Anxiety, Sleep Problems and Positive Emotions (Gratitude and Happiness) in Long-Covid Patients:

An Experience Sampling Study

Master Thesis

Positive Clinical Psychology and Technology

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Abstract

Background: In many patients, the infection with the covid-19 virus has led to persistent symptoms, such as anxiety and sleep problems, which last weeks to months after the initial recovery. So far, few studies focused on the interaction between sleep problems and anxiety in long-covid patients. It is also unknown what role positive emotions take in the progression of these symptoms and their potential for long-covid interventions.

Objective: The current study explored the predictive relationship between sleep problems and anxiety on within and between level. Further, the momentary association between anxiety and positive emotions (happiness and gratitude) over two weeks in long-covid patients after hospital discharge was assessed.

Method: In this study, the Experience Sampling Method (ESM) was used to collect data for 14 consecutive days. The Ethica app was used to collect the longitudinal data in a convenience sample of ten Dutch ex-hospitalized participants with long-covid (M_{age}= 59.7, SD = 6; 50% women, 80% one or more comorbidities). Participants filled out a daily morning questionnaire, which examined their sleep problems the previous night. Further, they answered six times per day one questionnaire which examined their anxiety, gratitude, and happiness. Multiple linear mixed models were conducted to analyze the temporal relationships between sleep problems, anxiety, and positive emotions.

Results: It was found that there was neither a bidirectional nor one-directional relationship between anxiety and sleep problems. Moreover, the analyses for between-person and within-person associations were not significant. Finally, it was found that gratitude was not related to anxiety, but happiness was found to be related to anxiety. The association of happiness and anxiety was relatively small (β=-.07, p=.04).

Conclusion: In contrast to previous studies in other conditions, this study could not detect a relationship between anxiety and sleep problems in long-covid patients. The distinct outcomes might be related to the new field of long-covid and the design of this study. However, the severity of anxiety and sleep problems strongly fluctuated for some participants. Further, it was found that happiness and gratitude did not influence anxiety. This indicated that anxiety was influenced by other internal or environmental factors, which should be investigated further.

Keywords: long-covid, anxiety, sleep-problems, gratitude, happiness, experience sampling method, intensive longitudinal data

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Introduction

The ongoing worldwide pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) affected various areas of life and the general population's health. Initially, the virus was first observed in December 2019 in China and spread rapidly worldwide at the beginning of 2020 (Nadeau et al., 2021). When infected with Covid-19, a variety of symptoms can appear. The key symptoms associated with Covid-19 are dry cough, shortness of breath, fever, fatigue, headache, and body aches, which usually appear 2-14 days after exposure to the virus (Desai & Patel, 2020). The course of the disease depends on the individual's age and general health condition. Over 432 million people were currently infected with the virus, and the number of deaths due to the virus reached almost 6 million (Our World in Data, 2022). The Covid-19 pandemic in the Netherlands resulted in over 12 thousand hospitalizations (Ritchie et al., 2022). In the week of 14-18th March 2022, around 1,545 patients were hospitalized in the Netherlands, of whom about 91 were in ICU admission (National Institute for Public Health and the Environment, 2022). While the recovery from a mild Covid-19 infection occurs within 7-10 days after the onset of the symptoms, the recovery from severe infections can take up to three weeks or in case of long-covid longer than four weeks (Faes et al., 2020). A substantial proportion of patients reported that one or more symptoms persist even weeks or months after recovering from the Covid-19 virus, which is called long-covid. Long-covid patients seemed to experience various symptoms such as persisting headache, depression, anxiety or sleep problems (Lopez-Leon et al., 2021). Yet, this field of research is new, and only few studies investigated the etiology and the course of long-covid symptoms. For this reason, the development of intervention programs is progressing slowly, and more research is needed in the field of long-covid and possible protective factors, such as positive emotions.

Long Covid

The National Institute for Health and Care Excellence (NICE, 2021) defines long covid as *'signs and symptoms that develop during or after an infection consistent with COVID-19, continue for more than 12 weeks, and are not explained by an alternative diagnosis.'* (p. 5). Long-covid generally has an impact on everyday functioning, as well as on the physical and psychological wellbeing of patients. Several reports showed that the number of patients suffering from long-covid was relatively high. An international cohort

study analyzing the impact of long covid symptoms over seven months found that almost 65% of the respondents experienced symptoms for at least six months after recovery from the virus (Davis et al., 2021).

Symptoms of long-covid can range from pulmonary- to neurological symptoms. The key symptoms associated with long covid were chronic fatigue, shortness of breath, headache, muscle and joint pain, and sleep problems (Salamanna et al., 2021). Carfi et al. (2020) found similar results. The study followed 143 Italian individuals hospitalized due to mild to severe infection with Covid-19. They found that 87% of the people who were recovered and discharged from the hospital showed at least one symptom 60 days after discharge. In 55% of the patients, even three or more symptoms persisted. The most common reported symptoms were fatigue (53%), worsened quality of life (44%), joint pain (27%), and chest pain (21%) (Carfi et al., 2020). Similar results were described by Tenforde et al. (2020), especially fatigue, cough, and headache were seen quite often and least likely to resolve. The recent literature review on the long covid symptoms, conducted by Salamanna et al. (2021), highlighted that long covid was highly associated with three symptom categories, namely (1) persistent lung symptoms and dysfunctions, (2) persistent neurological symptoms and olfactory dysfunctions, and (3) widespread persistent symptoms. The first category refers to lung damage resulting in respiratory symptoms and dyspnea (shortness of breath) persisting six months after hospitalization in mild to severe Covid-19 patients (Bellan et al., 2021; Chun et al., 2021). Neurological symptoms and olfactory dysfunction include deficits in memory, attention, calculation, and short-term memory, after six months (Negrini et al., 2020; Pilotto et al., 2021). Moreover, studies focusing on olfactory symptoms indicated that many patients did not experience any improvement after recovery. They even struggled for up to six months with anosmia (partial or complete loss of smell) and hypogeusia (reduced ability to taste things) (Otte et al., 2020; Pilotto et al., 2021; Ugurlu et al., 2021).

Long-Covid Impact on Sleep

As long covid impacts almost all areas of health, it also affects individuals' sleep. Sleep is one of the essential fundamental needs of human beings. The recent meta-analysis on the long-term effects of Covid-19 by Lopez-Leon et al. (2021) indicated that sleep disorders were among the most prevalent consequences of long-covid. More specifically, sleep disturbances and poor sleep quality were commonly reported following recovery from Covid-19. The study performed by Poyraz et al. (2021) found supporting evidence. After the

recovery from the Covid-19 virus, 38% of the subjects rated their sleep quality as 'fairly poor' to 'very poor sleep'. In addition, almost a quarter of the subjects had a sleep duration of 5-6 hours or even shorter. Around 19% reported one hour or longer sleep latency in the previous month after recovery. Therefore, a negative impact of long-covid on patients' sleep can be assumed.

According to Hirshkowitz et al. (2015), sleeping between seven to eight hours for good health is recommended, which can vary across the lifespan and depends on the person. Otherwise, sleep deprivation can cause adverse effects on health, such as a decline in mental health, cognitive functioning, and bodily function. Strongly affected are especially neurocognitive functioning regarding executive attention, working memory, and other higher cognitive functions (Durmer & Dinges, 2005). Problems with sleep can develop into different types of sleep disorders. The most common sleep disorder is insomnia, characterized by difficulties falling or staying asleep. According to Udha et al. (2009), the prevalence of insomnia in anxiety patients ranges from 70% to 90%, and it was found that both disorders mostly co-exist in patients. It is also widely established that sleep problems and quality can contribute to physical and mental fatigue (Boolani & Manierre, 2019).

Further, is sleep an essential factor for psychological and physical wellbeing. Good sleep can give individuals the necessary resources to cope with distress, anxiety, and worries (Morin & Benca, 2020). In return, poor sleep quality increases the vulnerability to mental health complaints like anxiety symptoms, especially while experiencing long-covid symptoms (Chaput et al., 2016). The longitudinal relation between long-covid and sleep over time in people with long-covid remains unclear. Possible explanations for sleep problems developing due to long-covid could be loneliness, as patients feel high levels of loneliness due to hospitalization and isolation (Lopez-Leon et al., 2021). On the other side, patients experiencing long-covid symptoms show increased psychological distress in general and worrying and anxiety regarding their future, which are also known for negatively affecting sleep quality (Lopez-Leon et al., 2021; Poyraz et al., 2021). Examining anxiety and sleep problems may provide important information about diagnostics and treatment approaches for long-covid patients. Therefore, the current study aimed to explore the time-varying association between sleep and anxiety in long-covid patients.

Long-Covid Impact on Mental Health

Despite physiological symptoms, eight weeks after infection with the virus, nearly half of the study participants indicated that they were emotionally affected by long-covid

symptoms, and some even sought psychological care (Lopez-Leon, et al. 2021). To understand the consequences of long-covid on mental health, it is essential to understand the term mental health. The World Health Organization (WHO, 2022) defined mental health as *"a state of well-being in which the individual can fully function and cope with daily stresses of life and productively contribute to the community."* With this, the presence of psychological and social well-being is crucial for complete mental health (Arslan & Allen, 2020).

Issues that came along with covid-19 and applied to long-covid, such as hospitalization, decreased social contacts, quarantine, and economic consequences, can impact mental health. Saltzman et al. (2020) found associations between social isolation due to hospitalization or illness and poor mental health. Social contact and support are primarily perceived as essential factors in mental health. Patients who need to be hospitalized or feel less motivated to keep social contacts due to long-covid symptoms can be more at risk for poor mental health and the development of psychiatric disorders (Saltzman et al., 2020).

According to Taquet et al. (2021), the probability of a first psychiatric diagnosis in the following 14 to 90 days after a covid-19 diagnosis was around 18%. The study compared the likelihood of developing psychological symptoms after Covid-19 with similar events such as comprised influenza, respiratory tract infection, and skin infection. Especially elderly people were reported to be more prone to develop psychiatric disorders after being infected with the coronavirus. Taquet et al. (2021) addressed in their study the following psychiatric complaints: anxiety disorders, mood disorders, and psychotic disorders. It was found that generalized anxiety disorder and adjustment disorder were the most frequent anxiety disorders that developed after being diagnosed with Covid-19. Panic disorder and post-traumatic stress disorder were observed to a lesser extent. The diagnosis of mood disorder came in second place. Kamal et al. (2021) indicated that almost 28% of people with long-covid symptoms suffered from depression, and 38% suffered from anxiety disorders. The development of psychotic disorders was also observable after being infected with Covid-19; however, the number was deficient (0.1%) (Taquet et al., 2021).

