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The effect of COVID-19 lockdowns on sleep time perception: Comparing actigraphy and sleep diary measures

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ABSTRACT

COVID-19 has become a long-term problem, and global pandemic conditions may persist for years. Researchers are providing mounting evidence of relationships between COVID-19 lockdowns and sleep problems. However, few studies have investigated the impact of home isolation on sleep time perception, especially in comparable social isolation situations with similar pressures. Subjective sleep time perception parameters were derived from sleep diaries. Objective parameters were derived from actigraphy. Subjective and objective data were obtained between February 17 and February 27, 2020 from 70 adult participants subject to COVID-19 related lockdown provisions in China. We divided participants into a home stayers (HS) group (subject to full stay-at home orders) and an area-restricted workers (ARW) group (permitted to work at their nearby workplaces). The HS group demonstrated significantly delayed actigraphy-defined sleep onset time compared to self-reported sleep onset time; this effect was absent in the ARW group. Between-group differences in actigraphy-defined sleep onset time and significant between-group differences for actigraphy-defined and self-reported wake-up time were observed. HS group participants also presented significantly delayed actigraphy-defined wake-up time compared with self-reported wake-up time. No significant effect was found on total sleep time perception. Moreover, sleep/wake time misperception were found to be associated with daylight exposure and physical activity levels respectively. To the extent they are generalizable, these results suggest that lockdown restrictions can affect sleep onset and wake-up time perception but not total sleep time perception. Public health policy should consider such effects in the present pandemic situation and in future emergent public health situations.

1. Introduction

Since December 2019, the world has faced continual pandemic conditions and has struggled to manage coronavirus disease 2019 (COVID-19) outbreaks. According the World Health Organization's (World Health Organization, 2021) official website, as of February 16, 2021, over 109 million cases of confirmed COVID-19 infection and over 2 million COVID-19-related deaths had been reported worldwide. The pandemic impacts the daily life of the public enormously due to overloaded medical systems, perceived psychological stressors, disrupted social connections, and decreased subjective well-being (Cooke et al., 2020; Haleem et al., 2020; Wang et al., 2021). Many countries are locking down their populations and enforcing the toughest of measures in hopes of preventing transmission of this highly contagious disease. Among these measures, physical distancing interventions (e.g., stay-at-home orders) have been found effective in slowing the spread of the virus (Fowler et al., 2020). However, these types of interventions may lead to psychological distress from social isolation and financial risk (Tull et al., 2020).

Among the types of psychological distress, pandemic-related sleep disturbances have gained much attention from the public and mental health professionals globally (Gualano et al., 2020; Jahrami et al., 2021). Previous studies have shown that this disrupted sleep may be associated with perceived psychological stress (Jahrami et al., 2021;

Abbreviations: ARW, Area-restricted workers group; HS, Home stayers group; PSQI, Pittsburgh sleep quality index; ISI, Insomnia severity index; PSG, polysomnography; BZ, benzodiazepine; ERQ, Emotion Regulation Questionnaire.

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Zhao et al., 2020), negative emotions (e.g., anxiety, depressive symptoms) (Huang and Zhao, 2020), and insufficient physical activity (Diniz et al., 2020). In studies conducted during the pandemic, the sleep patterns of participants have been typically assessed by subjective measures such as the Pittsburgh sleep quality index (PSQI), sleep diaries, and the insomnia severity index (ISI). These studies concluded that participants experienced delayed sleep-wake schedules, increased total sleep time, decreased sleep efficiency, and lower sleep quality (Gupta et al., 2020; Li et al., 2020). However, subjective reports of sleep are usually confounded and inaccurate; objective measures derived from actigraphy or polysomnography (PSG) are valuable complements to self-reported sleep data (Krystal, 2008; Wang et al., 2021). The discrepancy between subjective and objective measures, called "sleep state misperception," is often observed in individuals with insomnia, and the extent of misperception varies between different insomnia subtypes (Bastien et al., 2014). Patients with insomnia symptoms tend to underestimate or overestimate their sleep duration compared to actigraphy- or PSG-defined sleep durations. Although this discrepancy has been corroborated in clinical populations, few studies have further investigated this phenomenon in adult populations during a global pandemic.

