

# A population-level analysis of changes in diel rhythms and sleep and their association with negative emotions during the outbreak of COVID-19 in China

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## Research Article

**Keywords:** Diel rhythm, sleep, negative emotion, COVID-19, quarantine

**Posted Date:** September 15th, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-75920/v1>

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# Abstract

**Introduction:** From December 2019, COVID-19 (novel coronavirus pneumonia) began spreading in China and has significantly affected the industrial economy and peoples' daily lifestyle. Beginning on January 23, the public was asked to constantly stay at home for quarantine and community containment.

**Methods:** To assess the effects of the changes in diel rhythms and sleep and their association with negative emotions during the COVID-19 outbreak, a questionnaire was administered to 451 responders for analysis between January 20, 2020, and January 31, 2020, in China.

**Results:** We found that 34.6% of the participants reported diel rhythm disturbance. Moreover, 67.2% of the participants presented negative emotions regarding the pandemic situation, including worry, fear, downheartedness, anxiety, depression, and stupefaction; among them, worry was the most prevalent. Gender and age were significant factors for changes in the diel phases and emotions. There was a correlation between diel rhythm alterations and negative emotions. Three factors, i.e., the Spring Festival holiday, quarantines and concern regarding the pandemic situation, were associated with changes in diel rhythms, sleep, and negative emotions during the pandemic period. Holiday jet lag, quarantine (or community containment), and concerns regarding the pandemic situation had significant effects on diel rhythms, sleep and negative emotion in a substantial part of the population.

**Conclusions:** Our findings suggest that diel rhythms and sleep and their association with negative emotions in COVID-19 patients and the normal population need to be considered. Moreover, the adjustment of diel rhythms could help relieve negative effects and improve the global health during the pandemic period.

## Introduction

COVID-19 (novel coronavirus pneumonia) is a newly emerging severe acute respiratory infectious disease that is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. To suppress COVID-19 spread in China, 31 provinces, autonomous regions and municipalities declared a level 1 health emergency; furthermore, the public was required to stay at home for quarantine and community containment [2, 3]. This resulted in extensive lifestyle changes with the public continuously staying at home for long periods since January 23, 2020, and only leaving discreetly to shop for food and necessities was allowed.

The circadian clock controls the rhythmicity of physiology and behavior, which endows the adaptability to cycling environmental cues with a period of 24 h [4, 5]. Circadian rhythms display over a period of 24 h, i.e., entrained by natural daily environmental cycles, which are called diel, diurnal or nyctohemeral rhythms [6]. Moreover, circadian rhythms are affected by social cues, including working schedule, shift work, and jet lag [7]. Circadian rhythm disturbances cause disorders, metabolic diseases, and decreased immunity [8]. Circadian desynchronization is related to several mood disorders, including depression, seasonal affective disorder, and bipolar syndrome [9-13]. Confinement is also a social factor that has

been shown to affect diel rhythms. In the Mars500 mission that mimicked the impacts of confined cabin, Earth-Mars communication, and space tasks, the crew members showed prolonged sleep duration (8.4%), disturbed sleep-wake cycles and decreased sleep quality during the simulated voyage [14].

During the outbreak of COVID-19 in China, multiple factors, including confinement due to quarantine and community containment, irregular lifestyle during the Spring Festival and concerns regarding the pandemic situation, may have imposed influenced the diel rhythms, and mood of the public. To this end, we conducted a nationwide survey of public sleep-wake schedules, exercising, dining, and mood from January 20, 2020, to January 31, 2020, which revealed that alterations in diel rhythms, sleep and negative emotion occurred in a substantial proportion of participants.

## **Materials And Methods**

### **Measurements and procedures**

Due to the COVID-19 outbreak, a lockdown was implemented in Wuhan on January 23; from this time, Chinese people across the country began staying at home for quarantine. We designed a questionnaire to collect information regarding diel rhythms, sleep, and negative emotions. The surveyed period was between January 20, 2020, and January 31, 2020, which comprised nine days after the emergency was launched. Furthermore, the Spring Festival holiday was between January 20, and February 2. To discriminate changes between the period after and before (control) the emergency launch, most sections consisted of questions comparing changes in variables between the period January 20, 2020, and January 31, 2020, and the period of one week before January 20, 2020.

The questionnaire obtained information on characteristics, diel rhythms and sleep, negative emotions, and the subjective evaluation of the effects of three factors (Spring Festival holiday, concerns regarding pandemic situations, and constant quarantine) on diel rhythms and sleep. We assessed sleepiness with the Karolinska Sleepiness Scale (KSS) and we used the simplified Beck Depression Inventory (BDI) to evaluate changes in emotions [15 16]. The questions regarding diel rhythms and sleep were designed by referring to the Morningness-Eveningness Questionnaire [17]. The questionnaire was administered on the Wen Juan Xing platform website ([www.wjx.cn](http://www.wjx.cn)) between February 2, 2020, and February 3, 2020, with 451 filled forms being collected (see details in suppl. protocol).

### **Participant characteristics**

The 451 Chinese responses were obtained from participants in 31 provinces, autonomous regions, municipalities and Special Administrative Regions by random. Three responders were from other countries (Fig, 1A and suppl. file 1). There were 170 (37.7%) and 281 (62.3%) male and female participants, respectively. The responders were in different ages, education levels and occupations (suppl. file 2).