The negative impact of anxiety symptoms on individuals' life and health are tremendous. Persistent symptoms of anxiety can develop into an anxiety disorder and cause impairments in social functioning and diminish the quality of life of individuals (Dymond et al., 2015; Uzunova et al., 2021). Uzunova et al. (2021) searched for factors contributing to anxiety in patients with COVID-19 and indicated that social isolation, stress, ICU stay, gender, age, and the current health status are influential factors. Especially elderly females seemed to

show higher anxiety levels after hospitalization and being infected with the virus (Uzunova et al., 2021). Besides the factors already mentioned, also sleep deprivation can increase the likelihood of anxiety (Morin & Benca, 2020).

Existing literature has extensively described the relationship between sleep and anxiety. Nevertheless, the etiological relationship remains unclear. Alvaro et al. (2013) conducted a systematic review concerning the association between anxiety and sleep. Their results revealed no clear answer, but most studies found a bidirectional relationship. According to Johnson et al. (2006), anxiety disorder occurred among a community-based sample of adolescents prior to poor sleep quality. In contrast, Jansson-Fröjmark and Lindblom (2008) found a bidirectional relationship between anxiety and insomnia over a year. Both studies indicated that age, gender, and prior disorders could influence the relationship.

All in all, the association between sleep problems and anxiety is ambivalent. As the field of long-covid is new, it is essential to explore further the relationship between sleep problems and anxiety within long-covid patients in this study.

Positive Emotions as Protective Factor in Long-Covid Patients

Because of the challenges, long-covid introduced, finding ways and opportunities to deal with the adverse effects is important. One possibility is to introduce and focus on positive emotions. Positive emotions like happiness are highly valued and can lead to long-term benefits in different domains, including physical and mental health, work and interpersonal relationships. Further, they can elevate the mood and help cultivate resilience, resulting in coping abilities with the negative consequence of long covid (Israelashivili, 2021; Sun et al., 2020). An important new insight was given by Israelashivili (2021). He found during the first wave of the Covid-19 (spring 2020) that in the general population, individuals experiencing high levels of positive emotions showed higher levels of resilience. Resultingly, individuals who experienced high levels of negative emotions showed poorer resilience. These results implicate that, especially during the covid-19 pandemic, positive emotions can help cope with the global pandemic's consequences on health. Therefore, it would be interesting to investigate whether positive emotions have a beneficial impact on long-covid patients as well.

Happiness is one of the most known and experienced emotions among positive emotions. It is defined as the absence of negative affect and the presence of positive affect, which may result in higher overall life satisfaction (Demiur & Weitkamp, 2007). Based on existing literature, directly and indirectly, happiness promotes physical health, qualitative social relationships, productivity, and prosocial behaviour, as well as resilience for psychiatric

disorders like anxiety (De Neve et al.,2013; Li et al., 2019). Supporting evidence was found recently by Spinhoven et al. (2021). In particular, happiness seemed to predict psychiatric disorders and the symptom severity. They found that higher happiness levels enhanced recovery from depression and reduced anxiety symptoms (Spinhoven et al., 2021).

What can also lead to happiness is gratitude, also a positive emotion. Sansone and Sansone (2010) defined gratitude as *'The appreciation of what is valuable and meaningful to oneself and represents a general state of thankfulness and/or appreciation.'* (p.3). Gratitude was found to be a fundament of mental health and is associated with psychological, physical, and relational benefits as well (Emmons & Mishra, 2011). Grateful individuals seem to show more fulfilling, meaningful relationships and lower levels of psychopathological symptoms, like anxiety and depression (Algoe et al., 2010; Kendler et al., 2003; Petrocchi & Couyoumdjian, 2015). Thus, practicing gratitude may be a possibility to increase happiness and thereby promote and maintain mental health in long-covid patients after hospitalization. However, in the context of long-covid, it is still unclear if positive emotions like happiness and gratitude can decrease anxiety. Therefore, this study will focus on happiness and gratitude and their relationship with anxiety in long-covid patients.

Experience Sampling Method

Most research concerning long-covid has been performed by retrospective cross-sectional surveys that asked participants about their symptoms over a certain period, such as past week or month (Sykes et al., 2021; Taquet et al., 2021). Such retrospective measurements can include sensitive risks, such as recall biases, as behaviors and feelings are measured simultaneously. This could lead to under-or overestimation of emotions and experiences and diminish the validity of measurements (Conner & Barrett, 2012). Therefore, the results are not guaranteed to represent the variables of interest and need to be handled cautiously. Secondly, the variables of interest are measured only once in a cross-sectional design. Therefore, causal relationships between variables cannot be explored (Reinecke et al., 2014). Further, fluctuations of behavior, feelings, or contextual moderators within individuals remain undetected in this type of method. Especially, in this study it is crucial to study patients' feelings and behaviours, to be able to put the symptoms of long-covid into a broader context.

Lastly, cross-sectional designs hinder separating between-person and within-person associations (Hamaker, 2012; Lundh & Falkenström, 2019). Therefore, this leads to undetected relationships on the intra-individual level (within-person) and inaccurate inferences. The analysis on the intra-individual level can give more insight into the fluctuations in daily sleep

problems and their influence on daily changes in anxiety levels. The between-person analysis would give an insight into the overall association of sleep problems and anxiety and show whether people who generally sleep well also experience less anxiety or vice versa.

A longitudinal measurement design seems more suitable to overcome the limitations of cross-sectional designs. With this, fluctuations in the variables of interest can be explored more in-depth. The experience sampling method (ESM) will be a more appropriate method for accomplishing the aim of the study, because it allows the exploration of participants' actual behaviors and emotions in real-world settings when they occur (Conner & Barrett, 2012; Larson & Csikszentmihalyi, 2014; Sato & Kawahara, 2011). It measures the variables of interest, such as behaviour and feelings, multiple times per day through self-reports or passive measurements such as smartwatches. Therefore, ESM separates experiences from recall and global biases, resulting in less room for recall biases through the real-time assessment (Napa Scollon et al., 2009).

Further, multiple measurement points within a day over a certain period give richer insight into fluctuations within the day and their longitudinal nature. Another advantage of ESM is that the study is not limited to between-person investigations, and researchers can obtain more substantiated information at the within-person level (Curran & Bauer, 2011). Lastly, ESM acquires large datasets from small sample sizes compared to the cross-sectional design. The smaller sample size is advantageous as it facilitates the recruitment process in an ESM study (Verhagen et al., 2016).

As this study will focus on sleep problems, anxiety, and positive emotions, it is advantageous to obtain real-life assessments multiple times per day to detect possible temporal associations between the variables. This measurement technique could provide a more detailed insight into the emotions and behaviour of long-covid patients compared to the previous cross-sectional designs. Therefore, the knowledge obtained from this study regarding the relationships between the variables will help to develop targeted treatments and interventions for long-covid patients.

Aim of the Study

In sum, long-covid is a relatively young field of research and requires exploratory and longitudinal investigations. Therefore, the current study aims to investigate further the relationship between sleep, anxiety, and positive emotion in long covid patients. It seeks to identify the relationship between sleep problems and anxiety in long covid patients after hospitalization. Further, this study will draw attention to the influence of positive emotion,

namely happiness and gratitude, on anxiety of long covid patients. As a result, it will be possible to find protective factors to enhance the mental well-being of long-covid patients. In summary, the variables of interest will be anxiety, sleep problems, and positive emotions within long-covid patients six months after hospitalization. Based on the abovementioned paragraphs, the following research questions (RQ) were formulated:

What is the temporal association between sleep problems and anxiety in Dutch people with long-covid six months after hospital discharge?
Based on the literature, it is expected that there is a bidirectional relationship between sleep problems and anxiety.

Is the association between sleep problems and anxiety different when comparing between-person and within-person over time in Dutch people with long-covid at least six months after hospital discharge?
Significant associations are expected on between- and within person levels.

To what extent are positive emotions, namely gratitude and happiness, protective factors for increasing anxiety in Dutch individuals with long-covid six months after hospital discharge?
For RQ 3, it is expected that gratitude and happiness may help to decrease anxiety in long-covid patients. Therefore, negative but significant associations are expected. These results would offer new insights for the development of intervention programs.

Method

This study concerns a complementary study derived from an ongoing longitudinal cohort study investigating the long-term consequences of Covid-19 in hospitalized patients. All participants have been hospitalized due to Covid-19 at the Medisch Spectrum Twente (MST). Patients filled out surveys immediately, three months, six months, nine months and twelve months after discharge from the hospital. Demographical data, such as age, gender and Body Mass Index (BMI) and comorbidities were assessed to identify possible risk factors.

Participants

The study consisted of patients discharged between September 2020 and February 2021 from the MST. They were recruited via purposive selection using data from the cohort study. Forty-two patients, who have been discharged from the hospital after acute covid-19, at least three months before, were chosen. This was done based on their self-reported health changes compared to one year ago (prior to covid-19 hospitalization), which was assessed with the Dutch SF-36 (Aaronson et al., 1998). Two cut-off scores were indicated. Scores of 50 or higher indicated that patients recovered (similar to or better than one year ago) and scores ≥25 (much worse than a year ago), indicated that patients did not recover. Patients who indicated a worsening of their health status one year after hospital discharge (n=32) and ten patients who indicated improvement one year after hospital discharge were invited to participate in an interview, of which 16 non-recovered and 10 recovered patients were willing to participate in the interview. Within the interview, self-reported recovery status was reassessed based on the participants responses.

The inclusion criteria concerning the ESM study were that patients (1) discharged from the hospital after PCR-confirmed of acute covid-19, (2) at least 18 years or older, (3) proficient in Dutch for the interviews and surveys, (4) fluctuating symptoms like fatigue, pain dyspnoea and/or cognitive dysfunction attributed (primarily) to post covid or lack of recovery from the virus. Based on the inclusion criteria and the interviews, 11 of the 16 participants were eligible and willing to participate in the ESM study. Further, one participant was excluded from the study as he did not meet the required compliance rate of 30% or more of the ESM surveys (Delespaul, 1995). Thus, the data of the remaining 10 participants were analyzed in this ESM study.