Recent investigations have found that home isolation induced an expanded sense of time due to confusion over the exact time of day among participants during the COVID-19 lockdown in Italy (Cellini et al., 2020). Yet, to date, direct empirical evidence of the impact of lockdowns on sleep time perception remains absent. Therefore, we attempt to investigate whether subjective and objective perceptions of sleep time are consistent between two groups of participants with differing lockdown restrictions during the COVID-19 pandemic in China. In addition to an altered experience of time, home isolation can reduce physical activity levels and daylight exposure. It has been argued that those with disrupted daily physical activity routines during COVID-19 quarantines face increased risk for disturbed sleep patterns (Diniz et al., 2020) and that outdoor activity coupled with sufficient sunlight exposure may effectively improve sleep quality (Lee et al., 2014). Although there is converging evidence on the beneficial effects of regular physical activity on sleep quality (Kredlow et al., 2015), its relationship with sleep time perception remains unclear. Furthermore, there may be additional psychological factors affecting sleep time perception. For example, some researchers found that economic satisfaction and social relationship quality were associated with sleep misperception in middle-aged adults (Park et al., 2020). Other researchers have demonstrated that poor self-reported sleep efficiency was related to lower levels of social support and more depressive symptoms, but objective sleep efficiency measurements showed not significant correlation (Jackowska et al., 2011). Understanding the effects of psycho-physiological and COVID-19-related restrictions on sleep time perception may contribute to developing evidence-driven strategies for present and future emergent public health issues.

To those ends, our study aimed to address the issues described above in the following ways: First, we assessed the impact of the COVID-19 lockdown on sleep time perception. The subjective and objective parameters of sleep time in participants staying at home were compared with that of area-restricted workers during COVID-19 pandemic. Second, we explored psycho-physiological factors affecting sleep time perception. We hypothesized that people isolated at home can present distorted perceptions of sleep onset time, wake-up time, and total sleep time when compared with participants who were working outside the home. Furthermore, reduced day-light exposure and physical activity may relate to distorted sleep time estimation.

2. Materials and methods

2.1. Participants

Between February 17th and 27th 2020, during a COVID-19 lockdown in China, 75 volunteers were recruited through social media advertisements. During the study, over 70,000 confirmed cases of Covid-19 were reported in China, with a minimum of 300 new confirmed cases per day. This period was selected because individuals' daily lives were being greatly impacted during this time. The current study was a part of the project titled "Sleep, Eating behaviors, and Physical activity (SEP) during COVID-19 pandemic in China. The participants were asked to complete health-related questionnaires and wear a medical-grade actigraphy monitor (wGT3X-BT, https://www.theactigraph.com/support/activity-monitors/wgt3x-bt/) for five consecutive days. People between 31 and 65 years old with no diagnosed current or past neurological and psychiatric disorders met the basic inclusion criteria. Five participants were excluded because of incomplete questionnaires. The remaining participants were divided into the home stayers group (HS, $n = 47$) and the area-restricted workers group (ARW, $n = 23$) according to their lockdown status. Four of the participants in the HS group and one in the ARW group reported infrequent use of benzodiazepine (BZ) or non-BZ hypnotics in low doses. Participants who completed the experiments would receive ¥ 100 in remunerations. All persons gave their informed consent prior to their inclusion in the study, which was approved by the Ethics Committee of Southwest University (H20037), and all procedures involved were in accordance with the Declaration of Helsinki principles.

2.2. Subjective parameters: health-related questionnaires

2.2.1. Sleep diary

All participants were asked to complete a 5-day online sleep diary comprising three questions: 1) "When did you fall asleep last night?"; 2) "When did you wake up today (eyes open, ready to get up)?", and 3) "How would you rate your sleep quality last night?" (van Hees et al., 2015). Participants were asked to estimate their sleep quality in the third question on a 10-point scale (1 = very bad, 5 = ordinary, 10 = very satisfied).

2.2.2. Emotion Regulation Questionnaire (ERQ)

The Chinese version of the ERQ, an established 10-item self-report questionnaire, was used to assess participants' emotion-regulation processes, (Gross, 2003). It was designed to assess habitual use of cognitive reappraisal and expressive suppression, commonly used strategies for altering emotion. Participants rated items on a seven-point Likert scale where 1 is strongly disagree and 7 is strongly agree. Six items constitute the subscale for cognitive reappraisal (e.g., "When I'm faced with a stressful situation, I make myself think about it in a way that helps me stay calm"). Four items constitute the subscale for expressive suppression (e.g., "When I am feeling negative emotions, I make sure not to express them").

2.2.3. Pittsburgh Sleep Quality Index (PSQI)

The Chinese version of 19-items PSQI (Buysse et al., 1989) was used to assess participants' global sleep quality during the past month. It includes seven "component" scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Global PSQI scores ranging from 0 to 21 were calculated by adding the seven component scores. Participants with a global score greater than eight were defined as having poor sleep quality.

2.2.4. Insomnia Severity Index (ISI)

The Chinese version of the ISI, a seven-item questionnaire on subtypes of sleep difficulties in the past 2 weeks, was used to measure the severity of patients' insomnia symptoms (Morin, 1993). Each item is rated on a five-point Likert scale from 0 (not at all) to 4 (very severe). Global ISI score ranges were from 0 to 28, and participants with a global score greater than eight were recognized as having clinical insomnia symptoms.