### **Statistics**

The Kolmogorov-Smirnov test was conducted to assess the normality of samples [18]. The Wilcoxon signed-rank test was performed to assess between-period differences in diel rhythms and sleep [19]. Between-group differences were analyzed using the Mann-Whitney U test with statistical significance set at  $P \leq 0.05$  [20]. Bivariate (Spearman) correlation analysis was used to assess the between-variable correlation for each comparison [21]. SPSS 26 (IBM, USA), GraphPad Prism 8 (Graphpad Software Inc., USA), and RStudio 3.6.1 (RStudio Inc., USA) were used for statistical analysis and picture drawing.  $P \leq 0.05$  was considered significant with the significant values being \*  $P < 0.05$  and \*\*  $P < 0.01$ . Additional details regarding the method and the results of correlation coefficient analysis can be found online in the suppl. protocol.

## Results

### Changes in the diel rhythm, sleep-wake cycle, dining and exercise

We found that 85.6% (386) of participants self-reported changes in at least one variable related to diel rhythmicity. The sleep schedule became irregular and regular in 31.0% (140) and 14.6% (66) of the participants. To assess the changes in the diel phases, we classified the participants into three chronotypes based on their sleep onset time during the survey period as follows: early-type, slept before 22:00; intermediate type, slept between 22:00 and 24:00; late-type, slept after 24:00. In addition, irregular type denotes people who showed no fixed sleep time. Both the time of falling asleep and waking up are diel phase references. In this study, we used the former parameter to assess the changes in the diel phase since there was a significant positive correlation between both parameters (suppl. file 3).

Among the 451 participants, during the quarantine period, 34.6% (156) of the participants reported chronotype changes. Among these 156 individuals, 81 individuals (18.0%) showed a delayed phase while 33 (7.3%) showed an advanced phase (Fig. 1B). The most prevalent (13.7% participants [62/451]) changed from the intermediate type to the late type (62/451) (Fig. 1C). During the quarantine period, the proportion of participants who woke up prior to 7:00 before and during the quarantine period was 35.5% (160) and 10.6% (48), respectively. In contrast, the fraction of participants who woke up after 9:00 before and during the quarantine period was 12.9% (58) and 42.1% (190), respectively (suppl. file 4). Compared to the parameters before the quarantine period, 16 (3.6%) and 119 (26.4%) participants showed an increase and decrease in exercise, respectively. 20 (4.3%) and 95 (21.1%) participants reported more and lesser dining times, respectively (Fig. 1D,E).

Among the teachers, 29.6% (21/71) of individuals showed a delayed sleep phase, which was a notable increase from the average (18.0%). Among the students, 9.5% (20/210) and 13.8% (29/210) reported an advanced and delayed sleep phase, respectively (Fig. 2A). Among the participants, 102 (36.3%) females and 38 (22.4%) males reported an irregular time of sleeping. Difficulty waking up and falling asleep was reported by 18.8% and 14.7% of the males, respectively, and 24.9% and 23.5% of the females, respectively (Fig. 2B, C). In addition, 26.7% (27/101) individuals aged between 41 and 50 years showed a delayed sleep phase, which was approximately 9.0% more than the proportion in other age groups (suppl. file 5).

There was a positive correlation between gender and irregular rhythms ( $r=0.130$ ,  $P=0.006$ ), delayed waking up ( $r=0.163$ ,  $P=0.001$ ), and difficulty falling asleep ( $r=0.115$ ,  $P=0.015$ ). Furthermore, there was a positive correlation between age and increased nocturnal wake-up episodes ( $r=0.122$ ,  $P=0.011$ ) and prolonged daytime napping ( $r=0.236$ ,  $P<0.001$ ); moreover, age was negatively correlated with KSS-rated sleepiness ( $r=-0.115$ ,  $P=0.015$ ). Education level was positively associated with increased exercise ( $r=0.094$ ,  $P=0.046$ ). Exercise was negatively associated with self-reported diel change ( $r=-0.109$ ,  $P=0.021$ ), difficulty falling asleep ( $r=-0.109$ ,  $P=0.021$ ), delayed degree of waking up ( $r=-0.164$ ,  $P<0.001$ ), and delayed degree of falling asleep ( $r=-0.125$ ,  $P=0.012$ ) (Fig. 2D and suppl. file 3).

### **Analysis of changes in sleep duration and quality**

The questionnaire was used to assess the quantity and quality in terms of daily total sleep duration, daytime nap duration, nocturnal wake-up times, and KSS-rated sleepiness. During the quarantine period, 59.7% (269), 3.1% (14), and 37.3% (168) of the participants reported an increase, decrease, and no change in the daily total sleep duration during the quarantine period (Fig. 2F). Nocturnal wake-up episodes were associated with sleep quality and caused sleep fragmentation and sleep cycle disturbance. The female gender was positively associated with KSS-rated sleepiness ( $r=0.133$ ,  $P=0.005$ ). Education level was positively associated with prolonged daytime napping ( $r=0.154$ ,  $P=0.001$ ). Age was positively associated with increased waking episodes ( $r=0.122$ ,  $P=0.011$ ) and prolonged daytime napping ( $r=0.236$ ,  $P<0.001$ ) and negatively associated with KSS-rated sleepiness ( $r=-0.115$ ,  $P=0.015$ ) (Fig. 2G and suppl. file 3).

