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Original Article

Owls and larks do not exist: COVID-19 quarantine sleep habits

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ABSTRACT

Background: The coronavirus pandemic presented a unique opportunity to study the daily temporal patterns and sleep habits of humans. The question to be explored was: Are there discernible differences in sleep between the normal operational environment and the stay-at-home condition?
Methods: This international prospective study analyzed results from the sleep-wake patterns questionnaire, daily logs, and interviews. Surveys were administered to the healthy volunteers (age 15–60 y) with stay-at-home for a month or more, without previous sleep disorders and mood-related complaints; volunteers were not involved in online education/work daily timetable-related activities.
Results: We analyzed 3787 subjects with average stay-at-home of 65 ± 9 days. The most significant changes in sleep occurred during the first ten days when the difference between weekdays and weekends disappeared and changes occurred in napping habits. The majority of the participants (66.8%) shifted toward eveningness when the self-selected sleep was possible and 1869 volunteers appeared to be owls (49.4%), 823 (21.7%) exercised “typical” sleep, 478 (12.6%) were larks, and 617 (16.3%) participants were completely desynchronized to the end of stay-at-home. In addition, 497 participants (13.1%) alternated their sleep habits. The most of the desynchronized participants (n = 414) were older than 50 years (age correlation r = 0.80), and predominantly males (n = 297, r = 0.76).
Conclusion: In self-selected sleep conditions, the timing of sleep and sleep habits significantly differ from those of socially and economically fixed daily routine conditions. The changes in daily temporal patterns of humans during a prolonged stay-at-home situation indicate that human sleep habits may change according to existing living conditions.

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Every Morning I walk'd out with my Gun for two or three Hours if it did not rain, then employ'd myself to work till about Eleven a-Clock, then eat what I had to live on, and from Twelve to Two I lay down to sleep, and then in the Evening to work again. … I was at a great Loss for Candle; so that as soon as ever it was dark, which was generally by Seven-a-Clock, I was oblig'd to go to Bed.

Daniel Defoe. Robinson Crusoe.

1. Introduction

The current coronavirus pandemic presents a unique opportunity to study the daily temporal patterns and sleep habits of humans. Nature itself has designed a global experiment that could never have been designed and performed in vivo during normal circumstances. The COVID-19 pandemic has put hundreds of thousands of humans in quarantine and millions of humans worldwide in stay-at-home and temporary-unemployed situations. As a result, it permitted the study of daily temporal patterns and sleep habits of a large cohort of healthy humans under “stay-at-home-nothing-to-do” and self-selected sleep conditions.

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The topic of sleep-related chronobiology and daily temporal patterns during "lockdown" events is not just a theoretical question. The authors have a suspicion that similar stay-at-home circumstances might reappear in the future and psychologists, physiologists, psychiatrists, public health professionals, and behavioral science practitioners should be more prepared for such situations. Our better understanding of chronobiology may stimulate efforts in optimization of work schedules, prevention of sleep disorders, and possible subsequent mood disorders.

An investigation into sleep timing is embedded into the much broader subject of chronobiology, circadian rhythms, and human chronotypes of which the sleep-wake cycle is one of the main components. Already in the 19th century, numerous authors indicated that sleep habits, in general, and sleep timing, in particular, are extremely variable among individuals [1–3]. The 19th-century descriptions of the variability of human sleep habits were crystallized into the concept of "owls" (eveningness) and "larks" (morningness) when in 1976 Horne and Östberg developed their questionnaire to determine morningness-eveningness in human circadian rhythms [4]. This concept was most widely accepted [5–7]. But this was an oversimplification and further studies distinguished between "owls", "larks," and intermediate ("typical sleep") types [8]. Then the four-type concept of Larks, Typical sleep, Insufficient sleep, and Owls was discussed [9]. Already in 2020, the attempt was made to introduce the six-type classification that included Early Larks, Larks, Intermediate, Owls, Variable Owls, and Late Owls [10]. Thus, the latest studies confirmed the 19th-century statement that everything is possible for the human organism. The emerging literature on chronobiology, circadian rhythms, and chronotypes further postulates that despite inter-personal variability, the circadian clock of an individual is almost fixed because the circadian period is generated at the level of the cell [8,11–13].

The authors hypothesized that the change of routine daily activities and lockdown conditions may change the daily temporal patterns and sleep timing of the involved healthy people. We aimed to collect enough data to prove or disprove this hypothesis and to investigate human sleep-wake patterns in lockdown/stay-at-home conditions. In the current study, the term "chronotype" was used for "individualized sleep time preferences based on genetics, development, and external influences" according to the existing definition [14] and differed from the term "circadian rhythms" that are strongly driven by the light/dark cycle and include rhythmical changes of the body temperature, melatonin and cortisol levels, mood, and some other variables. The question to be explored was: Are there discernible differences in sleep habits between the normal operational environment and the stay-at-home condition? This question inevitably led to the subsequent question: Are human chronotypes fixed?