As can be seen in Table 1, the mean age of the sample was 59.7 years (*SD*=6.02), which ranged from 48 to 76 years. The gender was equal among women (*n*=5, 50%) and men (*n*=5,

50%). The average BMI of the sample was around 31.7, which indicates that the participants were slightly obese. To be more concrete, five of the participants (50%), were overweight, whereby the other half was categorized in healthy weight or morbidly obese. The educational level varied within the sample. Three of the participants (*n*=3, 30%) had at least the level of junior general secondary education (MAVO), two participants (*n*=2, 20%) had higher vocational education and the other half of the participants were differently educated, from lower vocational education (LTS) up to university (WO). Concerning comorbidity, eight participants (80%) indicated that they had one or more comorbidities such as rheumatism, hypertension, liver, or diabetes.

Table 1

Descriptive Data of Variables of Interest

Participants Characteristics	N	%	Minimum	Maximum	Mean	SD
Age	10		48	76	59.7	6.02
BMI	10		21.97	41.77	31.7	7.4
Gender						
Female	5	50%				
Male	5	50%				
Comorbidities						
Rheuma	3	30%				
Hypertension	3	30%				
Liver	1	10%				
Diabetes	1	10%				
Depression	1	10%				
Other	3	30%				

Note. SD=Standard Deviation, BMI= Body Mass Index

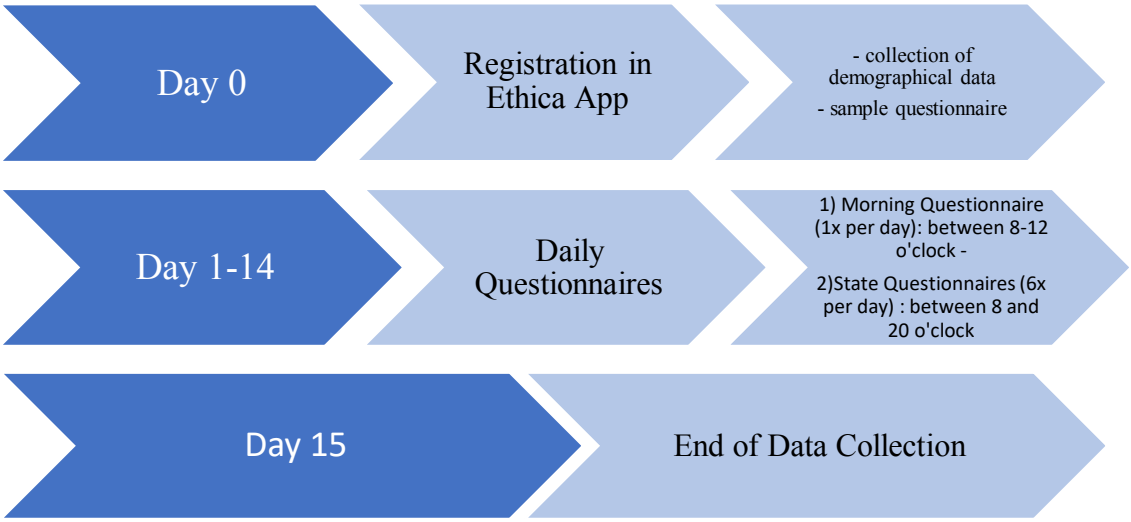
Design

This study was built on the initial study and based on the experience sampling method (ESM) design. Based on previous studies and the guidelines of Conner and Lehman (2012), it was decided that the study would last 14 days. Thus, a minimum of a week is required for representative sample data, and after 14 days, data quality tends to decline (Hektner et al., 2007; Stone et al., 1991). Data was gathered between September 1 and November 5, 2021. Figure 1 provides an overview of the study design and the structure. The study used the signal-contingent

sampling strategy whereby participants received unpredictable notifications within two-hour time intervals. Considering the fact that five to eight measures per day are needed for optimal test results, it was decided that seven measures per day would be optimal for this study (Klasnja et al., 2008).

Figure 1

Overview of the Study Design



Note. Each arrow displays what was done on the particular day.

Procedure

The study was approved by the Ethics Committee of the Faculty of Behavioural Sciences of the University of Twente in May 2021 (approval number: 210799). For the data collection, the Ethica app was used. First, the Ethica questionnaire was pilot tested by the researcher (n=7) and by non-hospitalized sufferers from post covid (n=4). Based on the evaluation, some minor issues were fixed, such as non-visible VAS-scale lines. As already mentioned, the researcher interviewed chosen individuals at the beginning of the study. With this, the first informed consent was taken by the participants. After the interviews, patients who met the inclusion criteria were asked to participate in the ESM study.

When starting the ESM, individuals needed to download the Ethica app on their smartphone, which contained all necessary information concerning the study and the procedure. Within the app, participants were once again asked for their informed consent. On the first day of the study, participants received a practice survey identical to the actual survey to get comfortable with the app. As shown in figure 1, participants were asked to complete a morning

questionnaire each morning between 8-12 o'clock that assessed their sleep quality. Furthermore, they received unpredictable notifications for the mood and symptoms survey six times daily. These notifications were between 8-10 o'clock, 10-12 o'clock, 12- 14 o'clock, up until 20 o'clock. To avoid memory biases and increase the data's ecological validity, it was decided that the surveys were only accessible for 15 minutes after the notification. In total, participants had to answer seven surveys throughout the day for 14 days in a row. On the 15th day, the study was closed, and the participants were thanked for their participation.

Materials

The ESM study's surveys and data collection were conducted with the platform Ethica Data (Ethica Data, 2020) on the participants' smartphones. As can be seen in Figure 1, the daily assessment consisted of two surveys: (1) a retrospective sleep survey in the morning once a day and (2) a momentary mood, behavior, and symptoms survey six times per day. The items included in the questionnaires were based on studies on related topics (Brys et al., 2020; Dietvorst et al., 2021; Jean et al., 2020; Lenaert et al., 2020; Maes et al., 2015; Worm-Smeitink et al., 2021).

The morning survey (see Appendix A) included six single-answer questions. The first item asked the participants to rate their health from the previous day. The other five items assessed participants' sleep last night. More concretely, hours of sleep, trouble with sleeping, and the number and length of naps throughout the day. Sleep problem was assessed with the following question: 'To what extent did you experience sleep difficulties last night?' (Brys et al, 2020; Jean et al., 2020). No further explanation was given to this item, to avoid interpretation biases. Participants could rate their answers on a scale from one 'no trouble' to five 'extreme trouble.'

The second survey assessing momentary symptoms and complaints consisted of 21 questions divided into three categories: somatic symptoms, affect, and context. The somatic symptoms concerned the momentary complaints such as mental and physical fatigue, shortness of breath, and headache. Participants could choose out of the given answer possibilities, ranging from zero (strongly disagree) to six (strongly agree) (Bentall et al., 1993; Kroenke et al., 2001; Worm-Smeitink et al., 2021; Yorke et al., 2010).

The questions from 10 to 19 concerned the affect states, such as feeling anxious, happy, and grateful (e.g., 'Right now I feel anxious.'; 'Right now I feel grateful.'; or 'Right now I feel happy.' (Appendix B). Participants were able to rate on a 7-point Likert scale ranging from one (strongly disagree) to seven (strongly agree) (Brys et al., 2020; Dietvorst et al., 2021; Maes et

al., 2015; Worm-Smeitink et al., 2021). The last question focused on the participants' momentary activity and was concerned about what they were doing before completing the survey.

Data Analysis

The data analysis of the ESM data was conducted with the statistical program SPSS version 27 (International Business Corporation). The standardized β coefficients were interpreted according to Cohen (1988), whereby values >.5 (-.5) were considered as strong association, >.3 (-.3) considered as moderate association, and >.1 (-.1) considered as weak association. As this study was a subpart of a more extensive study, only the measures relevant to the scope of this study were used, namely trouble with sleep, anxiety, gratitude, and happiness.

The first step of the data analysis was to compute descriptive statistics of variables of interest to get an overall impression. All research questions of this study were answered by performing Linear Mixed Models (LMM) with an autoregressive covariance structure (AR(1)) to model the repeated measures. An AR(1) covariance structure was selected due to the assumption of homogenous variances and the assumption that correlations between measurements exponentially decline over time (Kincaid, 2005). This method was chosen as it is known for handling longitudinal repeated measurement data and missing data of participants who did not answer all surveys, which is a common problem in ESM studies (Verhagen et al., 2016). As this study concerns longitudinal data analysis, in all LMMs, measurement timepoints were set as repeated measurements and participants as subjects. To obtain standardized regression estimates, all variables of interest were transformed into z-scores; therefore, all analyses of this study were performed with the standardized variables.

To examine the first research question concerning the association between sleep and anxiety, a new lagged (lag6) variable for anxiety was created. This was done because the questionnaire asked about the sleep of the previous night. Therefore, the anxiety variable needed to be lagged to the previous day, to investigate whether anxiety in the previous day predicted sleep problems in the night. The first LMM was performed in which trouble with sleep was set as the dependent variable and the lagged anxiety variable from the previous day was included as the fixed covariate. To test the bidirectionality, a second LMM was performed in which anxiety was set as the dependent variable and trouble with sleep in the previous night included as the fixed covariate.

To examine the between-person and within-person association between sleep and anxiety, person mean scores (PM) and person-centered mean scores (PC-M) of trouble with sleep, and the lagged anxiety variable were computed. In the first analysis, anxiety was set as the dependent variable, and trouble with sleep PM (between-person) and trouble with sleep PM-centered (within-person) were set as fixed covariates. In the second LMM, trouble with sleep was set as the dependent variable. The lagged anxiety PM (between-person) and lagged anxiety PM-centered were included as the fixed covariates.

To answer the last research question, whether there is an association between positive emotions and anxiety within long-covid patients, a LMM was performed as well. To examine this research question, anxiety was set as the dependent variable and gratitude and happiness were included as fixed covariates. In addition, two separate LMMs were also conducted with only one fixed covariate, either gratitude or happiness. Again, anxiety was set as the dependent variable in both LMMs.