Compared to that in the control period, there was an increase in the incidence of nocturnal waking episodes (53, 11.8%) during the pandemic period. An assessment of KSS-rated sleepiness showed that most participants had a score of 5 (33.9%, 153). In addition, 123 (27.3%) participants had a score of 1-3, 319 (70.7%) had a score of 4-7, and 9 (2.0%) had a score of 8-10 (Fig. 2E). Furthermore, 12.6% (57) reported a subjective decrease in sleep quality (Fig. 2F). Before January 20, 2020, 27.9% (126) of the participants did not have a daytime napping habit; among them, 80.2% (101) maintained this habit after the emergency launch. Some of the participants with previous daytime napping did not report them during quarantine. The proportion of participants without daytime napping habits during the quarantine period was 49.0% (221) (Fig. 2F). Exercise was negatively associated with prolonged total sleep duration ( $r=-0.157$ ,  $P=0.001$ ) (Fig. 2G and suppl. file 3).

### **Analysis of changes in negative emotions**

The questionnaire assessed negative emotions, including worry, fear, downheartedness, anxiety, depression, and stupefaction, which might be associated with diel rhythms and sleep. Among the 451 participants, 303 (67.2%) showed at least one negative emotion as follows: worry, 257 (57.0%); anxiety, 231 (51.2%); stupefaction, 222 (49.2%); downheartedness, 214 (47.5%); fear: 208 (46.1%); and depression: 166 (36.8%). Moreover, 148 individuals (32.8% of 451) reported no obvious negative emotions. Among the six negative emotions, responders scored the highest on worry (average 2.18) with

16.4% (74/451) of the participants rated 4 (moderate negative emotion) or 5 (severe negative emotion). Furthermore, 7.1% (32/451) of the responders rated  $\geq 4$  on depression (Fig. 3A, B and suppl. files 6,7).

The age groups of 26-30, 18-25 and 31-40 years had the highest negative emotion averages, i.e., 2.26, 2.04 and 1.96, respectively (suppl. file 6). Age was negatively associated with worry, stupefaction, dismissal, anxiety, and fear (Fig. 3D and suppl. file 3). The averaged total scores in men and women were 1.97 and 1.90, respectively, with men showing higher scores than women on stupefaction (men 2.05; women 1.89), downheartedness (men 1.97; women 1.85), depression (men 1.74; women 1.60) and anxiety (men 2.05; women 1.97) (Fig. 3C and suppl. file 6). In addition, individuals with higher education levels reported more negative emotions (Fig. 3C and suppl. file 6).

### **Correlation coefficient analysis among changes in diel rhythms, sleep and negative emotions**

There was a positive correlation between total sleep duration and the frequency of irregular sleep-wake cycles ( $r=0.180$ ,  $P<0.001$ ), and changes in wake-up time ( $r=0.393$ ,  $P<0.001$ ), as well as a negative correlation between total sleep duration and changes in dining times ( $r=-0.187$ ,  $P<0.001$ ). Changes in sleep quality were positively associated with changes in wake-up time ( $r=0.094$ ,  $P=0.045$ ), and negatively associated with the frequency of irregular sleep-wake cycles ( $r=-0.102$ ,  $P=0.030$ ), difficulty falling asleep ( $r=-0.275$ ,  $P<0.001$ ), daytime sleepiness ( $r=-0.252$ ,  $P<0.001$ ), and changes in sleep onset time ( $r=-0.162$ ,  $P=0.001$ ). Increased waking times were positively associated with the frequency of irregular sleep-wake cycles ( $r=0.148$ ,  $P=0.002$ ) and increased difficulty falling asleep ( $r=0.160$ ,  $P=0.001$ ). Increased daytime napping was positively associated with changes in sleep-onset time ( $r=0.108$ ,  $P=0.029$ ) and changes in dining times ( $r=0.171$ ,  $P<0.001$ ) (Fig. 4A and suppl. file 3).

A negative correlation of changes in sleep quality was revealed with all the studied negative emotion types (worry, stupefaction, downheartedness, depression, anxiety and fear), with the following correlation coefficients:  $-0.116$  ( $P=0.014$ ),  $-0.130$  ( $P=0.006$ ),  $-0.180$  ( $P<0.001$ ),  $-0.127$  ( $P=0.007$ ),  $-0.134$  ( $P=0.004$ ), and  $-0.140$  ( $P=0.003$ ), respectively. Among the sleep parameters, prolonged daytime napping was negatively associated with stupefaction ( $r=-0.093$ ,  $P=0.047$ ); moreover, KSS-rated sleepiness was positively associated with stupefaction ( $r=0.125$ ,  $P=0.008$ ) and downheartedness ( $r=0.111$ ,  $P=0.018$ ). Regarding the diel rhythm parameters, changes in daytime sleepiness were negatively associated with fear ( $r=-0.098$ ,  $P=0.037$ ) and downheartedness ( $r=0.111$ ,  $P=0.018$ ). Changes in wake-up time were negatively associated with fear ( $r=-0.098$ ,  $P=0.037$ ) (Fig. 4B and suppl. file 3).

Among the diel rhythm variables, self-reported diel changes were positively associated with difficulty falling asleep, difficulty waking up, changes in wake-up time, and changes in sleep onset time, with the following respective correlation coefficients: 0.337, 0.426, 0.356 and 0.367. Furthermore, diel change was negatively associated with changes in dining times ( $r=-0.189$ ). Difficulty falling asleep was positively associated with difficulty waking up ( $r=0.252$ ), changes in wake-up time ( $r=0.131$ ,  $P=0.005$ ) and changes in sleep onset time ( $r=0.173$ ). Additionally, difficulty waking up was positively correlated with wake-up time ( $r=0.195$ ) and changes in sleep onset time ( $r=0.231$ ). Changes in wake-up time were positively associated with changes in sleep onset time ( $r=0.308$ ) and negatively associated with changes in dining

times ( $r=-0.212$ ). Total sleep duration was positively associated with increased sleep quality ( $r=0.229$ ) and increased daytime napping ( $r=0.141$ ,  $P=0.003$ ). Sleep quality was negatively associated with increased nocturnal wake-up episodes ( $r=-0.174$ ) (suppl. file 3).