2. Methods

2.1. Participants

Surveys were administered to the physically and mentally healthy volunteers with stay-at-home period of one month or more and without education/work-from-home or other activities that require timetables and daily schedules. *Exclusion criteria*: chronic diseases, known sleep disorders or mood-related complaints, usage of sleeping pills, night shifts at work prior to stay-at-home, work-from-home and other daily schedule/timetable-related activities, and pregnancy.

The age limit was set from 15 to 60 years. The older persons were excluded from the study because of age-related changes in sleep habits among this segment of population. The participants were divided into Adolescence group (Group 1, 15–18 y) and Adulthood group (Group 2, 19–60 y). The study cohort consisted of 3787 participants (M 1,782, F 2005). The prospective study was approved by the responsible Institutional Review Boards (IRB) and Ethics Committees as a "non-interventional anonymous survey of volunteers".

2.2. Researched tools

This prospective study involved an analysis of the collected survey results obtained from daily logs, the sleep-wake patterns questionnaire, and phone/Zoom interviews. The applied daily log was a shortened form of the existing Sleep Diary/Sleep Log of the National Sleep Foundation (NSF USA) [15]. Our log required from a participant to document time for seven to nine variables that included food intake, mental activity (including work-from-home without a schedule), physical activity, leisure, feeling of fatigue ("getting tired"), and bedtime and wake-up time for nocturnal sleep and for naps/snooze/siesta (if applicable). It should be kept for at least one month or during the whole stay-at-home period. The questionnaire avoided self-rating items and questions touching estimations and desires; only the time-related facts such as usual bedtime and wake-up time for nocturnal sleep and for possible naps were to be indicated. In addition, two free-response items were added: "If you go to bed in different times, specify the main pattern" and "Any other remarks on your current sleep pattern changes are welcome". The questionnaire should be filled after one month of the stay-at-home and after two months (if applicable).

Through structured interviews, the volunteers should provide information on sleep timing and daily temporal patterns in a free conversation manner. The conduction of the interview and the confidentiality of the respondents were maintained according to the NSF principles established for the 2005 "Sleep in America poll" [16]. The interview topics were similar to those of the questionnaire and the daily log. The main purpose of the implementation of this research tool was to establish a certain temporal pattern of a participant and to detect its possible evolution during the stay-at-home period. During interviews, we aimed to grasp some logic, if any, behind the possible changes of daily temporal patterns of the participants, and the participant's permission was be obtained to contact him/her at the end of each week during the stay-at-home. The interview averaged 15–20 min in length.

Therefore, all three research tools were designed to collect similar data from the participants. By choosing three tools instead of one we aimed to attract as many participants as possible. A volunteer had a choice either to keep the log (daily activity), or to participate in the interviews (once a week), or to fill the questionnaire (once a month). In all three cases, the first duty of a participant was to indicate his/her usual bedtime and wake-up time during workdays and weekends before the stay-at-home situation, the use of alarm clocks, and the time and duration of naps (if applicable).

2.3. Data collection

The data were collected from March 1 to June 15, 2020, in various countries. The authors had spread the questionnaire and the daily log form in a friend-to-friend manner, to the collaborators, through an online forum, and via Internet social networks. The collaborators translated the questionnaire and log forms into local languages and repeated the same procedure country-specific. The inclusion/exclusion criteria were specified on the top portion of each form. Following the IRBs' regulations, while the study used mostly phone-contact and online-manner survey, the confidentiality of the volunteers was maintained in compliance with the requirements of the Data Protection Act 1998 and the subsequent

General Data Protection Regulation (GDPR) and only depersonalized data spreadsheets were used for further analysis. Phone/Zoom interviews were conducted in the USA and Israel. By selecting the filled questionnaire and log forms, preference was given to the forms that were kept for two months or longer. The forms with ambiguous answers (multiple responses for a single question, "unsure" answers, questions left blank, etc.) were excluded from the analysis. The interviews were conducted among 500 volunteers. The initial interview was used to collect the data about a volunteer's sleep habits before the stay-at-home situation. At least five subsequent weekly interviews were collected from each participant.