2.3. Objective parameters: actigraphy

Objective parameters were obtained via medical-grade actigraphy wristwatch-like devices that efficiently measure sleep parameters and sleep quality, wake-time activity, and intensity of movements in free-living settings (Mazza et al., 2020). This is considered a non-invasive method of monitoring human rest/activity cycles. Sample epoch of actigraphy was set to 60 seconds, which was used to export summary statistics through the ActiLife software (Version 19.2) and manufacturer algorithms. Specifically, the Choi algorithm (CHOI et al., 2011) was used to define wear time validation. The algorithm predicted that 69 participants (98.6%) would wear the device the full five days and that one participant (1.4%) would only wear it for three days. The Cole-Kripke algorithm (Cole et al., 1992) was used to measure sleep quality. The Troiano algorithm (Troiano et al., 2008) was used to calculate activity patterns, including activity levels, light (lux) exposure levels, and step counts. Some measures were divided as low-level or high-level according to their values, for example, 0–50 lx is defined as low-level lux (Boubekri et al., 2014).

2.4. Sleep time misperception

Sleep time points were converted to numbers based on the 24-hour clock (e.g. 23:30 p.m. = −0.5, midnight = 0, 7:30 a.m. = 7.5) for use in statistical analyses. In the present study, sleep time misperception is defined as the discrepancy between self-reported and actigraphy-defined sleep time (variables: sleep onset time, sleep wake-up time, and total sleep time). For example, the misperception of sleep onset-time was defined as the difference between mean values of self-reported sleep onset time and actigraphy-defined sleep onset time over the five recording days.

2.5. Statistical analysis

IBM SPSS Statistics 26 for Windows was used as the statistical analysis toolbox. As noted, participants were divided into the HS and ARW groups according to their lockdown status. For both groups, continuous variables were reported as means and standard deviations (SD), and discrete variables were reported as percentages (see Table 1). These variables included participants' demographic characteristics and objective and subjective sleep parameters. Two sample *t*-test or χ^2 was used to find between-group differences in demographic characteristics. Mixed-effect ANOVAs were conducted to evaluate the main and interaction effects between factors, with group (HS versus ARW) as the between-subject factor and sleep perception (subjective parameters versus objective parameters) as the within-subject factor. The Greenhouse–Geisser correction was used to adjust the effects for any violation of sphericity. Post-hoc pairwise comparisons were corrected for multiple comparisons with Bonferroni corrections. Moreover, explorative correlations were performed to evaluate the relationship between sleep time misperception and other psycho-physiological variables. All significant thresholds were set at $p < 0.05$.

3. Results

3.1. Demographic characteristics, subjective and objective parameters

Seventy participants (46 females, 65.71%) aged 31 to 60 years (M ± SD, 47.6 ± 5.36) were recruited for our study. The HS group included 47 participants (30 females, 63.83%) aged 35 to 60 years (M ± SD , 47.7 ± 5.7), and the ARW group included 23 participants (16 females, 69.57%) aged 31–54 years (M ± SD , 47.3 ± 4.7). As shown in Table 1, there were no significant between-group difference in demographic characteristics including age, gender, BMI, and marital status. In addition, there was no significant between-group difference in responses to health-related questionnaires including the ERQ, ISI, and PSQI.

Table 1
Between-group comparisons in demographic characteristics, subjective and objective parameters in the group of home stayers (HS) and area-restricted workers (ARW) (M ± SD).

