypothesized that sleep quality would improve linearly over time. Our findings suggest that the total PSQI scores increase at Time 2, a month in confinement, and then decrease at deconfinement, suggesting that sleep quality worsens about 4 weeks into confinement, but then improves at deconfinement. The number of adults reporting days where they were not feeling rested was substantially greater in 2020, during confinement, than in 2018 (Hisler & Twenge, 2021). These findings converge with cross-sectional findings of a high prevalence of sleep disturbances and poorer sleep quality during the pandemic in Chinese, Spanish, English, and Italian populations (Deng et al., 2020; Jahrami, BaHammam, Bragazzi, et al., 2020; Wright et al., 2020; Xiao et al., 2020b, 2020b). Martínez-Lezaun and colleagues (2021) found that sleep quality worsened during the confinement with almost half of participants showing continued worsening of sleep quality at 20 and 40 days of confinement. This shows that the effect of the confinement on sleep lasts longer than a month, explaining the increase of the total PSQI score in our sample four weeks into confinement. Conversely, individuals reported worse sleep quality at the third week of confinement than at eight weeks (Salfi et al., 2020). In an Italian sample, PSQI global score decreased significantly at post-lockdown than during the lockdown, indicating improved sleep quality (Alfonsi et al., 2021). These results are in line with our findings and indicate an improvement of sleep quality during the deconfinement period.

Even though sleep parameters improved with time, the average total PSQI score was well greater than 5, the clinical cut-off score, across all three timepoints, indicating 84.2% of our sample suffers clinically from poor sleep quality at Time 1, 87.3% at Time 2, and 80.2% at Time 3. Hence, our findings highlight the need to develop accessible interventions that target sleep quality during the pandemic. This could be a combination of sleep health education, training medical staff with cognitive-behavioural therapy for insomnia (CBTi) to make it accessible and affordable for vulnerable populations to seek out help during this difficult period. Previous studies have shown that delivering sleep knowledge, or sleep health information, through webinars is effective and increases accessibility to individuals in remote areas (Morin, Jarrin, et al., 2020; Osborne & Blunden, 2018). Additionally, unguided internet-delivered CBTi, using interactive modules and animations, is the treatment of choice and has been shown to be effective (Cheng & Dizon, 2012; Ritterband et al., 2009; Zachariae et al., 2016); participants who have completed an unguided internet-based CBTi program had better short-term outcomes, assessed at a 6-months follow-up, on sleep measures and showed improvement of insomnia symptoms than the control condition (Hagatun et al., 2018, 2019; Ritterband et al., 2009). Moreover, exercise interventions led to improvements in subjective sleep quality for individuals with insomnia symptoms (Lowe et al., 2019).

Our findings are also in line with research on psychological distress during the COVID-19 pandemic. In a longitudinal study that examined psychological distress during the pandemic in the U.S. using the Patient Health Questionnaire -4, researchers found evidence that distress increased from mid-March to early-April 2020 as the pandemic first emerged (Daly & Robinson, 2021). However, the spike in distress started to decline from late April onwards with a decline in worry, nervousness, loss of interest, and feelings of hopelessness. By June 2020, levels of distress were similar to levels reported in early March (Daly & Robinson, 2021). Similar results were found in the United Kingdom, where levels of mental health problems, identified by a score greater than 3 on the General Health Questionnaire-12, increased from 24.3 to 37.8 percentage points at the end of April 2020, then subsequently declined between April and June 2020. These levels, though, remained significantly above pre-COVID-19 levels at 31.9% (Daly et al., 2020). The persistence of mental health problems till June may reflect the severity of the restrictions imposed throughout the period of April to June 2020 in the UK, and the significant health and economic threat associated with COVID-19 at this time (Daly et al., 2020). Similarly, in Quebec, severe restrictions were imposed from March to end of May-early June 2020, after which outdoor bigger gatherings were permitted, provincial parks reopened, non-essential businesses, libraries, and museums reopened (Rowe, 2020).