### **Subjective assessments of the effect of quarantine on diel rhythms and sleep**

We assessed three potential factors: the Spring Festival holiday, concerns regarding the epidemic situation and constant quarantine and community containment. In this subjective assessment, the effects on diel rhythms and sleep were considered to be one entity. The responders reported the subjective assessments of these factors on diel rhythms and sleep using the corresponding scales 1-5. Among the 451 participants, 89.6% (404), 76.7% (346), and 88.0% (397) of the participants considered constant quarantine, holiday, and community containment, as the causative factors, respectively (rating  $\geq 2$ ) for diel rhythms and sleep disturbance (Fig. 4C,D and suppl. file 8).

There was a positive correlation of the Spring Festival holiday with daily sleep duration ( $r=0.292$ ,  $P<0.001$ ), sleep quality ( $r=0.123$ ,  $P=0.009$ ), delayed waking up time ( $r=0.160$ ,  $P=0.001$ ), irregularity in diel rhythms ( $r=0.130$ ,  $P=0.006$ ), KSS-rated sleepiness ( $r=0.127$ ,  $P=0.007$ ) and worry ( $r=0.150$ ,  $P=0.001$ ). Concerns regarding the pandemic situation were positively correlated with nocturnal wake-up episodes ( $r=0.112$ ,  $P=0.020$ ); and negatively related to sleep quality ( $r=-0.146$ ,  $P=0.002$ ) and the components of diel rhythms and negative emotions. Constant quarantine and community containment were positively related to total sleep duration, delayed waking up time, difficulty falling asleep and the degree of rhythms becoming irregular. There were positive relationships of constant quarantine, community containment, and five negative emotions, i.e., worry, stupefaction, depression, anxiety and fear (Fig. 4E and suppl. file 3).

Moreover, 80 participants (17.7%) listed that other factors could affect diel rhythms and sleep including family (38.8%, 31/80), work or schoolwork (30%, 24/80), environmental comfort (17.5%, 14/80), and economic pressure (2.5%, 2/80). Regarding environmental comfort we found that noise (3.8%, 3/80) and ambient temperature (2.5%, 2/80) could contribute to effects on diel rhythms and sleep (suppl. file 8).

## **Discussion**

In this study, we surveyed the changes in diel rhythms and sleep of 451 Chinese people during the traditional Spring Festival who had experienced quarantine and community containment for approximately two weeks during the outbreak of COVID-19. We show that from January 20, 2020, to January 31, 2020, the diel rhythms, sleep and negative emotions of a substantial part of the population were subject to change, owing to at least three factors: holiday, quarantine and concerns regarding the pandemic situation. In this study, we performed correlation coefficient analysis to address the possible associations among demographic characteristics, environmental factors, variables related to diel rhythms and sleep, and negative emotions.

Over the study period, there were changes in the diel rhythms of 386 individuals (85.6%) with 36.3% of these individuals developing irregular diel rhythms and sleep disturbance. Approximately 49.7% (224/451) of the responders showed a delayed wake-up time (Fig. 1D). There were sleep changes during the quarantine period, which was indicated by several parameters. First, 59.6% (269/451) of the participants showed increased total sleep duration (Fig. 2F). Nocturnal wake-up episodes are indicative of sleep disturbance; in our study, 47 (10.4%) participants reported increased nocturnal wake-up episodes, which was negatively associated with subjectively self-assessed sleep quality (suppl. file 3). There are close correlations among circadian rhythms, sleep, and emotions [9-13]. Our findings revealed extensive diel rhythm and sleep alterations during the pandemic period, which were negatively correlated with the six negative emotions (Fig. 4B).

Cain et al. analyzed diel changes in serum melatonin and core body temperature and reported that compared with men, women displayed more advanced phases of these variables [22]. Women have a shorter free-running period than men, which indicates gender-based differences in circadian patterns [23]. Consistently, in this survey female participants reported an earlier time of waking up and falling asleep than men did before January 20, 2020 (suppl. file 9). In contrast, after January 20, 2020, female participants reported a later time of waking up and falling asleep; moreover, they had higher ratios of delayed wake-up time and difficulty falling asleep than men did (Fig. 2C and suppl. file 9). There was a positive correlation between female gender and irregular sleep-wake cycles (Fig. 2D). These findings suggest that women could be more susceptible to the effects of the holiday, quarantine or concerns regarding the pandemic situation on the assessed parameters.

The majority of the responders (67.2%, 303/451) reported at least one negative emotion type, with worry being the most prevalent (57.0%; 257/451). Across all negative emotions, 7.1%-16.4% of participants reported very high scores (scales  $\geq 4$ ) (Fig. 3A,B and suppl. file 7), which suggests that a substantial part of the population had negative emotions. Circadian misalignment causes emotional deterioration [24-26]. We observed a negative relationship between fear and delayed waking up (Fig. 4B). The negative emotions could be more attributed to the pandemic situation than to the Spring Festival holiday.