	HS (n = 47)	ARW (n = 23)	t/χ^2	Cohen's *d*	*p*
Demographic characteristics					
Age, year, M ± SD	47.7 ± 5.7	47.3 ± 4.7	0.273		0.786
Gender (F, %)	30, 63.8%	16, 69.6%	0.225		0.635
BMI, M ± SD	23.8 ± 3	23.5 ± 3	0.431		0.667
Marital status (M, %)	42, 89.4%	17, 73.9%	5.27		0.072
Subjective parameters					
Emotion Regulation Questionnaire					
Cognitive reappraisal, M ± SD	31 ± 6.4	32 ± 4.7	−0.668	0.178	0.506
Expression suppression, M ± SD	16.3 ± 4.5	16.8 ± 5.4	−0.413	0.101	0.681
Insomnia Severity Index, M ± SD	5.9 ± 4.2	6.3 ± 5.9	−0.37	0.078	0.713
PSQI, total score, M ± SD	4.8 ± 2.4	5.6 ± 4.1	−0.852	0.238	0.401
Subjective sleep quality, M ± SD	1.1 ± 0.8	1.1 ± 1.1	−0.093	0.023	0.926
Sleep latency, M ± SD	1.1 ± 0.9	1.1 ± 1.1	−0.011	0.003	0.991
Sleep duration, M ± SD	0.2 ± 0.6	0.5 ± 0.9	−1.32	0.392	0.196
Habitual sleep efficiency, M ± SD	0.4 ± 0.8	0.5 ± 0.9	−0.587	0.117	0.559
Sleep disturbances, M ± SD	1.1 ± 0.4	1.2 ± 0.4	−1.025	0.250	0.309
Use of sleep medication, M ± SD	0.1 ± 0.4	0.04 ± 0.2	0.855	0.190	0.396
Daytime dysfunction, M ± SD	0.8 ± 0.7	1.1 ± 1	0.31	0.348	0.164
Sleep diary (5-day average)					
Sleep onset time, M ± SD	23:32 ± 1.06	23:16 ± 0.92	0.988	0.240	0.326
Wake up time, M ± SD	8:05 ± 1.05	7:20 ± 0.90	2.930	0.711	**0.005****
Total sleep time, M ± SD	8.54 ± 0.94	8.04 ± 0.89	2.151	0.546	**0.035***
Objective parameters: actigraphy					
Sleep parameters (5-day average)					
Sleep onset time, M ± SD	0:04 ± 1.35	23:15 ± 1.14	2.513	0.609	**0.014***
Wake up time, M ± SD	8:18 ± 1.25	7:26 ± 1.45	2.576	0.625	**0.012***
Total sleep time, M ± SD	8.23 ± 0.87	8.16 ± 0.54	0.181	0.097	0.857
Activity parameters					
Minutes of low-intensity activity, M ± SD	388.3 ± 112.6	358.1 ± 116.4	1.043	0.264	0.301
Minutes of moderate-intensity activity, M ± SD	373.5 ± 85.3	364.6 ± 80.7	0.404	0.107	0.688
Minutes of vigorous-intensity activity, M ± SD	254.4 ± 92.05	295.9 ± 87.6	−1.743	0.462	0.086
			0.694	0.161	0.490

(continued on next page)

Table 1 (*continued*)

	HS (n = 47)	ARW (n = 23)	t/χ^2	Cohen's *d*	*p*
Minutes of low-level lux, M ± SD	994.6 ± 118.1	968.5 ± 196.5			
Minutes of moderate-level lux, M ± SD	35.3 ± 32.4	27.1 ± 21.1	1.102	0.300	0.274
Minutes of high-level lux, M ± SD	26.7 ± 23.5	25.1 ± 23.4	0.266	0.068	0.791
Number of steps per day, M ± SD	8210.7 ± 3236.7	10,206.6 ± 3952.8	−2.251	0.552	**0.028***

* $p < 0.05$.
** $p < 0.01$.

We obtained actigraphy-defined sleep time, activity intensity, and lux level parameters during wake-sleep cycles (see Table 1). Regarding subjective sleep parameters obtained from sleep diaries, we found a significant between-group difference for wake-up time [t (68) = 2.93, p = 0.005, d = 0.711] and total sleep time [t (68) = 2.151, p = 0.035, d = 0.546]. Specifically, HS group participants reported waking up approximately 45 min later and sleeping approximately 50 min longer than the ARW group.

Regarding the objective sleep parameters obtained from actigraphy, we found a significant between-group difference in sleep onset times [t (68) = 2.513, p = 0.014, d = 0.609] and wake up times [t (68) = 2.576, p = 0.012, d = 0.625], but not in total sleep times. Specifically, HS participants often slept some 49 min later and woke some 52 min later than the ARW group. In addition, participants in ARW group took a significantly greater number of steps than people in the HS group [t (68) = −2.251, p = 0.028, d = 0.552]. There were no other significant between-group differences found for the other parameters.

3.2. *Discrepancies between subjective and objective sleep parameters*

To evaluate the impact of COVID-19 lockdowns on sleep time perception, we conducted mixed-effect ANOVAs to estimate the effects of sleep parameter type (subjective versus objective) and group (HS versus ARW) on sleep onset time, sleep wake-up time, and total sleep time.

3.2.1. *Sleep onset time*

We found that parameter type had a significant main effect on sleep onset time [F (1, 68) = 5.97, p = 0.017, η^2 = 0.081], that group had a marginally significant main effect on sleep onset time [F (1, 68) = 3.85, p = 0.054, η^2 = 0.054], and that group × parameter type interaction had a significant effect on sleep onset time [F (1, 68) = 6.93, p = 0.01, η^2 = 0.092] (Fig. 1A). Post-hoc pairwise comparisons revealed a significant difference between subjective and objective sleep onset time in the HS group (p < 0.001) but no significant difference was found in the ARW group (p = 0.908). In addition, we found a significant difference in objective sleep onset time between the HS group and the ARW group (p = 0.014), but not in subjective sleep onset time (p = 0.326). Specifically, objective sleep onset time was delayed about 33 min compared to subjective sleep onset time for the HS group. Participants in the HS group presented significantly delayed objective sleep onset time, about 49 min, compared to participants in the ARW group.