Results

Descriptive Statistics

The response rate of the sample ranged between 30% to 92% of all measurements, with a mean response rate of 60.8% (*SD*=20%). The mean anxiety score of the total sample over the two weeks was 2.78 (*SD*=1.86), with a possible score range of 1 (not at all) to 7 (strongly anxious). Hereby, the mean of 2.78 shows that the sample was not very anxious. The mean score for gratitude during the total assessment period was 4.75 (*SD*=1.41) and the mean score of happiness of the total sample was 4.18 (*SD*=1.54), whereby one indicated 'not at all' and seven 'very strongly' (see Table 2).

Table 2

Descriptive of Variables of Interest

Variables	Minimum	Maximum	Mean	SD
Anxiety	1	7	2.78	1.86
Gratitude	1	7	4.75	1.41
Happiness	1	7	4.18	1.54

Note. SD= Standard Deviation

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Description of Anxiety

Figure 2 represents the mean anxiety score of each participant on each day of the total assessment period. As it can be seen, most of the participants scored between one and four, indicating lower anxiety levels. For instance, participants 4, 6, 9, and 10 seemed to experience constantly no or little anxiety over the total assessment. Whereby participants 3 and 7 experienced higher levels of anxiety in general. Participant number 3 seemed to experience a stable level of anxiety around six throughout the total assessment. Whereby participant number 7 started the assessment period with a moderate level of anxiety around four, which increased during the assessment up to seven, indicating extreme anxiety. Prominent was also participant number 8, who experienced some fluctuations. The participants started the assessment with anxiety around three, which increased abruptly on the seventh day and remained at the level of five for three days. However, on the 10th day, the anxiety level seemed to decrease. In general,

most participants showed stable levels of anxiety, and only a small number of participants showed fluctuations over the course of the assessment of this study.

Similarly, the anxiety scores seemed fairly consistent during the day (Figure 3). The highest fluctuations can be seen in participant number 4. This participant started the day with relatively high anxiety, which decreased abruptly at noon and increased in the afternoon, and then decreased again in the evening. Overall, almost all participants showed stable anxiety scores over the assessment day.

Figure 2

Mean Anxiety Score per Participant on each Day during the Total Assessment Period

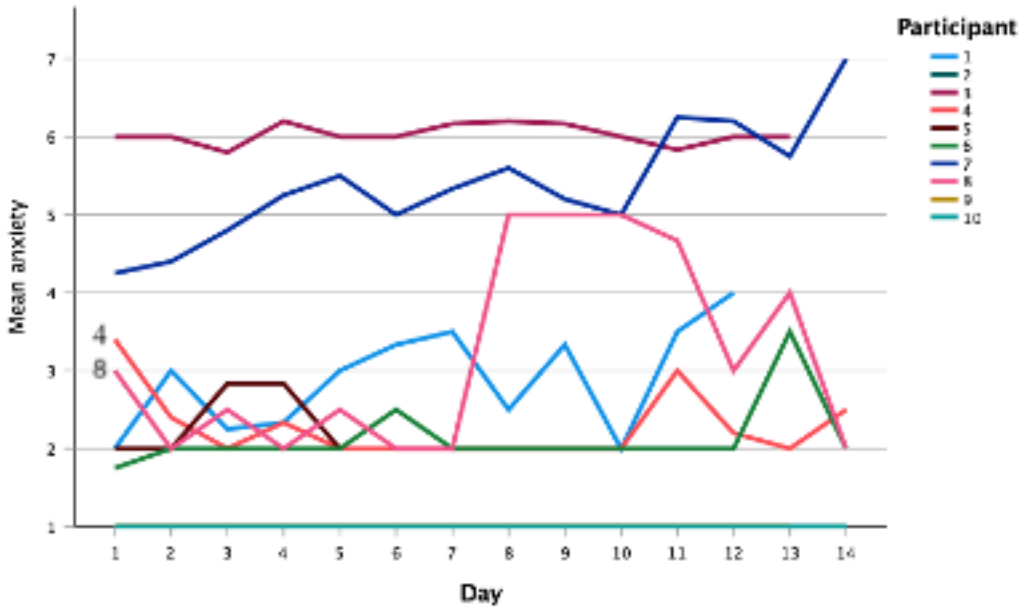
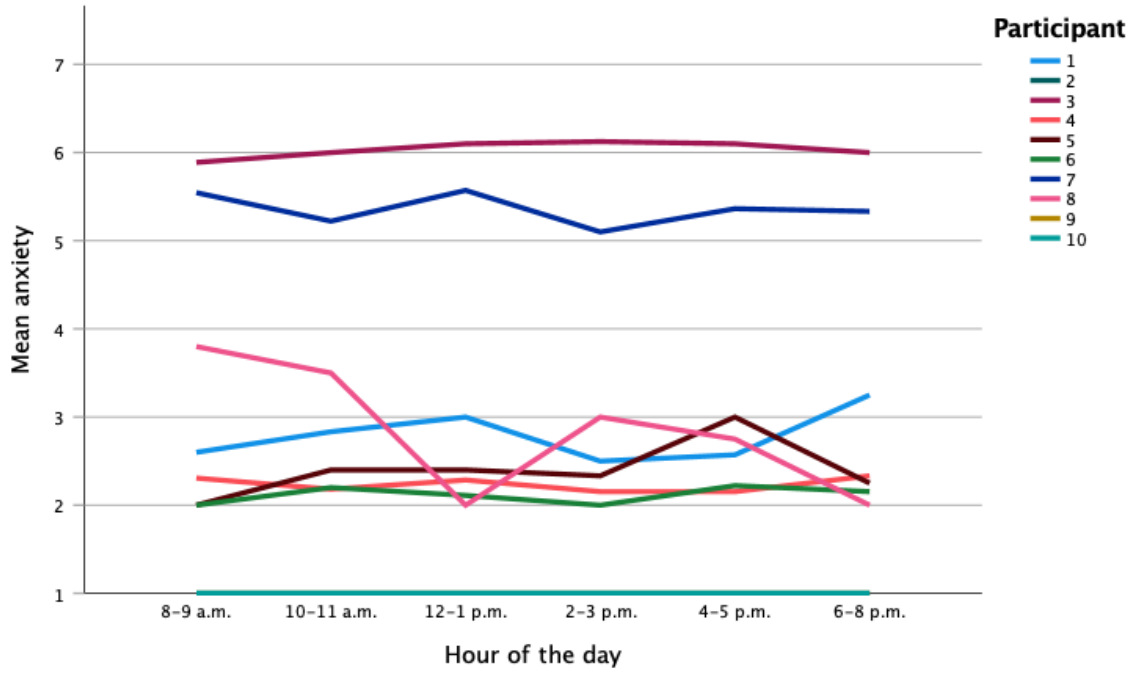


Figure 3

Mean Anxiety Score per Participant per Time-Point during the Day during the Total Assessment Period



Description of Sleep

The participants experienced, to some extent, trouble with sleeping during the total assessment period. In Figure 4 can be seen that the participants experienced in 43.6% of all nights a little bit of trouble with sleeping. A lot to extreme trouble with sleep was in total around 10% of the nights. On the other side, almost one-quarter of the nights, they reported having no problems at all with sleeping. In general, the participants slept during the assessment between six to eight hours (43.1%) and four to six hours (39%). None of the participants slept more than ten hours during the data collection. However, the sample group indicated that they slept less than four hours in 13.7% of the nights (Appendix C). The percentage of whether respondents took a nap or not was almost equal (no=55.5%; yes=44.5%) (Appendix D). Participants who took a nap during the day slept mostly between 30 minutes and two hours. Only in 6% of all the naps, participants slept between two to three hours (Appendix E).

Figure 4

Rate of Nights Scored on Trouble with Sleep of the Sample during the Total Assessment Period

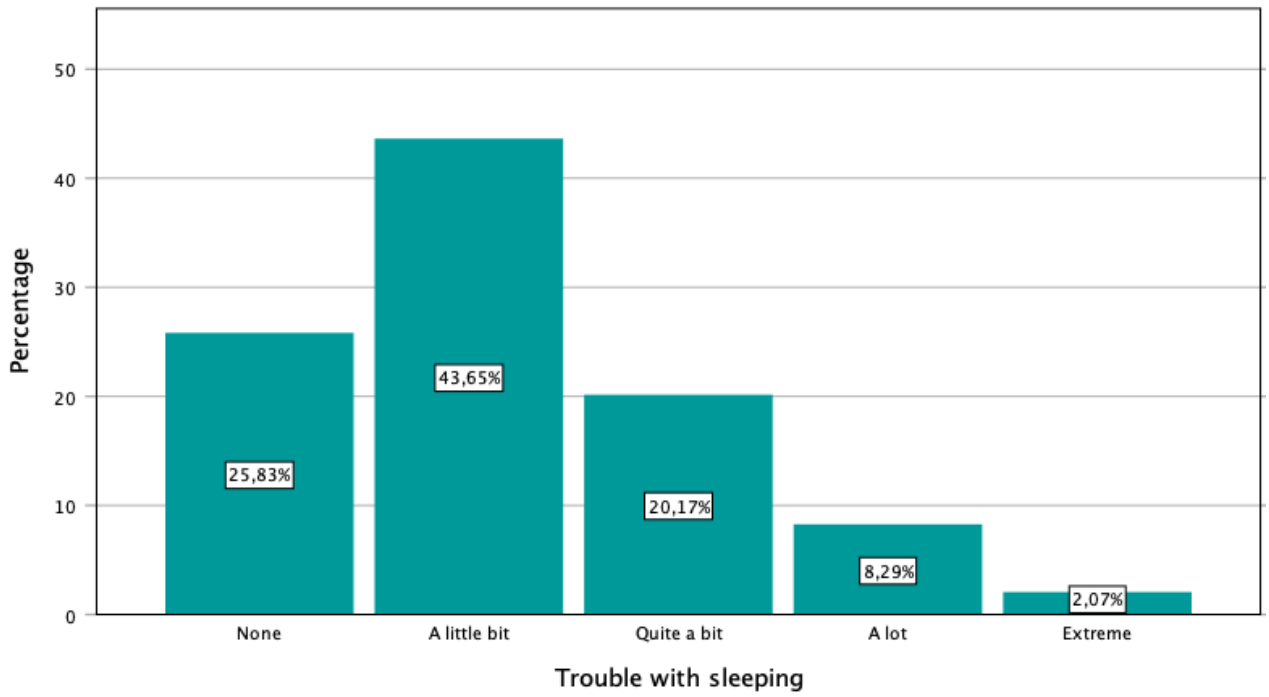


Figure 5

Sleep Difficulties Scores per Participant on each Day during the Total Assessment Period