Older individuals have been shown to have less negative emotions, which could be attributed to increased ability to regulate emotions [27, 28] Consistent with these previous studies, we observed a negative correlation between age and worry, stupefaction, downheartedness, anxiety, and fear (Fig. 3D and suppl. file 3). Exercise was negatively related to the degree of diel rhythms and sleep components (Figs. 2D, G and suppl. file 3), which suggests that appropriate exercise might improve sleep and diel rhythms. However, exercise was not associated with the six negative emotions (Fig. 3D and suppl. file 3).

Social jet lag caused by night work, shift work and transmeridian travel could cause circadian misalignment [29]. The traditional Spring Festival holiday lasted between January 24, 2020, and February 2, 2020, while the level 1 emergency was launched on January 23, 2020. Therefore, the periods for the three factors (Spring Festival holiday, quarantine, and concerns regarding the pandemic situation) might overlap.

To discriminate the effects of these three factors on diel rhythms and sleep, we analyzed their relationships with subjective self-assessed variables. We found that 63.2% (251/397) of the participants reported the holiday as a causative factor for diel rhythm and sleep disturbance. Moreover, a coefficient analysis revealed positive correlations between the Spring Festival and total sleep duration, sleep quality, KSS-rated sleepiness, delayed wake-up time, and self-reported changes in diel rhythms. However, among the six negative emotions, only worry was positively correlated with Spring Festival holiday (Fig. 4E and suppl. file 3), which suggests that holiday was not the primary cause of negative emotions.

Compared with the holiday, quarantine was correlated with more negative emotions, including worry, stupefaction, downheartedness, anxiety, and fear. Furthermore, 89.6% of the participants (404/451) reported that quarantine affected a number of diel rhythm components, including the growing irregularity of diel rhythms, difficulty falling asleep, delayed wake-up time and dining times. In addition, 346 (76.7%) of the participants reported that concern about the pandemic situation was significantly related to several sleep and diel rhythm variables, as well as all six negative emotions (Fig. 4E and suppl. file 3).

## Limitations

This study was conducted in the very early stage of pandemic outbreak hurriedly, bias may exist due to the limited quantity of the responders. This is the main limitation of this study implying that some of our findings should be interpreted with caution. For instance, though the overall negative association between age and negative emotions has been revealed, the quantity of participants who were < 20 years or > 60 years were very few (suppl. file 6). Therefore, the situation of these two parts of population remains unclear.

## Conclusions

Our findings show that quarantine and concerns regarding the pandemic situation contributed to the changes in sleep, diel rhythms, and negative emotions. Moreover, some factors, e.g., gender and age, might be causes for of the difference in some of the changes. These findings suggest that people who are not COVID-19 patients may also be subject to extensive influence. More than 4.0 million cases of COVID-19 have been reported worldwide as of May 14, 2020, and pandemic surveillance may last for additional months or even years [30]. Our findings could contribute to improvements in diel rhythms, sleep, and emotion during the pandemic period.

## Declarations

**Acknowledgements** The authors acknowledge the study participants for their contributions in making this study possible.

**Author contributions** SC, TH, XL, YX and JG: data analysis, manuscript writing. SC, TH, YT, CN, JL and XL: data collection.

**Funding** This work was supported by the Open Fund of the National Key Laboratory of Human Factors Engineering in the Astronaut Center of China (SYFD180051809K) and the National Natural Science Foundation of China (31871188).

### **Compliance with ethical standards**

**Conflict of interest** We declare that we have no conflict of interest.

**Informed consent** All the participants who signed the written informed consent form were invited to participate in the study.