3.2.2. *Wake-up time*

As illustrated in Fig. 1B, we found that group [F (1, 68) = 7.97, p = 0.006, η^2 = 0.105] had a significant main effect on wake-up time and that parameter type had a marginally significant effect on wake-up time [F (1, 68) = 3.26, p = 0.076, η^2 = 0.046]; however no significant effect of group × parameter type interaction was observed [F (1, 68) = 0.47, p = 0.50, η^2 = 0.007]. Post-hoc pairwise comparisons revealed a significant between-group effect for objective wake-up time (p = 0.012) and subjective wake-up time (p = 0.005). We also found a significant difference between parameter type in the HS group (p = 0.033) but not in the ARW group (p = 0.497). Specifically, objective wake-up time was delayed about 13 min compared to subjective wake-up time for the HS group. Participants in the HS group presented significantly delayed objective wake-up time, about 52 min, compared to the ARW group participants, and participants in the HS group also presented significantly delayed subjective wake-up time, also about 52 min, compared to participants in ARW group.

3.2.3. *Total sleep time*

Finally, we found no significant main or interaction effects for total sleep time (Fig. 1C).

Figs. 2 and 3 delineate the specific sleep-wake activity cycles for five consecutive days for the ARW and HS groups, respectively.

3.3. *Explorative correlations between sleep time misperception and other subjective parameters*

We conducted exploratory correlation analysis to investigate factors related to sleep onset time and wake-up time misperception. Sleep time misperception was calculated as the mean differences between self-reported sleep onset time or wake-up time and actigraphy-defined sleep onset time or wake-up time. As shown in Fig. 4A, we found significantly positive correlations between sleep onset time misperception and average low lux level time (r = 0.394, p = 0.006) in the HS group but not in ARW group (r = −0.38, p = 0.073). Similarly, as shown in Fig. 4B, we found significantly negative correlations between wake-up time misperception and average vigorous-intensity activity time (r = −0.291, p = 0.047) in the HS group but not in the ARW group (r = −0.036, p = 0.876).

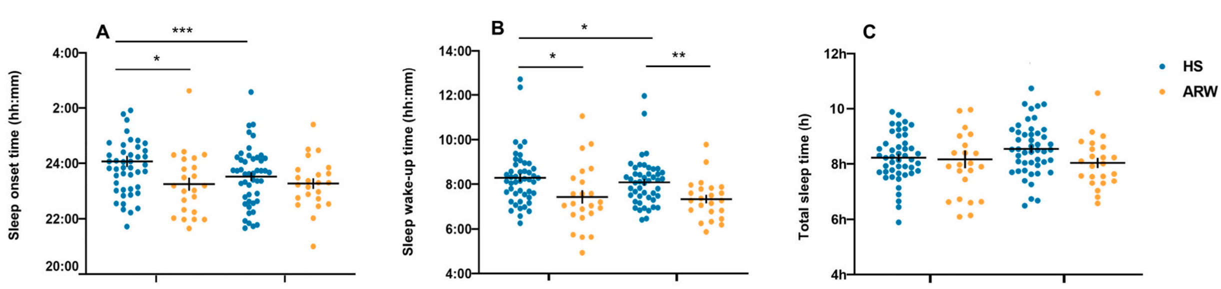

Fig. 1. The discrepancy between subjective and objective sleep time parameters in home stayers (HS) and area-restricted workers (ARW). (A) Objective and subjective sleep onset time in HS (blue cluster) and ARW (yellow cluster); (B) Objective and subjective wake up time in HS and ARW; (C) Objective and subjective total sleep time in HS and ARW. *p < 0.05; ***p < 0.001. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