The trajectory observed in our sample for sleep duration and sleep quality (total PSQI scores) as well as that in the aforementioned studies of an initial sharp rise in distress followed by gradual return to baseline levels, or a “recovery” response, has been identified as a common response in research examining adaptation to other types of major life stressor (Infurna & Luthar, 2018). Even though not all stressful events will lead to the emergence of posttraumatic stress disorder (PTSD), Kessler and colleagues suggest that remission occurs in the first year in 60% of cases, and usually PTSD symptoms decrease within 3 months into the first year (Kessler et al., 1995; Mcfarlane, 1997). In a systematic review that assessed evidence of PTSD following exposure to disasters, researchers determined that the prevalence of PTSD in the aftermath of natural disasters is often lower than the rates documented following human-made and other disasters. However, high prevalence of PTSD symptoms have been reported in clinical samples, among first responders, and in individuals who live in areas heavily affected by the disaster (Neria et al., 2008). As such, they concluded that that the prevalence of PTSD symptoms can be expected to be high in the first year following exposure to the disaster among risk groups, ranging between 30% and 40%, but is expected to be low among the general population, ranging between 5% and 10%; furthermore, it is expected to decrease across time (Eid, 2003;

Karamustafalioglu et al., 2006; Neria et al., 2008; Orcutt et al., 2004). A study that looked at predictors of chronic PTSD in SARS survivors showed that female gender, presence of chronic medical illness diagnosed prior to the onset of SARS, and high functional disability are all predictors of chronic PTSD (Mak et al., 2010); other studies have found that caregivers of individuals with medical disorders are also at an elevated risk of developing PTSD (e.g., Carmassi et al., 2020; Liang et al., 2019; Stukas et al., 1999). Thus, our sample is considered to be high risk since all of our participants are females, half of our participants are mothers of children with a disability, and 24% reported having a chronic medical condition. Adaptation theory argues that individuals are able to adjust to both negative and positive stimuli with an eventual return to baseline or pre-stressor level of a particular emotion or cognition (Diener et al., 2009). Hence, adaptation and improvement in sleep was reported after stay-at-home orders and restrictions on businesses were being lifted in Quebec during late May and June, which may have eased the distress in individuals indicating that the pandemic was under control and "normality" or the ability to gather with friends and family, hang out in a restaurant, watch a movie, go to a museum, was being restored (Daly & Robinson, 2021).

Previous literature on the effects of collective disasters (natural and man-made) on sleep would also help us draw parallels in understanding our findings during the pandemic and the effect of adaptation. Studies show that survivors of disasters report, even after few years later, severe sleeping difficulties along with psychological distress such as symptoms of depression, anxiety, and intrusive thoughts (Green et al., 1990; Norris, Friedman, & Watson, 2002; Norris, Friedman, Watson, et al., 2002). Individuals who were exposed to the Italian L'Aquila earthquake of 6.3 magnitude in 2009 continued to suffer in reduction of their sleep quality, subjectively reported using the PSQI, after two years of the incident (Tempesta et al., 2013).

However, studies indicate that most physical and mental health-related problems decline with time, with the first year, generally, being the time of peak of symptoms and effects (Norris, Friedman, Watson, et al., 2002), with survivors, those who have experienced disasters, reporting more and more persistent health problems than non-survivors (control group) (Bromet et al., 2002; Grace et al., 1993). The prevalence of severe sleeping problems decreased in individuals affected by the firework disaster in the city of Enschede, Netherlands from the third week to 18 months after the disaster, with the prevalence being higher for the affected residents than residents in a comparable city, Tilburg, who served as the control group (Grievink et al., 2007). This could have explained the presence of worse sleep quality and shorter sleep duration a month into confinement, but then declining with time as adaptability develops with the beginning of deconfinement (Diener et al., 2009).

In the current study, financial stress was a significant predictor of sleep quality (total PSQI score), sleep duration, and sleep efficiency with a moderate effect size at the beginning of the confinement. Consistent with this finding, cross-sectional studies found that worries about the inability to pay bills, accessing food or medication, and having family responsibilities were associated with poorer sleep quality and sleep health during the pandemic (Robillard et al., 2021; Wright et al., 2020). The association of poor sleep quality and quantity (duration) with financial stress has been established in the literature prior to the pandemic (e.g., Du et al., 2021; Galambos et al., 2011; Peltz et al., 2020). Additionally, unemployment worries and unstable employment have been shown to be associated with less total sleep time (E.-S. Lee & Park, 2019), and over half of our sample reported having financial worries. Longitudinal studies looking at the effect of the confinement on mental health also found that income loss due to the pandemic and financial stress are associated with mental health threats and concerns, such as the worsening of depressive symptoms, beyond any pandemic health-related concerns (Hertz-Palmor et al., 2021). Moreover, the Canadian government initiated The Canada Emergency Response Benefit (CERB) during the second week of April to support the income of Canadian workers who lost their jobs because of COVID-19 (Service Canada, 2020). This helped ensure that incomes of Canadians and their ability to meet basic needs was minimally compromised during the pandemic and may have had an impact on the improvements in sleep duration, sleep efficiency, and sleep quality observed at Time 3. This may also explain why financial stress is associated with sleep at baseline online, but not over time.