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## Figures

Figure 1

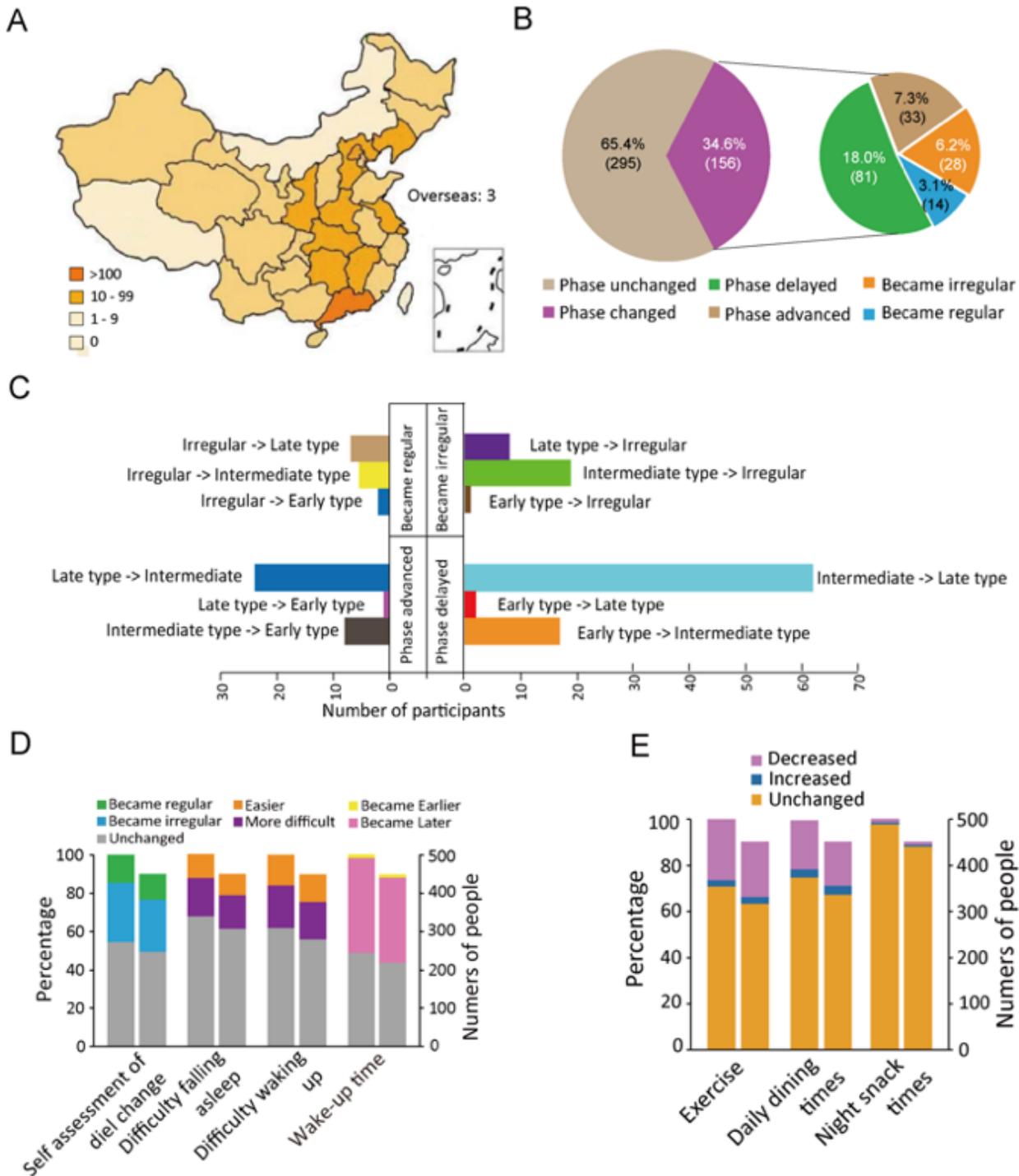


Figure 1

Changes in the diel rhythm characteristics. A) Geographical spread of the response. B) The proportions of participants who reported changes in their die rhythms. C) The bar chart shows the number of people who reported each of the 4 phase-change types (12 subtypes). D) The percentage and number of people who reported each of the four types of diel rhythm changes. E) The percentages and numbers of people who reported changes in exercise, daily dining times and night snack times. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