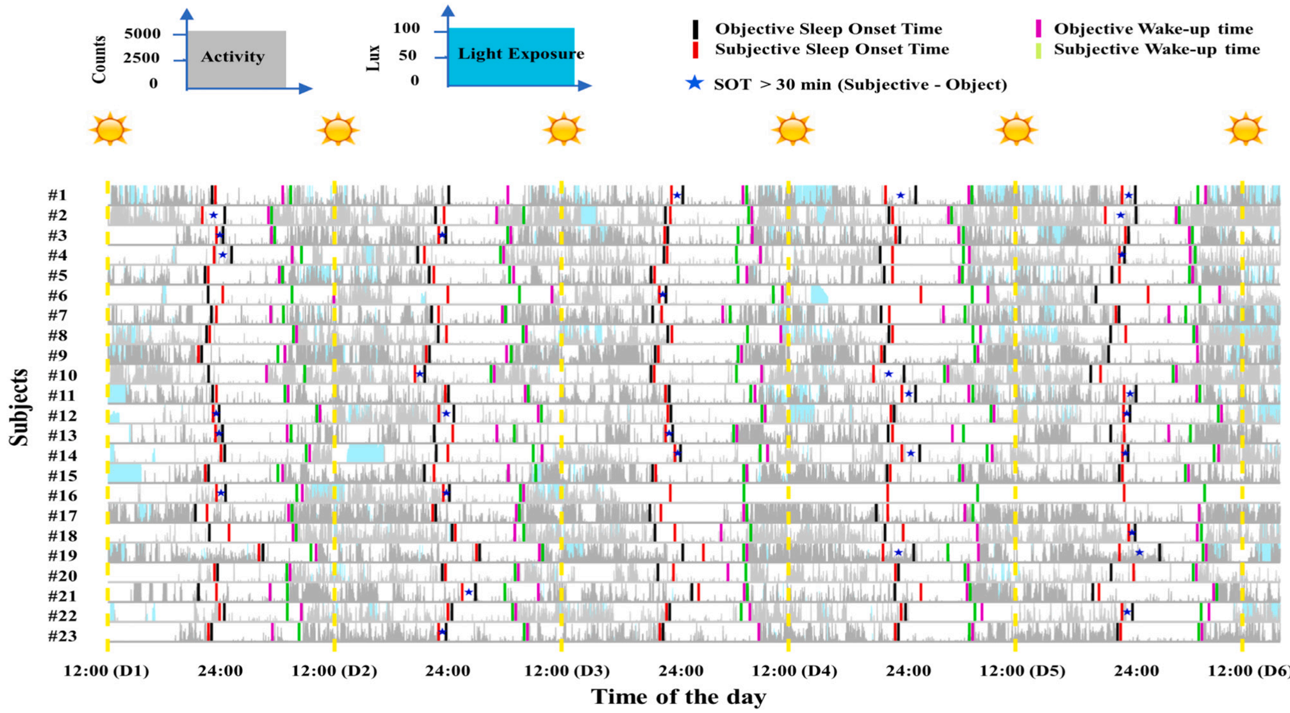

Fig. 2. Comparison of subjective and objective sleep parameters of area-restricted workers (ARW) with activity and light exposure derived from actigraphy. Each row represents one participant, and light gray and cyan lines represent the activity count and light expose. The sun indicated the middle-day, i.e., 12:00. The pentagrams illustrated the period with large misperception, which was defined as larger than 30 minute difference between subjective and objective parameters of sleep onset time. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

In the current study, the impact of the COVID-19 lockdown on HS and ARW participants' sleep time perception was investigated. Self-reported sleep questionnaires and medical-grade actigraphy devices were used to obtain subjective and objective sleep time parameters. Participants staying at home and working in a limited area were recruited during a period of the COVID-19 lockdown in China. We found that HS group participants showed significantly delayed objective sleep onset time compared to self-reported sleep onset time, but this effect disappeared in ARW group. There was also a between-group difference in objective sleep onset time.

We found significant between-group differences both in subjective and objective wake-up time. HS group participants presented significantly delayed objective wake-up time compared to subjective wake-up time. No significant effect was found for the parameter of total sleep time. Moreover, sleep onset time misperception was found to be positively associated with daylight exposure and wake-up time misperception was found to be negatively associated with physical activity.

These findings indicate that home isolation during the COVID-19 pandemic primarily affected participants' accurate perception of sleep onset time and wake-up time, but not their perceived total sleep time. Factors such as lower levels of light exposure and vigorous-intensity physical activity may be related to this distorted sleep/wake time estimation.

Previous studies have provided evidence of the relationship between COVID-19 lockdowns and sleep problems (Jahrami et al., 2021). Blume and colleagues found that the COVID-19 lockdown that began in March 2020 was related not only to an increase in sleep duration but also to an overall decrease in sleep quality for participants in three European countries (Blume et al., 2020). Research performed in other countries yielded similar results, researchers concluded that participants experienced delayed sleep-wake schedules, longer total in bed time and total sleep time, and, simultaneously, decreased sleep efficiency (Salehinejad et al., 2020; Wright et al., 2020). However, all these conclusions were yielded from self-report questionnaire data. Subjective reports are often inconsistent with objective actigraphy- or PSG-derived measures. Thus, in the current study, we obtained both self-reported and actigraphy-defined sleep time parameters among participants staying at home and participants working outside the home. We performed mixed-effect ANOVAs to evaluate interaction between the group and parameter type factors.

Consistent with prior studies, we found that people who isolated at home reported significantly earlier sleep onset and wake-up times than actigraphy-defined, which suggests that participants staying at home during COVID-19 pandemic tend to overestimate their specific sleep times. We failed to obtain similar results for area-restricted workers and for the total sleep time parameter. As previously reported, during the lockdown, increases in sleep problems are associated with sense of time and are more pronounced in individuals with higher levels of depression, anxiety, and stress (Cellini et al., 2020). Overestimation of sleep has been found to be associated with social relationship quality, economic satisfaction, and social support (Park et al., 2020). Moreover, the extent that subjective sleep efficiency reflects objective experience was found to influence psychological characteristics and affect (e.g., health anxiety, depressive symptoms, social support) (Jackowska et al., 2011). Therefore, the discrepancy between subjective and objective perception of sleep time associated with stay-at-home orders during COVID-19 pandemic may be attributable to increased levels of psychological distress, social isolation and financial risk.