Caregiving status was not a significant predictor of PSQI total scores, sleep duration, and sleep efficiency and had a small effect size for sleep duration and efficiency, but a moderate effect size for the total score at the beginning of confinement. This suggests that both mothers of children with and without neurodevelopmental disorders did not differ on their measures of PSQI total scores, sleep duration, and sleep efficiency. Research has illustrated the link between caregiving status and sleep difficulties such that caregivers of children with neurodevelopmental disorders, such as autism spectrum disorder, self-report greater impairment on all sleep parameters including sleep efficiency, duration and overall quality compared with age-matched controls (e.g., Gallagher et al., 2009, 2010; Meltzer, 2008; Micsinszki et al., 2018). In a recent study, researchers found that sleep efficiency was objectively poorer in caregivers than non-caregivers control, but caregivers' total sleep time and time in bed was greater than controls, as measured using an actigraphy (Lovell et al., 2021). Even though caregivers and non-caregivers, according to the literature, show differences in sleep parameters, it seems that the pandemic has affected all mothers' sleep efficiency and sleep duration equally, as a stressful period for all. Furthermore, it could possibly be that the flexibility of work schedules imposed by the confinement and being home and available for their child has been helpful to mothers with children with disability, and could potentially explain why caregiving status did not seem to be a significant predictor of these parameters at the beginning of the confinement. However, with the observed moderate effect for sleep quality, it seems that mothers with children with disability's sleep quality is worse than that of non-caregiving mothers, but the effect did not reach statistical significance. Finally, even though ethnicity was not a significant predictor, it showed a moderate effect, with non-White ethnicities showing poorer sleep quality. This is in-line with the literature that non-White ethnicities usually show poorer sleep quality and have more sleep difficulties than White ethnic individuals (e.g., Hicken et al., 2013; Patel et al., 2010; Petrov & Lichstein, 2016).

The present study was the first, to our knowledge, that examined the moderating role of HF-HRV in the association of sleep disturbances and time in confinement. In our sample, HF-HRV was not a significant predictor of sleep quality, sleep efficiency or sleep duration at the beginning of the confinement. Moreover, HF-HRV did not predict the changes in the dependent variables over time. This suggests that individuals with higher HF-HRV did not have a significantly different sleep quality, efficiency, or duration scores at baseline than those with lower HF-HRV. HF-HRV is widely accepted as a biomarker of vagally-mediated parasympathetic activity (Berntson et al., 1993). Findings propose that individuals with low resting HF-HRV and excessive HF-HRV reactivity may be at a higher risk for experiencing sleep disturbances in response to stress compared to those with high resting HF-HRV and lower HF-HRV reactivity (Castro-Diehl et al., 2016; Jackowska et al., 2012). However, resting HF-HRV was not associated with sleep quality in the present study. A potential explanation for this inconsistency in our findings is attributed to methodological factors. HF-HRV was only measured at rest, and previous research has measured HF-HRV reactivity during a worry task (Gouin et al., 2015; MacNeil et al., 2017). Hence, measuring HF-HRV at rest and during a stress-induction task may have provided an opportunity to further explore how parasympathetic function interacts with stress. Studies have demonstrated good reliability (intraclass correlation coefficients of 0.70-0.73) for resting HF-HRV over a course of 3 weeks (Bertsch et al., 2012). A longitudinal study that examined the stability of HF-HRV at rest while estimating sex and ethnic differences found resting HF-HRV ethnic differences consistent across 1.5 years with an intraclass correlation coefficient of greater than 0.5, which suggests some stability over time (Z. Li et al., 2009). Similarly in a three-year follow-up on 64 subjects, researchers obtained high interclass correlation coefficients of 0.8 for sitting HF-HRV between the time points (Goedhart et al., 2007). The substantial differences in reliability estimation in the literature may be related to occasion-specific influences, situation and person-situation interaction, which usually have a stronger impact on HRV measures in less controlled task conditions (Bertsch et al., 2012; Sandercock et al., 2005). Hence, even though HF-HRV seems to be a fairly stable measure (Kleiger et al., 1991; Pitzalis et al., 1996), results should be interpreted with caution and this might explain our findings.

Strengths, Limitations and Future Directions

The present study has different strengths. It is the first longitudinal study, to our knowledge, to examine change in sleep quality, sleep efficiency, and sleep duration during the confinement of the first wave of the COVID-19 pandemic and to investigate the role of HF-HRV as an individual difference in sleep reactivity to confinement. This study captured the effect of confinement, only a week after the first lockdown measures were in effect, and deconfinement on sleep quality in a sample of mothers of adolescents with and without developmental disability living in Montreal, Quebec using a validated and commonly-used scale, the PSQI.