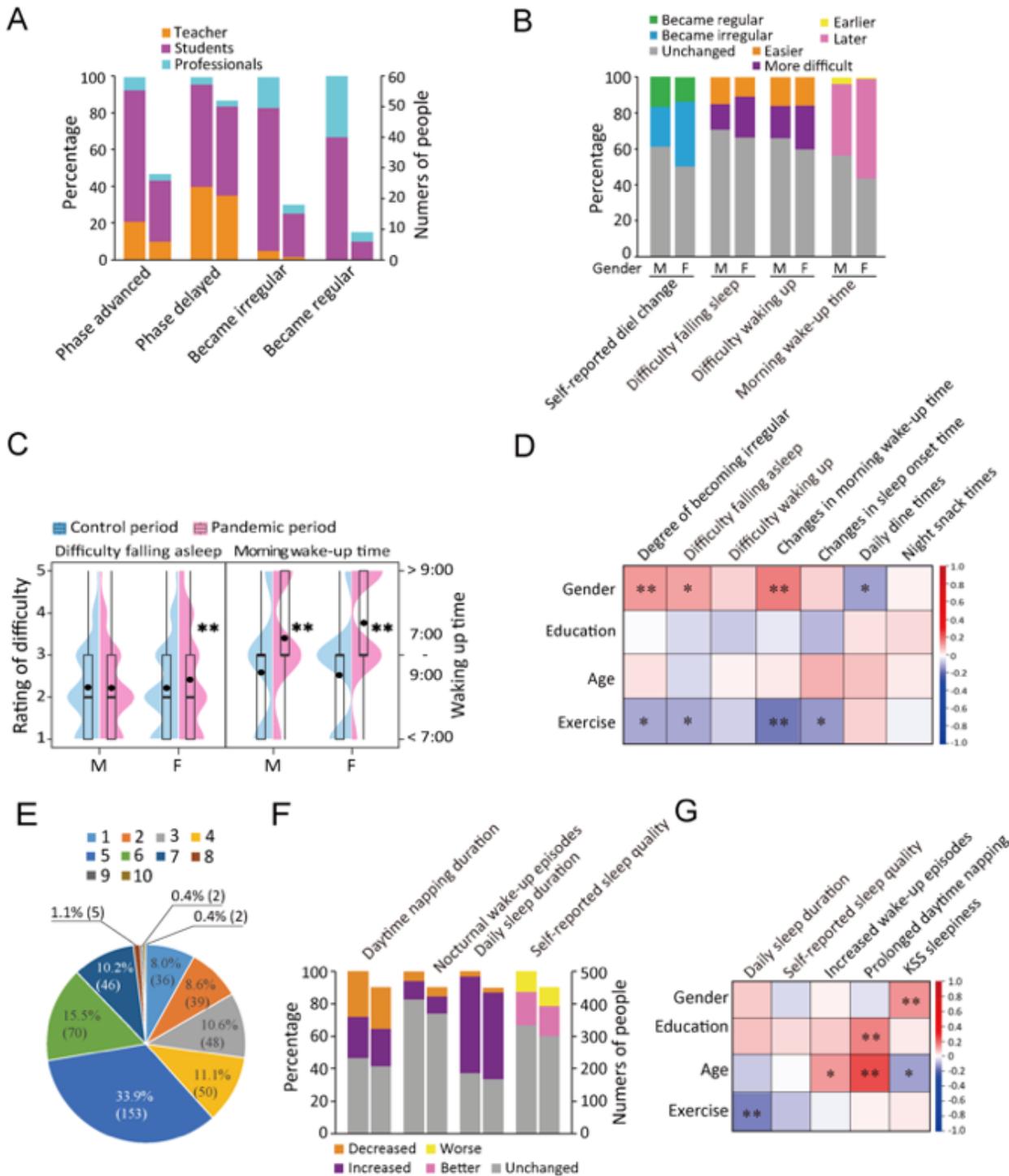


Figure 2

Changes in sleep-related parameters. A) The percentages and numbers of participants of each profession (teachers, students, and professionals) in phase changes of the four variables. B) The percentages of people of different genders in four diel rhythm variables. M presents male and F presents female. C) Violin plot visualizing the between-gender comparison of difficulty falling asleep and wake-up time. M presents male and F presents female. \*\*P < 0.01. D) Correlations between demographic factors and diel

rhythms. \* P <0.05, \*\*P <0.01. E) Distribution of 10 scores of KSS-rated sleepiness. F) An accumulative bar diagram showing the percentages and numbers of people who reported changes in the four sleep variables. G) Correlations between demographic factors and sleep. \* P <0.05, \*\*P <0.01.

Figure 3

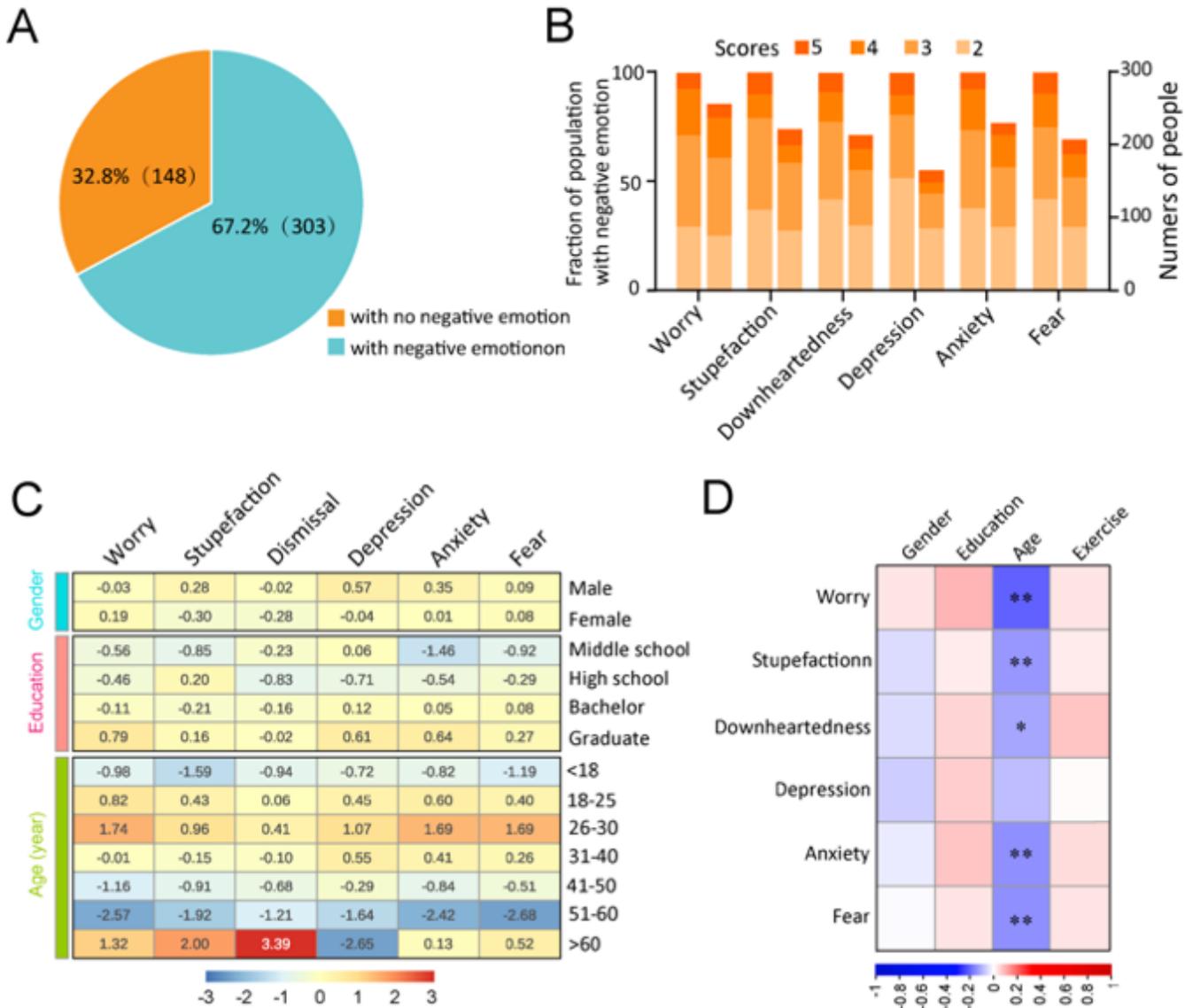
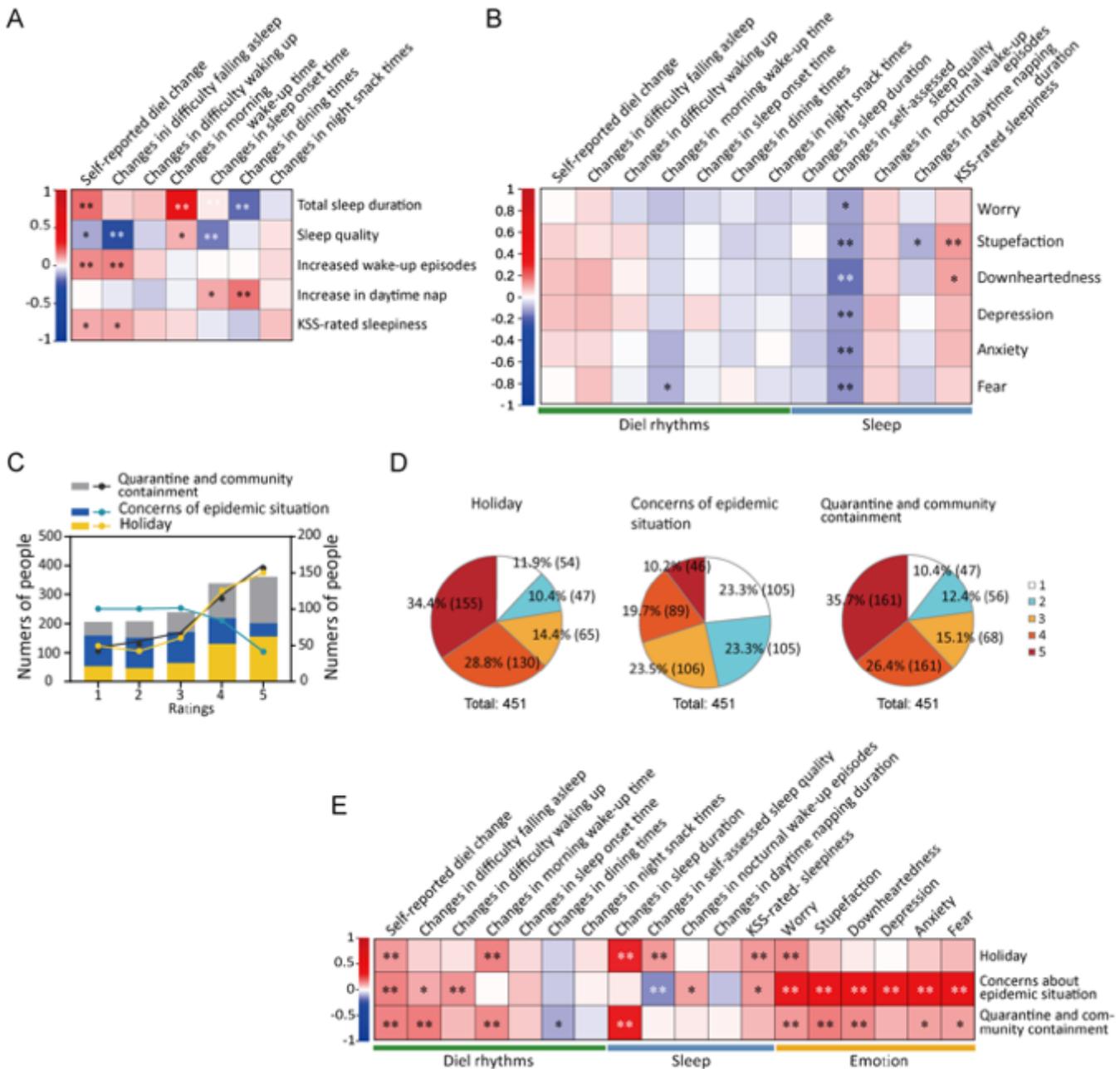