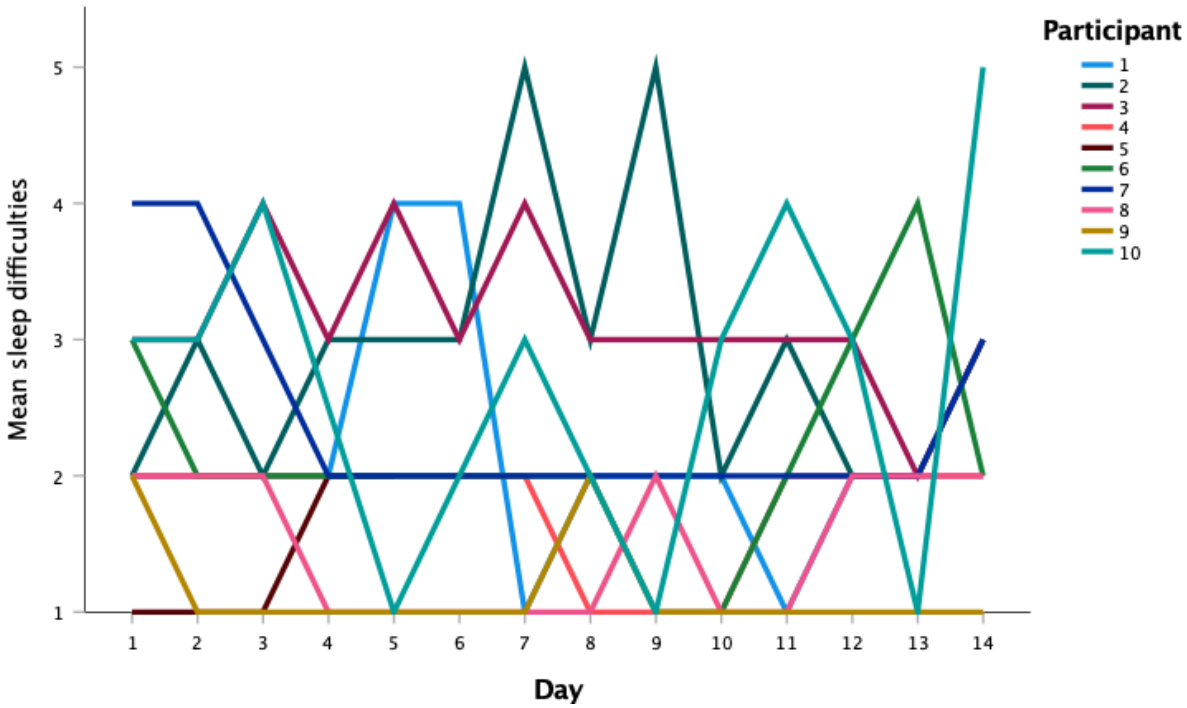


Figure 5 represents the sleep difficulties of each participant over the 14 days of the assessment. As it can be seen, sleep difficulties varied more for some participants than for others. Participants 3, 5, 8, and 9 seemed to experience approximately the same amount of sleep difficulties most of the time and experienced slight fluctuations of one score. On the other hand, there were also patients experiencing high fluctuation in their sleep problems, such as participants 2, 6, and 10. For instance, participant number 10 seemed to have very irregular problems with sleep. At the beginning of the assessment, the participant indicated moderate sleep problems. However, this seemed to change during the assessment because the patient indicated a different severity of sleep difficulties each day. Also, participant number 2 indicated fluctuations in sleep difficulties. This participant seemed to experience sleep difficulties between moderate to extreme, whereby the scores fluctuated up to three. Therefore, it can be assumed that the stability of problems within individuals seemed to be unrelated to the severity of their sleep difficulties. Overall, Figure 5 shows that there were participants who experienced stable problems with sleep difficulties, but also participants for whom sleep difficulties varied almost every day during the assessment of this study.

Association Anxiety and Trouble with Sleep

Concerning the temporal association between anxiety and trouble with sleep, both independent variables were lagged. The lagged anxiety variable gave the anxiety scores at the former day and sleep difficulties indicated the difficulties of the last night. The performed LMMs indicated that there was no significant association in both directions. The first LMM, in which the lagged variable of anxiety was the predictor of trouble with sleep, showed non-significant results (β=0.009; p=0.84*)*. Non- significant results were also found in the second LMM, in which anxiety was the dependent variable and trouble with sleep in the previous night the predictor (β= .02; p=.57). The results revealed that there was no momentary association between these variables.

Within-and Between Analysis of Anxiety and Trouble with Sleep

Two linear mixed models were conducted to analyze between-person and within-person associations between anxiety and sleep problems in both directions. First, the model in which sleep difficulties was set as the dependent variable was conducted. In this model, the person-mean and person-mean-centered scores of the anxiety at the former day were set as the predictors. Hereby, the between-person association was shown to be insignificant (β=.21, p=.2). The within-person association was not significant as well (β=-.002, p=.9). The second LMM

for anxiety as dependent variable with person-mean and person-mean scores of troubles with sleep the previous night, indicated similar results. Also here, the between-person (PM) association was shown to be small and not significant (β= .28, p=.15). The within-person association was shown to be weak and not significant (β=.01, p=.69). More detailed findings of the models were summarized in Table 3.

Table 3

Summary of the Linear Mixed Models for Within and Between Analysis of Standardized Anxiety and Trouble with Sleep

Dependent variable	Parameter	β	SE	df	t	Sig.	CI 95% Lower Bound	CI 95% Upper Bound
Trouble with Sleep	Lagged Anxiety (PM)	.21	.16	19.06	1.31	.2	-.12	.54
	Lagged Anxiety (PMC)	-.002	.02	461.18	-.11	.9	-.04	.04
Anxiety	Trouble with Sleep (PM)	.27	.18	14.89	1.5	.15	-.11	.39
	Trouble with Sleep (PMC)	.01	.02	464.43	.39	.69	-.04	.06

Note. SE= Standard Error, df= Degrees of Freedom, CI= Confidence Intervals, PM=Person-mean, PMC= Person-mean-centered, Lagged Anxiety= Anxiety at the former day, PM and PMC of Trouble with Sleep= Sleep of previous night

Anxiety and Positive Emotions

Description of Gratitude and Happiness

The gratitude score of the sample ranged from one (not at all) to seven (very strongly), with a mean score of 4.75 (*SD*=1.41). This indicated that the participants experienced moderate to high levels of gratitude (Table 2). To have a closer look at the gratitude scores two figures were created. Figure 6 shows the mean gratitude score per participant on the different time points from 8 am until 6 pm during the day. Most of the participants showed none to very little fluctuations over the day in their gratitude score. The fluctuations were mostly around one score. For participants number 1, 3, 5, and 6 gratitude seemed to decrease after 4 pm in the afternoon. Overall, participants' gratitude seemed to be stable during the day.

Looking at Figure 7, which represents participants' individual mean gratitude scores on each assessment day, gratitude differed more clearly throughout the assessment for some participants. Thus, participant number 4 fluctuated between moderate to high levels of gratitude, with a change of two points. Participants 3 and 7 started the survey with little gratitude, which fluctuated but increased at the end of the assessment to moderate levels of gratitude, indicating that they felt more grateful at the end of the assessment period. For the other participants, such as 2, 8, 9, and 10, their gratitude levels remained stable over the course of the assessment. For instance, they reported to experience constantly higher levels of gratitude. Further, participants experiencing less gratitude also reported more fluctuations and showed an inconsistency in their gratitude, which can be seen in participant number 7. Overall, the participants reported to experience moderate to high levels of gratitude during the 14 days. Even though their gratitude remained relatively stable during the day, some participants still showed individual variations in the course of the total assessment period.

Figure 6

Mean Gratitude Score per Participants per Time-Point on each Day during the Assessment Period