Though novel strengths also include having resting HF-HRV measure of the sample, which has been considered to be a fairly stable biomarker of sleep reactivity, our sample is a convenience sample. The survey was not available to mothers of the general public to complete, instead, only mothers who participated in the previous Transition study were contacted to complete the measures. Moreover, our sample compromised of only mothers, with half of the sample obtaining at least one university degree. Hence, future research should replicate the study in another sample of more diverse academic background and include fathers.

A second limitation pertains to the reliance on self-report measures, PSQI, to measure sleep duration. The PSQI measure asked participants to report their sleep in the last week, which could have introduced recall bias. Participants may have under-reported their sleep duration. Thus, future studies should use actigraphy or polysomnography to obtain objective measurements of sleep duration. Moreover, the use of sleep-diaries are more accurate subjective measures of bedtime, wake-up times, and daytime napping since individuals report the time in the moment instead of reporting an approximation. Finally, the current analysis examined sleep patterns at the beginning of the confinement to deconfinement and did not examine pre-pandemic baseline measures. It would have been important to examine sleep measures right before the pandemic emerged in Quebec (end of February or early March) to better characterize change associated with the onset of the confinement. Furthermore, future studies should include a question asking whether participants have received CERB to help us better understand its role in mitigating stress-related sleep disturbances.

Out of the sociodemographic factors used in the study, only financial stress predicted poor sleep quality at the beginning of the confinement and none predicted the observed trend over time. Other predictors that may explain these results were not assessed in the current study's model. Research has illustrated the link between obesity, physical exercise, daytime naps, alcohol and tobacco consumption, and prolonged TV watching with sleep quality (Dalmases et al., 2019; McGhie & Russell, 1962; Romero-Blanco et al., 2020). Fear of infection, worries about relatives' health, mental health problems such as anxiety, PTSD, and depression are all associated with poor sleep quality, but were not included as covariates in our model (Dinis & Bragança, 2018; Hyun et al., 2021; Maaravi & Heller, 2020; Romero-Blanco et al., 2020). Moreover, the transition of seasons from winter to spring (Time 1 to Time 2), and spring to summer (Time 2 to Time 3) which is accompanied by longer days and more exposure to daylight might have explained the results since it has a strong impact on the circadian rhythm and mood, such as seasonal affective disorder (SAD) in short winter days (Kronfeld-Schor & Einat, 2012; Landgraf et al., 2014). That said, future studies should incorporate a question pertinent to SAD, or should replicate the study across another wave whereby the drastic impact of seasonal change would not be a possible confounding factor. Biologically, during the menopause transition, females encounter fragmented sleep, increase in night-time awakenings, and sleep-onset insomnia (Kravitz et al., 2003, 2008; Zolfaghari et al., 2020). Hence, future research should include all the aforementioned factors as covariates in the prediction of sleep quality patterns over time. Additionally, all of these sociodemographic factors were administered at Time 1 only and so their causality cannot be determined in a correlational design. Thus, future studies should administer these factors at the different time points of the study.

A final limitation pertains to HF-HRV that was collected few years before the beginning of the pandemic. To our knowledge, no studies have reported ICC of resting HF-HRV over a period of longer than 5 years. Thus, it is unclear whether resting HF-HRV will remain stable with such time. Additionally and as discussed earlier, there are some inconsistencies in reporting reliability estimates of resting HF-HRV in the literature, and even though it has been considered to be fairly stable, the results should be interpreted with caution. HF-HRV was only assessed at rest and HF-HRV reactivity was not measured at all, which have been used in other studies (Gouin et al., 2015; MacNeil et al., 2017). Thus, future research should measure HF-HRV at the beginning of the confinement, at rest and during a stress-induction task which could provide an opportunity to further explore how parasympathetic function interacts with stress to develop and maintain poor sleep health during the pandemic.

In summary, this study suggests that sleep duration and sleep quality is shortest and worse, respectively, about 4 weeks into confinement and then improves at deconfinement. However, sleep efficiency is worse at the beginning of the confinement and improves linearly with time. These findings are in line with longitudinal and cross-sectional studies that examined sleep quality during the confinement in individuals who were adversely affected by the pandemic and their financial responsibilities increased due to the pandemic. Furthermore, findings indicate that financial stress is a predictor of poor sleep quality at the beginning of the confinement. Thus, the study supports the importance of financial support which helped ensure that the daily incomes of Canadians and their ability to meet basic needs were minimally compromised. It also highlights the need to develop accessible sleep interventions to alleviate the sleep disturbances experienced by 80% of our sample.