Other than the factors mentioned above, light exposure and physical activity may affect sleep time perception. First, we found a positive correlation between average sleep onset time misperception and low-level light exposure time in home stayers. It has been argued that light exposure intensity and subsequent sleep are intimately related (Wams et al., 2017). Our study tests and verifies this conclusion and further supports findings on the great impact light exposure levels have on sleep onset time misperception. Second, we found a significantly negative

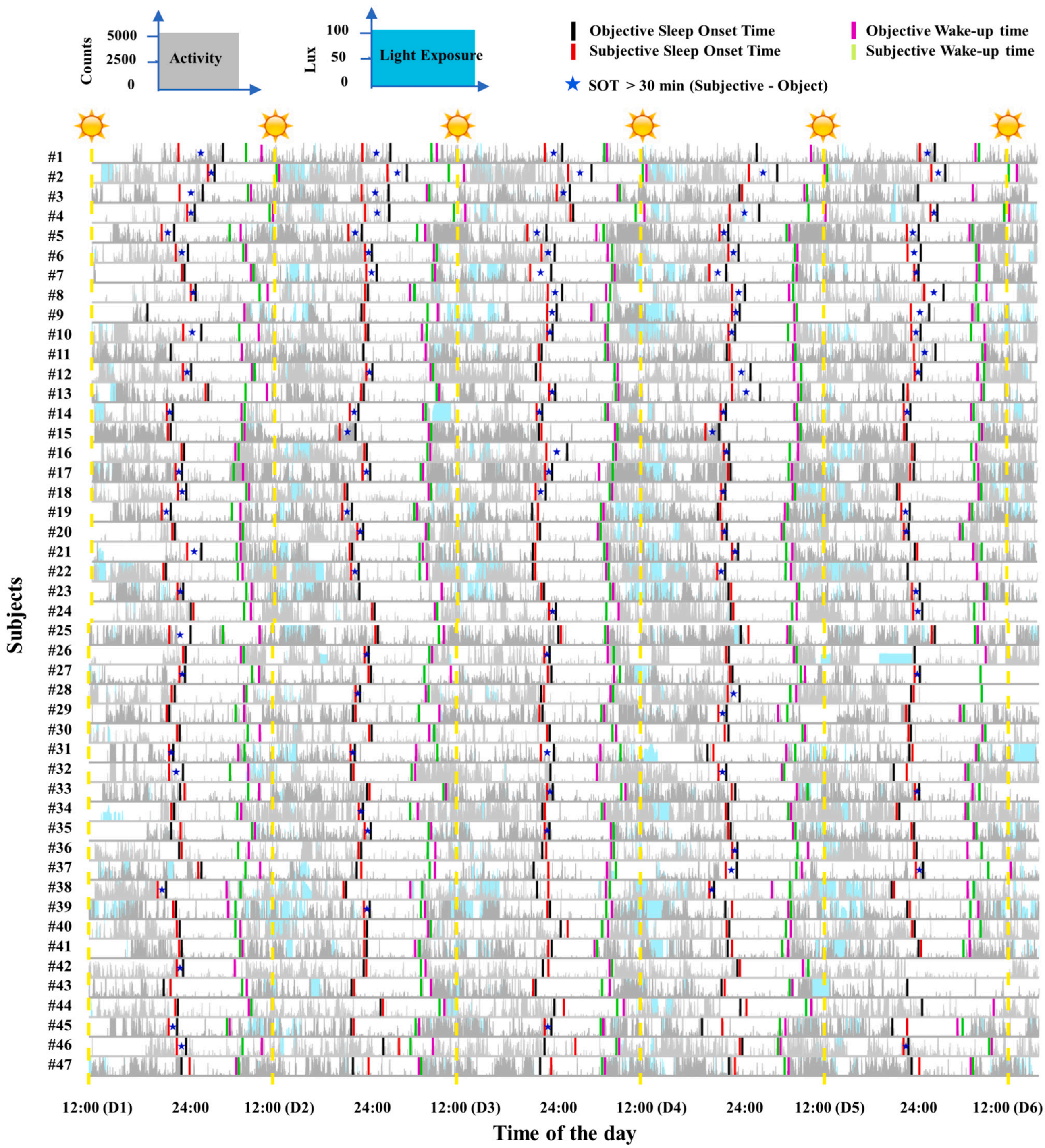

Fig. 3. Comparison of subjective and objective sleep parameters (HS) of home stayers with activity and light exposure derived from actigraphy. Each row represents one participant, and light gray and cyan lines represent the activity count and light expose. The sun indicated the middle-day, i.e., 12:00. The pentagrams illustrated the period with large misperception, which was defined as larger than 30 minute difference between subjective and objective parameters of sleep onset time. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

correlation between wake-up time misperception and average vigorous-intensity activity time. Insufficient levels of physical activity have been found a risk factor for depressive symptoms and poor sleep quality (Diniz et al., 2020). This suggests that maintaining daily physical activity routines during the COVID-19 pandemic may be a protective factor for those suffering from sleep time misperception.