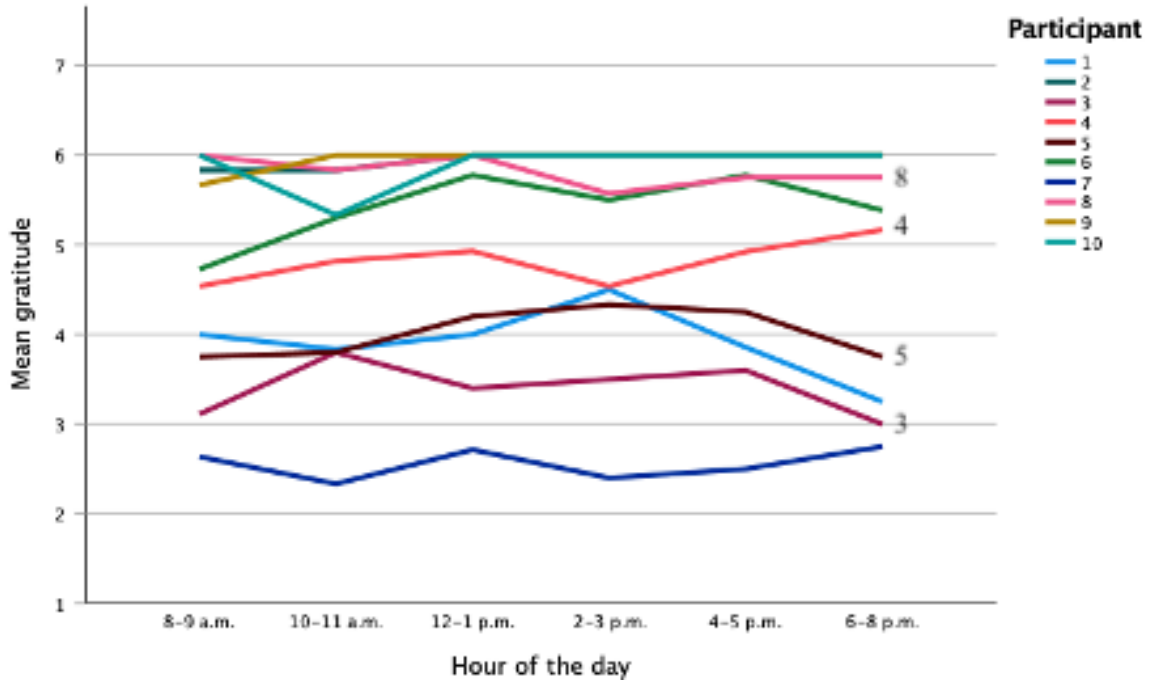
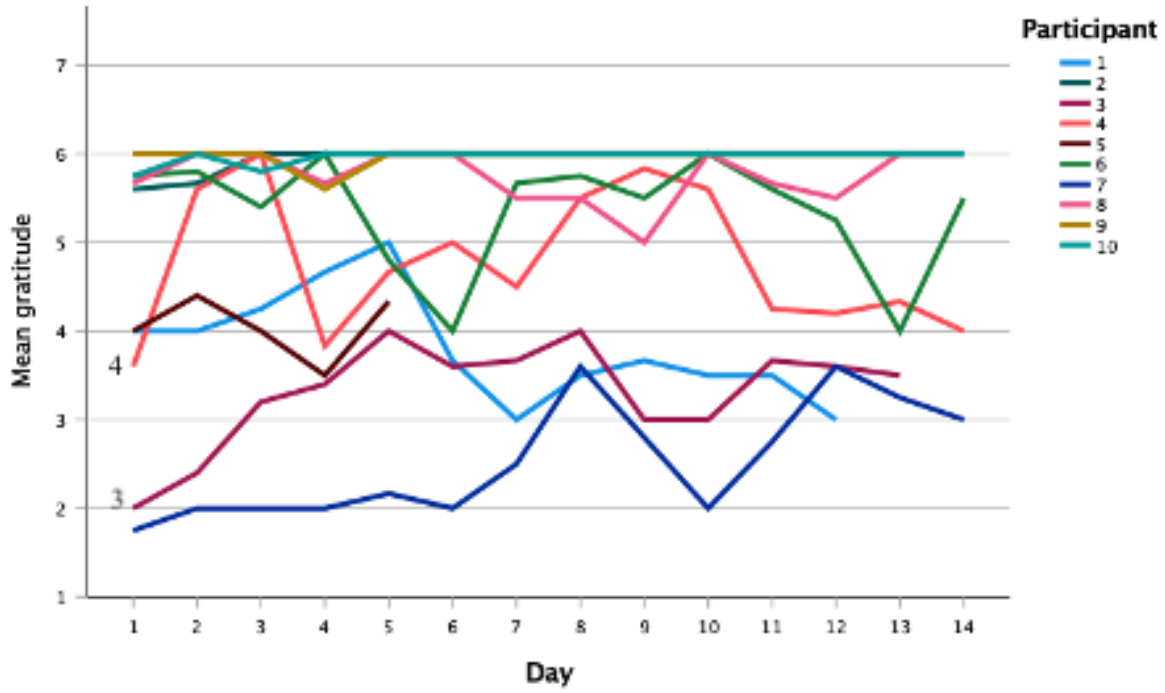


Figure 7

Mean Gratitude Score per Participant on each Day during the Total Assessment Period



The mean happiness score of the total sample was 4.18 (*SD*=1.54). Figure 8 represents the individual happiness mean scores of the participants during the different time points. It can be stated that happiness also seemed very stable during the day for most of participants, namely 3,4,7,8, and 9. The other participants showed small fluctuations, which also did not seem to be significant. What can be seen clearly is that the severity of the feeling happiness seemed to be stable. In other words, participants who felt generally less happy, such as participants 3 and 7, also felt during the different time points less happy and by this showed less variations. In Figure 8, two groups of participants can be observed. On the one hand, eight participants who scored above the happiness score of 3.5. On the other hand, two participants (participant number 3 and 7) who stood out in the bottom area of the graph and indicated lower levels of happiness. The mean happiness scores of each participant during the 14 days are displayed in Figure 9. When compared to gratitude, fewer fluctuations can be seen in their daily scores. However, participant number 5 experienced fluctuations between moderate to high happiness levels. Participants number 3 and 7 reported not only lower levels of gratitude but also lower levels of happiness during the 14 days. Overall, when compared to the other variables, most participants seemed to experience small fluctuations around one or two scores in happiness during the total assessment of 14 days.

Figure 8

Mean Happiness Score per Participant per Time-Point during the Assessment

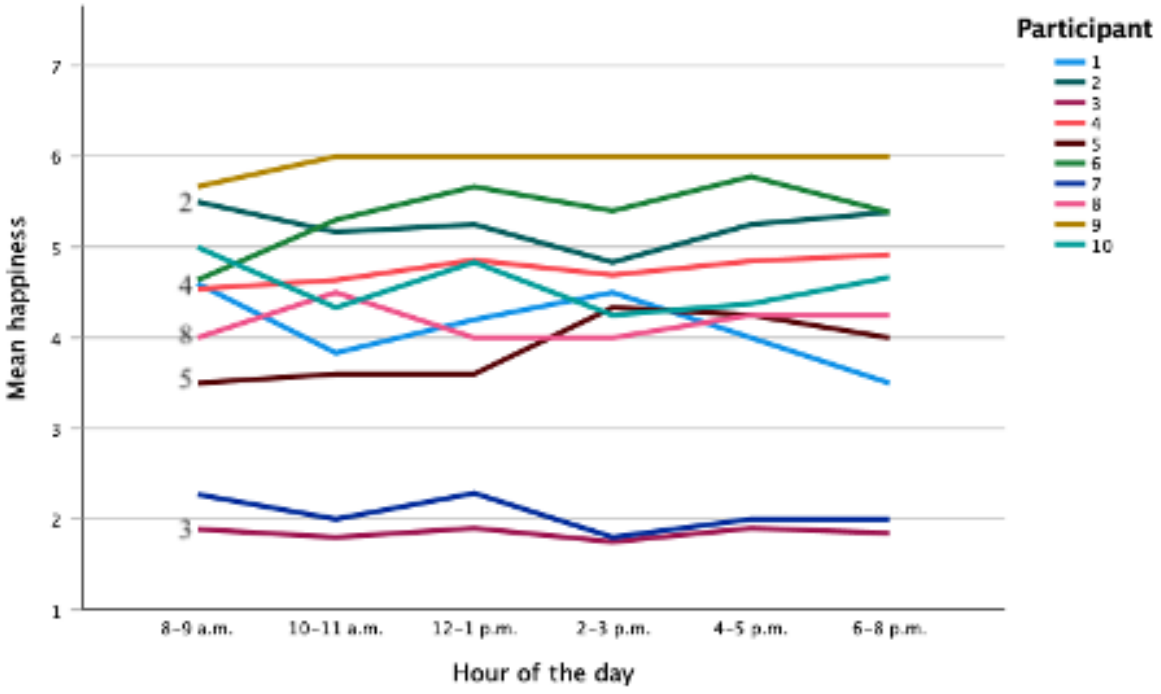
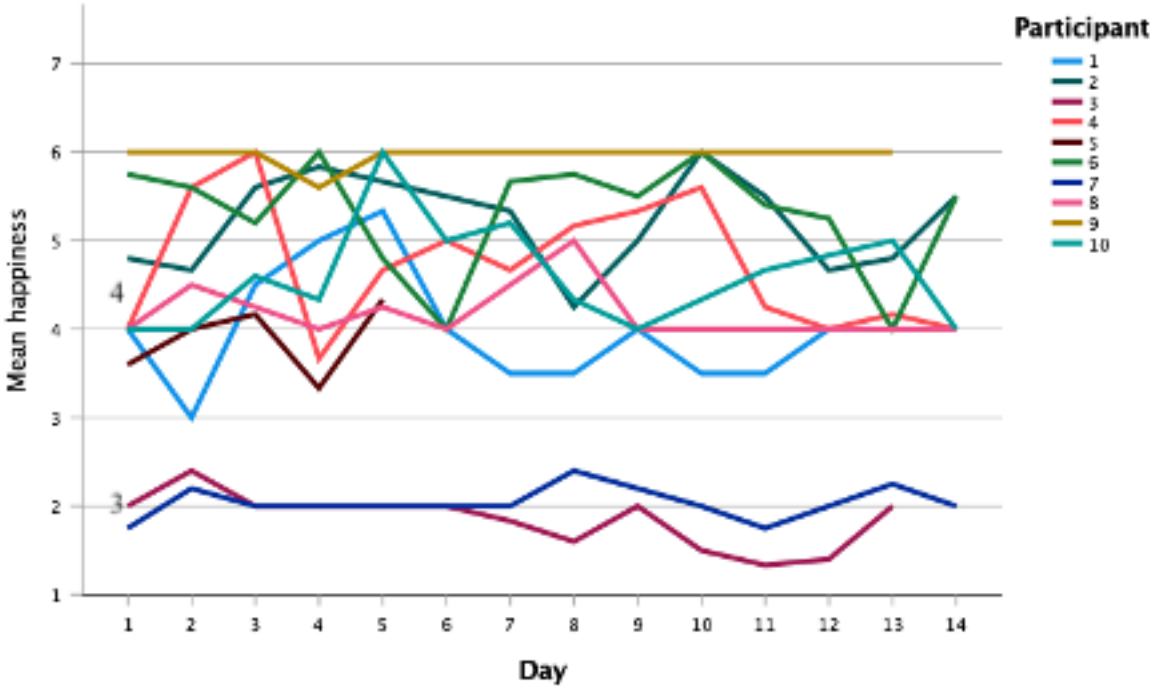


Figure 9

Mean Happiness Score per Participant on each Day during the Total Assessment



Association Between Anxiety and Happiness and Gratitude

In the LMM, in which both positive emotions, happiness and gratitude were included as fixed covariates, a significant but rather weak and small negative association between anxiety and happiness was found (β=-.07, p=.04). Gratitude was not associated with more or less anxiety (β=-.01, p=.67). Resultingly, happiness was significantly associated with less anxiety, however the association was very small (Table 4). To test, whether the associations would change when including the fixed covariates separately in LMM's two additional LMMs were performed. In the first LMM, happiness was included as the only fixed covariate and anxiety as the dependent variable. This model was significant (β= -.7, p=.01*)* but the standardized beta did not change when including happiness separately. The second LMM, in which gratitude was included as the only fixed covariate and anxiety as the dependent variable, was non-significant (β= -.04, p=.1*)*.