Figure 3

Analysis of the negative emotion. A) The percentages of participants who reported and did not report negative emotions. Six negative emotions were assessed with participants who reported at least one of these negative emotions. B) An accumulative bar diagram showing the fraction and numbers of participants with different grades of assessed negative emotion types. These negative emotions were assessed on a 1-5 scale indicating the different degrees of negative emotions as follows: 1, 2, 3, 4, and 5 indicated no, slight, mild, moderate, and severe negative emotions, respectively. C) Different negative emotions were reported during the holiday and pandemic period. The self-assessed negative emotions

were classified according to gender, age, and education. We calculated the average scores of each negative emotion. The numerals in the heat map are Z-score values after normalization by column. \* P <0.05, \*\*P <0.01. D) Correlations between negative emotions and gender, education, age and exercise. \* P <0.05, \*\*P <0.01.

**Figure 4**



**Figure 4**

Correlative analysis among the changes in diel rhythms, sleep and mood. A) Spearman correlation between diel rhythms and sleep. \* P <0.05, \*\*P <0.01. B) Spearman correlation coefficient analysis of diel variables, sleep and mood. \*P <0.05, \*\*P <0.01. C) Subjective self-evaluation of the effects of the three

factors: holiday, concerns about the epidemic situation, and quarantine or community containment on diel rhythms and sleep. Here, 1 indicates no effects while 2-5 indicate increased effects. Columns in the different colors represent the numbers and percentages of participants who rated the corresponding grades as indicated. Line graphs in the different colors represent the numbers of participants who rated the corresponding grades as indicated. D) Pie charts showing the proportions of responders who reported disturbed diel rhythms and sleep due to the following three factors: holiday, concerns about the epidemic situation, and quarantine or community containment. The ratings are the same to those in (C). E) Spearman correlation coefficient analysis among diel rhythms, sleep and negative emotion. \*  $P < 0.05$ , \*\* $P < 0.01$ .

## Supplementary Files

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