Table 1

Correlation Matrix of Main Study Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**Mothers of children with disability**																	
2	**Age**	**-.20***																
3	**Adherence physicaldist**	.1	-.02															
4	**Chronic medical condition**	.09	.04	-.14														
5	**Financial stress**	.04	-.01	.08	.04													
6	**Sleep Duration T1**	-.03	.03	-.08	-.03	**.24****												
7	**Sleep efficiency T1**	-.03	-.04	-.06	.01	.15	**.66****											
8	**PSQI Global T1**	.01	.01	-.1	-.1	**.23****	**.65****	**.70****										
9	**Sleep Duration T2**	.05	-.04	-.03	-.12	**.21***	**.45****	**.26****	**.35****									
10	**Sleep efficiency T2**	-.14	.00	.08	-.11	.1	**.28****	**.34****	**.38****	**.52****								
11	**PSQI Global T2**	-.11	-.02	-.05	-.18	**.19***	**.38****	**.32****	**.62****	**.69****	**.72****							
12	**PSQI Sleep Duration T3**	-.09	-.01	-.15	-.09	.14	**.51****	**.26****	**.17**	**.59****	**.23***	**.38****						
13	**Sleep efficiency T3**	-.02	-.15	-.05	.03	.1	**.34****	**.42****	**.38****	**.31****	**.36****	**.38****	**.46****					
14	**PSQI Global T3**	-.14	.09	-.1	-.13	.11	**.38****	**.29****	**.53****	**.38****	**.39****	**.67****	**.45****	**.65****				
15	**Education level**	.1	.1	**-.17***	-.08	**-.17***	.04	-.03	.01	.08	-.01	-.01	-.01	-.04				
16	**Ethnicity**	-.06	**.23****	.01	-.08	.06	-.04	.02	.05	.07	.11	.06	-.11	.01	.11			
17	**Resting RSA**	.11	**-.29****	-.01	**.19***	.02	-.11	.06	-.03	.03	.06	.02	-.02	-.03	**-.18***	.01		

* Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Table 2

Means, Standard Deviations and Frequencies of Main Study Variables (N = 150)

Constructs	Mean (SD) or Percentages	Range
Resting RSA ln(msec)^2	5.66 (1.30)	2.15-8.66
PSQI Total Score T1	9.47 (3.68)	4-20
PSQI Total Score T2	9.93 (3.84)	4-20
PSQI Total Score T3	7.96 (2.56)	0-18
Sleep efficiency T1	1.02 (1.13)	0-3
Sleep efficiency T2	.966 (1.08)	0-3
Sleep efficiency T3	0 (0)	0-3
Sleep duration T1	.51 (.79)	0-3
Sleep duration T2	.72 (1.0)	0-3
Sleep duration T3	0 (0)	0-3
Sleep duration T1 (hours)	7.27(1.45)	4-11
Sleep duration T2 (hours)	7.20(1.65)	0-13
Sleep duration T3 (hours)	6.97(1.43)	3-12
Bedtime T1	16:59(9:12)	0:00-24:00
Waketime T1	7:50(1:34)	4:00-12:00
Bedtime T2	16:47(9:23)	0:00-24:00
Waketime T2	7:54(1:42)	4:00-13:00
Bedtime T3	16:48(9:24)	0:00-23:45
WaketimeT3	7:28(1:23)	4:00-11:00
Age (T1) (years)	50.62 (6.0)	39-69

Adherence to physical distancing	9.2 (2.77)	7-22
Chronic medical condition (%; T1)	24	0-1
Education level (% university graduates)	47	1-7
Non-white ethnicity (%)	74	0-1
Financial Stress (%; T1)	54	0-3
Mothers of children with disability (%)	50.7	0-1

Note. Financial stress percentage refers to individuals who reported being somewhat or a lot worried about their finances.