COVID-19 has become a long-term global epidemic and may exist among us for years to come. As previously mentioned, although home confinement is an effective method for slowing the spread of COVID-19, psychological distress, poor sleep quality and sleep time misperceptions that disturb normal sleep patterns can accompany it. Therefore, it is imperative to monitor the sleep and wake time perception of the population and develop corresponding strategies to mitigate the adverse effects of ongoing COVID-19 lockdowns. These adverse effects may be alleviated through exposure to natural daylight and maintaining daily indoor or outdoor physical exercise routines. Furthermore, if possible, returning to workplaces, even with strict constraints, is a good choice for population.

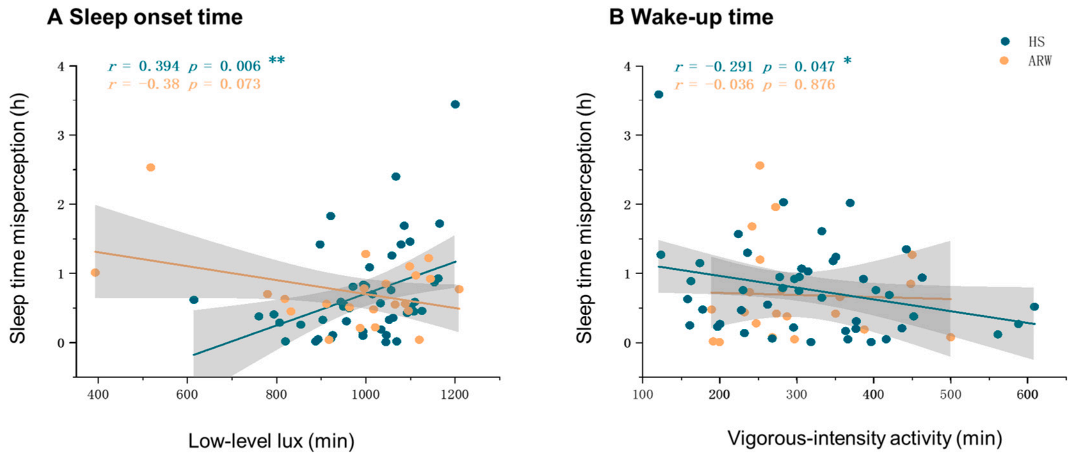

Fig. 4. Correlations between sleep time misperception and other parameters in home stayers (HS) and area-restricted workers (ARW). Sleep onset time misperception in HS was associated with average time of low lux level (A); Wake-up time misperception in HS was associated with vigorous-intensity activity (B).

There are several limitations to our study which merit further discussion. First, it was conducted with a limited number of participants due to the difficulties in getting the actigraphy to them through express delivery. Nonetheless, this study does provide a preliminary assessment of the impact of COVID-19 lockdowns on sleep time perception in adult participants. Second, because we were interested in the exact sleep times participants perceived, the questions we presented in the sleep diary were useful for yielding sleep time perception related-parameters but were insufficient for measuring subjective sleep latency and sleep efficiency. Future studies should employ additional measures to fully investigate inconsistencies between subjective and objective assessments of sleep state. Third, we failed to track participants' pre- and post-COVID-19 pandemic sleep pattern variations. Future longitudinal studies are essential for further clarifying dynamic sleep pattern changes. Fourth, whereas we intended to compare sleep patterns in participants staying at home with area-restricted worker participants working in, we cannot rule out the possibility that some participants in the working group were working from home offices. Finally, although only five participants reported taking low doses of hypnotic medications, we cannot rule out the effects of medication on the reliability of our results.

5. Conclusion

In conclusion, our study demonstrated that participants who were isolating at home during the COVID-19 pandemic in China tended to perceive their sleep onset and wake-up times as later than objectively recorded. However, the perception of total sleep time was not affected by home isolation. Factors such as light exposure and physical activity levels may be related to distorted sleep and wake time estimations. As lockdowns and home isolation may be long-term on a global scale due to the COVID-19 epidemic, evidence-driven strategies and interventions should be developed to mitigate the adverse impacts of these conditions on sleep time perception.

Declaration of competing interest

The authors do not have any conflicts of interest to disclose.

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