Table 4

Summary of Linear Mixed Model for Standardized Anxiety as the Dependent Variable and Happiness and Gratitude as Fixed Covariates

Dependent variable	Parameter	β	SE	df	t	Sig.	CI 95% Lower Bound	CI 95% Upper Bound
Anxiety	Happiness	-.07	.03	463.27	-2.01	.04	-.13	-.001
	Gratitude	-.01	.03	464.35	-.42	.67	-.07	.04

Note. SE= Standard Error, df= Degrees of Freedom, CI= Confidence Intervals

Discussion

The current study aimed to better understand the association between anxiety and sleep problems over time and to further explore the association between anxiety and positive emotions, namely happiness and gratitude, in long-covid patients. On average, the sample experienced little anxiety and felt moderately happy and grateful during the total assessment. The severity of emotions seemed to be stable over the day. However, some fluctuations were observable when looking at the course over the 14 days. Some participants experienced variations in the severity of sleep problems and anxiety. Within gratitude and happiness, a few individual variations were also seen. However, most participants experienced these emotions relatively stable throughout the assessment period. The results of this study showed that sleep problems and anxiety in long-covid patients were not related to each. It was found that neither the general level of sleep problems nor the daily fluctuations in sleep problems were related to the momentary experiences of anxiety and vice versa. Concerning the association between positive emotions and anxiety, no association between anxiety and gratitude was found. However, it was found that happiness and anxiety were related, whereby the association was relatively small.

Against expectations, the current ESM study could not suggest a bidirectional or one-direction association between anxiety and sleep problems. Also, literature describing the etiology of sleep problems and anxiety showed ambivalent results. Some studies indicated a bidirectional association (Alvaro et al., 2013; Jansson-Fröjmark and Lindblom, 2008), whereby other studies only indicated a single direction association (Johnson et al., 2006; Narmandakh et al., 2019). As most studies focused on the etiology of sleep problems and anxiety, they investigated the variables within young target groups. This could be a reason for contradicting results, as this study investigated the variables in an older age group (Mage= 59.7years) after hospitalisation due to covid-19. As this study concerns anxiety and sleep problems within long-covid patients, it is essential to differentiate between the current study and studies in other populations. Further, most of the studies focused on anxiety disorders such as generalized anxiety disorder (GAD) or separation anxiety disorder (SAD) (Shanahan et al., 2014). In contrast to this study, they used validated questionnaires such as the generalized anxiety disorder-7. In this current study, anxiety was only measured with one item. The focus was on experiencing anxiety, rather than having an anxiety disorder, as long-covid patients are known to experience high levels of anxiety due to various factors, such as job fears, fears about the future, and long-covid symptoms which persist over long periods (Pataka et al., 2021). These

factors are not considered in the current anxiety questionnaires yet. Therefore, it would be interesting to measure anxiety with a questionnaire focusing on the Covid-19 pandemic and long-covid symptoms. The measurement of sleep problems could also be another reason for contradicting findings. Since the participants in this study had to fill out questionnaires many times a day for 14 days, special attention was drawn to ensure that the questionnaires were not too extensive, which is why sleep problems were addressed with one item. Alimoradi et al. (2021) indicated that studies investigating sleep problems during the covid-19 pandemic mostly used the Pittsburgh Sleep Quality Index (PSQI) to measure sleep problems. Therefore, the different results could be due to the used questionnaires in the studies.

As one of the first studies, this ESM study explored sleep problems and anxiety over two weeks. This enabled the assessment of the temporal association within the 14 days and to detect patterns of internal and situational variations within the participants' daily lives. Previous cross-sectional studies (Zhuo et al., 2020) could not provide such information and only covered a small part of it (Myin-Germeys et al., 2009; Palmier-Claus et al., 2011). Pataka et al. (2021) investigated sleep problems in long-covid patients and indicated that sleep disturbances were highly prevalent among covid-19 patients in the long term. The current study detected that the severity of sleep problems and anxiety were not stable over the study period. Especially in sleep problems, some larger fluctuations were seen for some participants. For instance, for one patient, sleep problems ranged from not at all to extreme problems. Regarding anxiety, it was seen that the severity of anxiety was not linked to the time of day. Changes in anxiety were observable when looking over the 14 days. Therefore, it is assumed that sleep problems and anxiety were affected by internal or environmental factors which are not known yet. However, these factors could be momentary health conditions, certain types of pain, or fatigue, which are also known to be long-covid symptoms (Lopez-Leon et al. (2021). For later interventions, it is essential to consider the individual variations in anxiety and sleep problems and to investigate them further.

Regarding the second research question, whether there were between-person and within-person effects between sleep problems and anxiety, no different effects in both groups were found. Although there are already numerous studies suggesting a bidirectional association between anxiety and sleep problems, there are still few studies separating between- and within person effects. As this study also focused on a very specific sample group, namely long-covid patients, yet no comparable studies exist. But also here, the measurement of the constructs could be a reason for the insignificant outcomes. Narmandakh et al. (2019) distinguished between and within effects in the bidirectional association between anxiety and sleep problems in a sample

of young adolescents. They indicated that when anxiety increased compared to the last measurement, sleep problems were also more likely to increase. In this study, some individual variations in the variables were observable, however they were not influential.

Concerning the third research question of whether there is an association between anxiety and positive emotions, namely gratitude and happiness in long-covid patients, a relationship between anxiety and happiness was found. However, the relation of happiness with anxiety was minimal (β=-.07). Further, it was found that gratitude and anxiety were unrelated, which means that higher levels of gratitude did not predict less anxiety in long-covid patients. This finding contradicted previous findings in other populations (Algoe et al., 2010; Kendler et al., 2003; Petrocchi & Couyoumdjian, 2015). One reason for the distinct results could be the perception and definition of gratitude. Within the field of gratitude research, there is still a lack of agreement on the construct of gratitude. On the one hand, gratitude is perceived as an emotion that would occur after someone receives help which is perceived as costly or valuable. On the other hand, it is perceived as a disposition. Gratitude on a dispositional level would mean that a person has a more positive nature and appreciates the positive in the world (Wood et al., 2010). This differentiation was not made in this study; thus, it could be a reason for the insignificant association. However, this study found that gratitude remained rather stable within the subjects. This could be an implication that in this study gratitude was measured on a dispositional level and not as an emotion. Gratitude as a trait is expected to show less variability, as it is assumed that a person feels from nature more or less grateful (Wood et al., 2010). Nonetheless, expressing gratitude more frequently and reminding individuals of gratefulness has been shown to improve wellbeing and generate more happiness in individuals (Toepfer et al., 2012). Regardless of the association between anxiety and gratitude, it still seems to be important to focus on gratitude and its possible benefits on long-covid patients. Further, this study found that happiness and anxiety were related, but this association was very small and almost not affecting. Therefore, it cannot be said that happiness predicted less anxiety in long-covid patients. However, the benefits of gratitude and happiness on mental health are known and even though no association with anxiety could be detect, positive emotions still might have a positive influence on long-covid patients. Therefore, it is important to further investigate positive emotions in long-covid patients to detect possible protective factors.

Strengths, Limitations and Future Research

Against expectations, the findings of this ESM study contradicted the outcomes of previous cross-sectional studies in other populations, which might be related to the strengths

and limitations of this study. One strength of this study was that it provided the first detailed exploration of long-covid symptoms, in this case, anxiety, sleep problems, gratitude, and happiness over 14 days. Although the association between sleep problems and anxiety was already well researched, this was not the case within long-covid patients, as this is a new field of research. This study gave detailed insights into the symptoms mentioned above in long-covid patients, which are essential when developing interventions to reduce long-covid symptoms.

Furthermore, in contrast to previous cross-sectional studies, this study was an intensive longitudinal study investigating the overall associations of the variables of interest. With the help of the ESM, it was possible to analyze participants' momentary feelings and thoughts and their actual experiences of themselves during the assessment period (Trull & Ebner-Priemer, 2009). In other words, this study could obtain their momentary responses, contrary to cross-sectional studies. In cross-sectional studies, participants reported their feelings and thoughts retrospectively, which could lead to memory biases as previous experiences can be under-or overestimated (Conner & Barrett, 2012; Larson & Csikszentmihalyi, 2014). This was avoided in the current ESM study due to real-time assessment and therefore, the ecological validity of the study was increased (Araujo et al., 2007; Conner & Barrett, 2012; Sato & Kawahara, 2011).

Another strong point of this study was the longitudinal design, which was, an assessment period of 14 days. This design enabled a more precise and new perspective to analyze the association between the variables of interest and to determine potential group-level associations over time that were not known yet. The effects of anxiety on sleep problems and vice versa within individuals and between-person were demonstrated, resulting in a more precise illustration of the associations over time (Curran & Bauer, 2011). Thus, individual variations could be seen and analyzed further. Furthermore, the length of the assessment period allowed to measure fluctuations within the variables of interest. Lastly, although the sample consisted of ex-hospitalized participants with symptoms, the compliance rate of the daily measurements was considerably high (M=60.8%).

On the other side, several limitations of the study also need to be highlighted. The sample consisted of ten Dutch patients hospitalized in the same hospital, which can limit the generalizability of the current study's findings. Also, the participants in this study were around 60 years (*SD*=6). Extending the age range and the sample size could improve the generalizability of the results. Third, 80% of the participants indicated having one or more comorbidities. The analysis did not consider comorbidities as the general aim was to assess the association between anxiety and sleep problems. However, since the beginning of the Covid-19 pandemic it is known that pre-existing health conditions, such as hypertension or diabetes

are strongly related to a higher risk of infection, mortality or disease severity among covid-19 patients (Ejaz et al., 2020). Further, it was confirmed that individuals with pre-existing conditions reported persisting symptoms beyond 12 weeks after the infection with the covid-19 virus (Adab et al., 2022). Therefore, it may be that individuals with comorbidities, such in this sample group with hypertension, diabetes, and liver problems, experienced higher levels of anxiety due to the risk of being infected with the virus and the long-covid consequences. For this reason, it might be that comorbidities confounded the association between anxiety and sleep problems. To obtain more precise data and test this assumption, it might be helpful to address whether comorbidities were maybe a confounding variable and by this influenced the association between anxiety and sleep problems in long-covid patients.