Table 3

Longitudinal mixed effects modeling of the trajectory of changes in PSQI Total Score over time

		Intercept		Linear Slope		Curvilinear Slope	
		β (SE)	T-ratio	β (SE)	T-ratio	β (SE)	T-ratio
Level 1		9.90(0.41)	24.37***	-0.25(0.16)	-1.59	-0.61(0.25)	-2.42*
Level 2							
	Age	0.017(0.05)	0.36	-0.001(0.03)	-0.04	-0.02(0.05)	-0.37
	Mothers of children with disability	0.27(0.28)	0.95	0.28(0.17)	1.67	-0.008(0.27)	-0.03
	Chronic medical condition	-1.05(0.70)	-1.51	-0.22(0.41)	-0.54	0.52(0.70)	0.75
	Adherence to physical distancing	-0.11(0.17)	-0.99	0.005(0.06)	0.08	-0.08(0.10)	-0.82
	Financial Stress	1.02(0.34)	2.99**	-0.38(0.20)	-1.94	-0.28(0.33)	-0.85
	Ethnicity (White)	-0.37(0.67)	-0.56	0.27(0.39)	0.69	-0.18(0.67)	-0.27
	Education level	0.12(0.19)	0.63	-0.03(0.11)	-0.26	-0.04(0.18)	-0.23
	Resting RSA	-0.07(0.22)	-0.31	-0.19(0.13)	-1.49	-0.19(0.21)	-0.89

* $p < .05$;

** $p < .01$;

*** $p < .001$

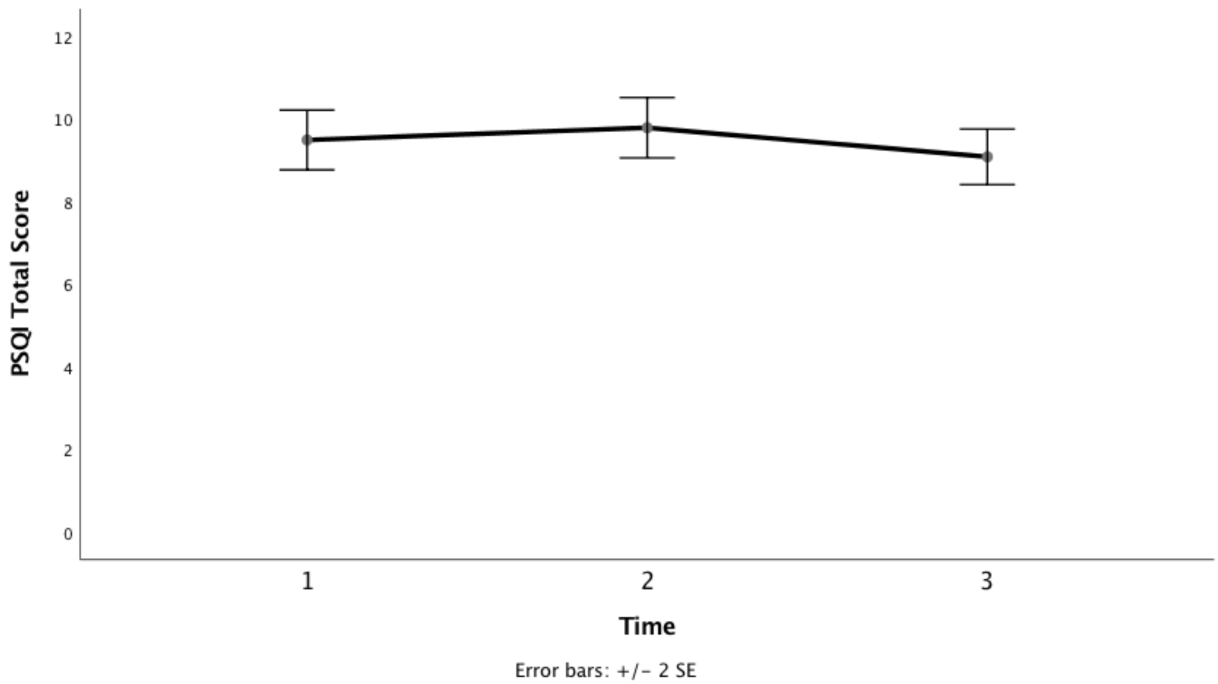

Figure 1. Curvilinear changes in PSQI Total Scores over time. *Error bars* represent the standard error of the mean.

Table 4

Longitudinal mixed effects modeling of the trajectory of changes in PSQI sleep duration scores over time

	Intercept		Linear Slope		Curvilinear Slope	
	β (SE)	T-ratio	β (SE)	T-ratio	β (SE)	T-ratio
Level 1	0.57(0.09)	6.15***	0.0002(0.04)	0.00	-0.22(0.07)	-3.20**
Level 2						
Age	0.003(0.01)	0.26	-0.001(0.007)	-0.19	-0.002(0.01)	-0.16
Mothers of children with disability	0.04(0.06)	0.6	0.03(0.51)	0.64	0.09(0.07)	1.21
Chronic medical condition	-0.14(0.15)	-0.91	-0.14(0.10)	-1.33	0.17(0.19)	0.93
Adherence to physical distancing	-0.02(0.02)	-0.89	-0.008(0.02)	-0.50	-0.02(0.03)	-0.79
Financial Stress	0.28(0.08)	3.75***	-0.08(0.05)	-1.55	-0.09(0.09)	-0.99
Ethnicity (White)	0.12(0.15)	0.82	0.16(0.10)	1.57	0.23(0.18)	1.27
Education level	0.06(0.04)	1.5	-0.02(0.03)	-0.59	-0.05(0.05)	-1.07
Resting RSA	-0.02(0.05)	-0.41	0.02(0.03)	0.73	-0.07(0.06)	-1.21

* $p < .05$;

** $p < .01$;

*** $p < .001$

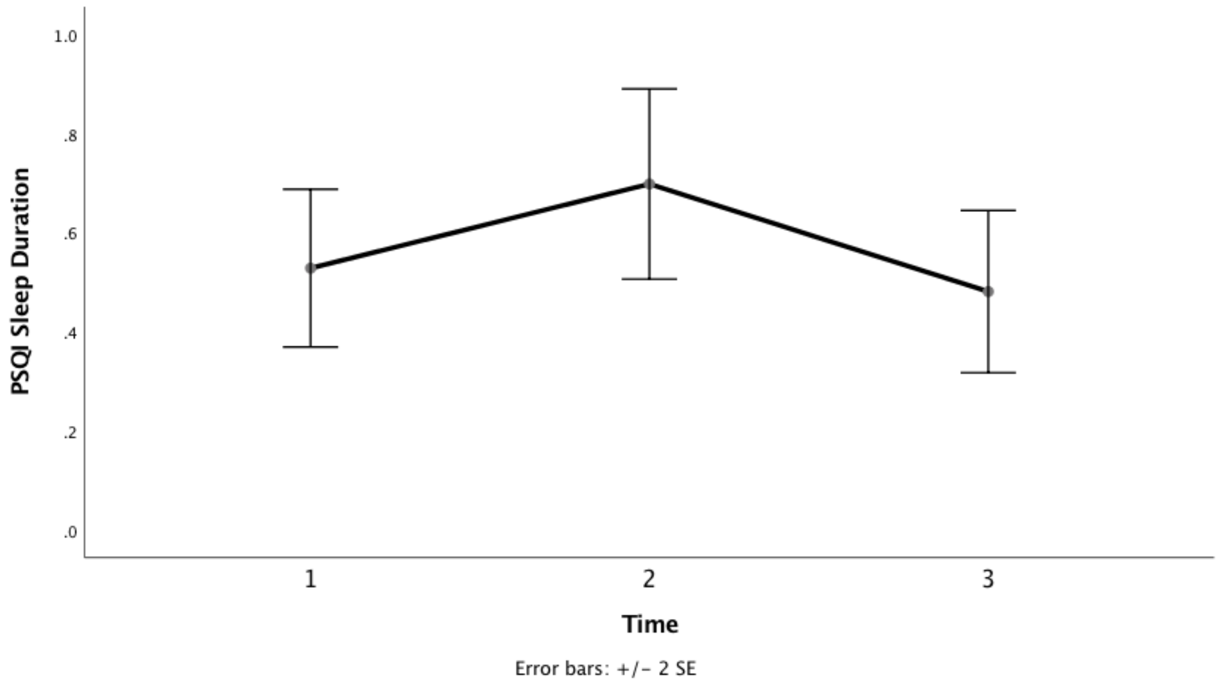

Figure 2. Curvilinear changes in PSQI Sleep Duration scores over time. *Error bars* represent the standard error of the mean.

Table 5

Longitudinal mixed effects modeling of the trajectory of changes in PSQI sleep efficiency scores over time

	Intercept		Linear Slope	
	β (SE)	T-ratio	β (SE)	T-ratio
Level 1	1.17(0.14)	8.76***	-0.13(0.05)	-2.36*
Level 2				
Age	-0.01(0.01)	-1.10	-0.01(0.01)	-1.29
Mothers of children with disability	0.10(0.08)	1.34	0.01(0.06)	0.18
Chronic medical condition	-0.01(0.19)	-0.06	-0.04(0.14)	-0.31
Adherence to physical distancing	0.009(0.03)	0.31	-0.006(0.02)	-0.30
Financial Stress	0.19(0.09)	2.13*	-0.10(0.07)	-1.47
Ethnicity (White)	-0.16(0.18)	-0.89	0.05(0.14)	0.37
Education level	0.03(0.05)	0.67	-0.0005(0.04)	-0.01
Resting RSA	0.02(0.06)	0.35	-0.05(0.04)	-1.15

* $p < .05$;