Another limitation of this study was the evaluation of the variables as they were assessed with single-item questions. Albeit the variables were measured six times per day, they still lacked detailed insight. As long-covid is still an emerging field of research, it would have been of interest to assess the variables of interest with more context. For example, by using open questions concerning anxiety to understand what long-covid patients fear. Also, underlying reasons for participants' happiness and gratitude were still unknown. As within this study, primarily insignificant results were obtained. More detailed insights into the variables would be helpful to understand and investigate them more effectively.

The final limitation of this study is related to the period of assessment of 14 days, which was selected to enhance the response rate and decrease the drop-out rate (Csikszentmihalyi, 201). Even though the frame of two weeks was already a difference compared to the cross-sectional designs, it is possible that potential long-term associations between sleep problems and anxiety and between anxiety and positive emotions were not detected. Lastly, in this study the between analysis were performed with the data of ten participants. This could also be a reason for the lack of correlations when comparing to cross-sectional studies with larger sample groups. A more extensive and longitudinal study with a larger sample size would allow the analysis of association in long term on between-person level and detect possible confounding variables.

Based on this study's strengths and limitations, future research should investigate anxiety and sleep problems with more than one item to obtain more accurate and precise results. Furthermore, as this study concerned long-covid, which is not yet well researched, open questions would help investigate the variables more in-depth. To understand the association between sleep problems and anxiety, it is important to know what kind of anxieties long-covid patients experience and how they are related to sleep problems. Hereby, open questions would

give participants the room to express their opinions and thoughts without being influenced by the researchers (Reja et al., 2003).

This study could not detect a relationship between anxiety and sleep problems, but it was seen that the severity of anxiety and sleep problems differed between participants. However, due to the small sample size, no subgroups of anxiety and sleep problems were created. Future studies with a larger sample size should consider creating subgroups such as weak, moderate, and extreme levels and investigating associations between subgroups. Further, they should also consider performing the between subject analysis in a larger sample size, as in this study it was done with the data of ten participants, which is rather low for between subject analysis. This might reveal associations which were not seen in this study.

Next, as already mentioned, the participants indicated comorbidities at the beginning of the study, which were not considered during the data analysis due to time restrictions. However, studies found that comorbidities increased anxiety in patients as they worried about being infected with the virus and experiencing severe covid-19 symptoms (Sayeed et al., 2020). Therefore, it could be important to investigate possible confounding variables when investigating the relationship between anxiety, sleep, and positive emotions.

Lastly, positive emotions were important variables in this study, as they were considered protective factors. Further analysis of these variables could help to develop interventions for long-covid patients. Therefore, also here research on the between-person and within-person effects should be conducted preferably in a lager sample size. Additionally, no lagged analysis was performed when considering the association between positive emotions and anxiety. Performing lagged analysis between positive emotions and anxiety in future studies would allow to see the directional influence these variables have on each other over time. Further, single case studies would be helpful to investigate the variables of interest in an individual. The analysis on individual levels could obtain important insight for developing individual treatment plans and interventions for long-covid patients.

Conclusion

The current ESM study was one of the first studies collecting longitudinal data for the intensive analysis of the association between anxiety, sleep problems, and positive emotions in ex hospitalized long-covid patients. The outcomes of the study suggested that anxiety and sleep were not related to each other, which means that sleep problems did not predict anxiety and vice versa. It was also found that there were no within and between-person effects, which means that the general level of sleep problems and the daily fluctuations in sleep problems were not

related to the experience of anxiety. As this was tested in both directions, neither the general level of anxiety nor the daily fluctuations in anxiety were related to the momentary experience of sleep problems. Regarding the analysis of anxiety and positive emotions, it was found that there was only a significant but small association between anxiety and happiness. No significant association could be found between anxiety and gratitude. The current ESM data explored a relatively new research field, making the study unique and essential for research. The study may contribute to a better understanding of the long-covid symptoms and the variations within the symptoms.

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Appendices

Appendix A

Morning Questionnaire

The morning questionnaire needed to be answered once a day and was available between 08.00 o'clock and 12.00 o'clock. Participants received a reminder at 10.00 o'clock. The questionnaire consisted of 6 items, but only items of interest will be shown.

How many hours did you sleep last night?

- Less than 4 hours
- Between 4 and 6 hours
- Between 6 and 8 hours
- Between 8 and 10 hours
- More than 10 hours

To what extent did you have **trouble sleeping** last night?

- No trouble
- A little bit of trouble
- Quite a bit of trouble
- A lot of trouble
- Extreme trouble

Appendix B

Symptoms and Complaints Survey

This survey needed to be answered six times per day, between 08.00 o'clock and 20.00 o'clock. The surveys were accessible for 15 minutes. Only the items of interest will be shown:

Right now I feel **anxious.**

- Strongly disagree
- Disagree
- Disagree a little bit
- Neutral
- Agree a little bit
- Agree
- Strongly Agree

Right now I feel **grateful.**

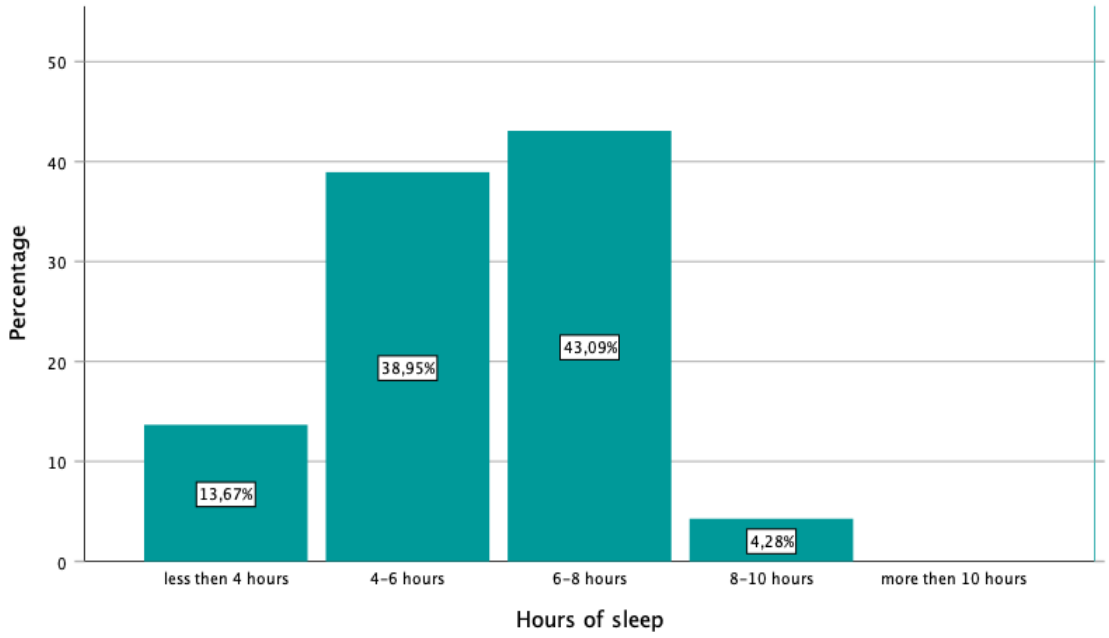
- Strongly disagree
- Disagree
- Disagree a little bit
- Neutral
- Agree a little bit
- Agree
- Strongly Agree

19. Right now I feel **happy.**

- Strongly disagree
- Disagree
- Disagree a little bit
- Neutral
- Agree a little bit
- Agree
- Strongly Agree

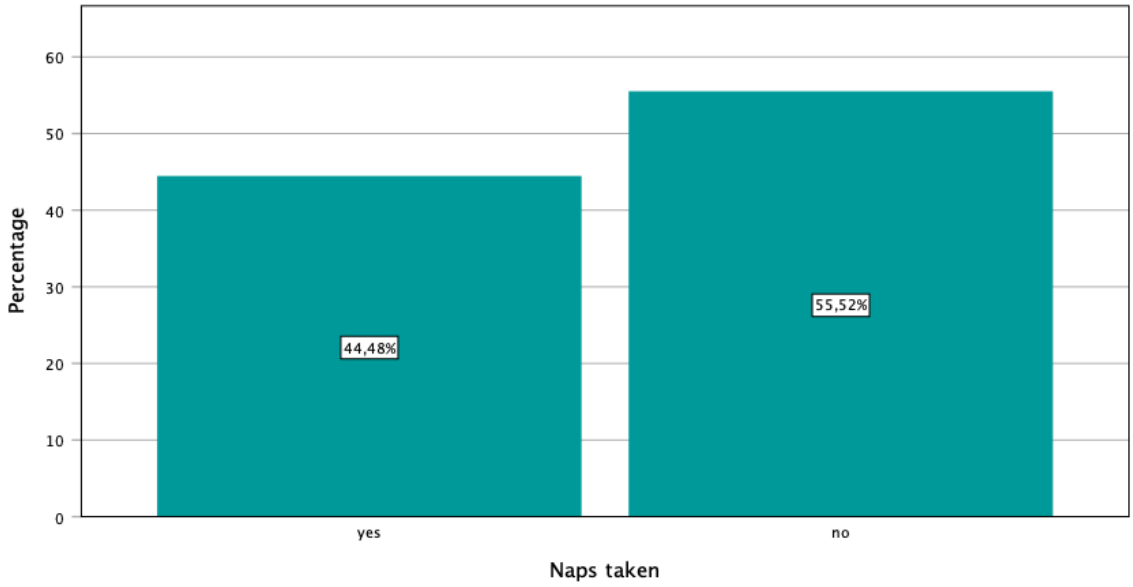
Appendix C

Percentage of scores on 'hours of sleep' of the sample during the assessment period



Appendix D

Percentage of scores on 'nap taken yesterday' of the sample during the assessment Period



Appendix E

Percentage of the scores 'Length of sleeps in hours' of the total sample during the assessment