** $p < .01$;

*** $p < .001$

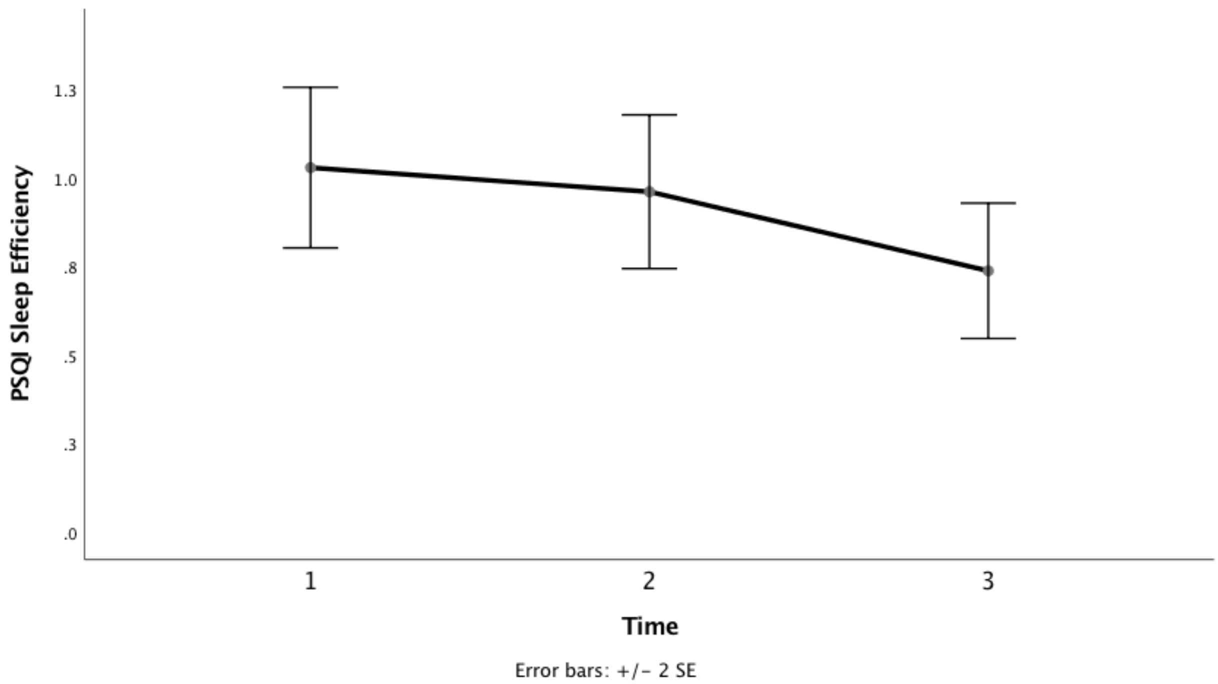

Figure 3. Linear changes in PSQI sleep efficiency scores over time. *Error bars* represent the standard error of the mean.

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		1	2	3	4	5	6	7	8	9	1
1	Caregiver status										
2	Age	-.20*									
3	Adherence physicaldist	.1	-.02								
4	Chronic medical condition	.09	.04	-.14							
5	Financial stress	.04	-.01	.08	.04						
6	Sleep Duration T1	-.03	.03	-.08	-.03	.24**					
7	Sleep efficiency T1	-.03	-.04	-.06	.01	.15	.66**				
8	PSQI Global T1	.01	.01	-.1	-.1	.23**	.65**	.70**			
9	Sleep Duration T2	.05	-.04	-.03	-.12	.21*	.45**	.26**	.35**		
10	Sleep efficiency T2	-.14	.	.08	-.11	.1	.28**	.34**	.38**	.52**	
11	PSQI Global T2	-.11	-.02	-.05	-.18	.19*	.38**	.32**	.62**	.69**	.72**
12	PSQI Sleep Duration T3	-.09	-.01	-.15	-.09	.14	.51**	.26**	.17	.59**	.23*
13	Sleep efficiency T3	-.02	-.15	-.05	.03	.1	.34**	.42**	.38**	.31**	.36**
14	PSQI Global T3	-.14	.09	-.1	-.13	.11	.38**	.29**	.53**	.38**	.39**
15	Education level	.1	.1	-.17*	-.08	-.17*	.04	-.03	.01	.08	-.01
16	Ethnicity	-.06	.23**	.01	-.08	.06	-.04	.02	.05	.07	.11
17	Resting RSA	.11	-.29**	-.01	.19*	.02	-.11	.06	-.03	.03	.06

*p< .05; ** p<.01