2.4. Data analysis

The simplified larks-intermediate-owls classification was used for the sleep timing. "Larks" were defined as people who went to bed before 11 p.m. and got up before 8 a.m. An intermediate sleep type ("typical") persons were defined as people who went to bed around 11:30 p.m./midnight and got up around 7:30/8 a.m. "Owls" were defined as people who went to bed at or after 12 p.m. and got up at or after 8 a.m. While arbitrary, these cut-off values for chronotypes have been used in previously published studies [17–20]. Subjects with a desynchronized sleep-wake cycle were defined as individuals without fixed bedtime and wake-up time both for nocturnal sleep and possible naps. Their sleep timing and sleep duration could change daily or weekly and were environmental light–dark cycle independent.

Sleep patterns data were analyzed using univariate analyses of covariance (ANCOVA) with age group and sex as fixed factors. For time-related data, SPSS TIME.HMS function was applied. To avoid decimal statistics, all time-related data were transferred into seconds during the analysis and the results were again transferred into hours and minutes. Chi-square tests were used to analyze age and sex distribution and the questionnaire or log responses for differences in sleep habits distribution between two groups. The correlation analysis (r value) was performed between V1 and V2 and age and sex. The correlation of presence/absence of regular naps was also performed against these two fixed factors. The $r > 0.60$ was counted as the significant correlation. All statistical analyses were performed using SPSS (version 19.0 for Mac, SPSS Inc., Chicago, IL). A significance threshold of $p < 0.05$ was used for all analyses.

3. Results

The sleep habit-related data were derived from the logs ($n = 426$; the margin of error 4.9% at a 95% confidence interval; 426×66 days = 28,116 responses for V1 and V2), interviews ($n = 500$, the margin of error 4.4%; 500×6 interviews = 3000 responses), and daily pattern-related filled questionnaires ($n = 2,861$, the margin of error 1.9%; 2861×2 filled forms = 5722 responses), and 3787 cases with sufficient data were analyzed (the margin of error 1.7%). The agreements between the data collection tools were: the log vs. the interviews – 98.6% agreement; the log vs. the questionnaires – 92.4%; and for the interviews vs. the questionnaires 96.3% of agreement were obtained. For V1a,c,d and V2a,c,d, 3787 responses were collected for each of the variable. For V1b and V2b, 926 responses were collected. The total number of responses collected for V1 and V2 during the whole time of the survey was 36,838 for each of them.

Table 1 presents demographic and general data of the surveyed cohort. For pre-lockdown conditions, the evening bedtime was 22:15 ± 0:20 for adolescents and 22:25 ± 0:45 for adults (Table 2). Table 2 demonstrates that the most significant changes in sleep timing occurred during the first week of stay-at-home. The owls-larks concept could not be analyzed for pre-quarantine conditions in its full complexity because the absolute majority of the participants ($n = 3,439$, 91%) used alarm clocks set at 06:50 ± 1:00 for adolescents and 07:10 ± 0:40 for adults and, therefore, were "must-be" larks because of social obligations.

The average data on bedtime and wake-up time changes during stay-at-home show that the majority of the involved individuals (66.8%) shifted toward eveningness in a situation when the self-selected sleep was possible. As Table 3 shows, the largest group of participants ($n = 1,324$, 35.0%) moved their bedtime to "about one hour later". This tendency permitted numerous pre-lockdown larks to enter the intermediate sleep group while some persons with intermediate sleep pattern became owls. At the same time, 906 (23.9%) participants moved their bedtime to "about two hours later" that permitted some larks to enter the group of owls. Table 3 indicates that most of the stay-at-home people moved their bedtime closer to midnight and the majority of forced larks and persons with intermediate sleep turned to be natural owls. The variability of daily temporal patterns of the participants was increased dramatically. While pre-quarantine standard deviations for bedtime were 20–45 min, they were increased up to 1:30 during the stay-at-home (Table 2). However, as the weekly interviews indicated ($n = 500$), most of the participants adjusted to new realities relatively quickly, in one to two weeks, and did not present any sleep-related complaints. The free-response questions of the questionnaire indicated sleep disturbances at the very beginning of the stay-at-home period in 52 participants (1.4%) that disappeared after first two weeks of the stay-at-home.

Using the above-described cut-off values for sleep timing, 1869 participants appeared to be owls (49.4%), 823 participants (21.7%) exercised "typical" sleep, 478 participants (12.6%) were larks, and 617 (16.3%) participants were completely desynchronized to the end of stay-at-home. At the same time, 497 participants (13.1%) alternated their sleep habits. If the evolution of stay-at-home is analyzed, 313 participants (8.3%) who maintained morningness during one or two first weeks of the stay-at-home period moved to eveningness closer to the end of the period. The rest of 184 participants (4.9%) changed their sleep habits in the opposite direction. Of them, however, almost all can be classified as desynchronized cases. The most of the desynchronized 617 participants ($n = 414$) were older than 50 years (age correlation $r = 0.80$), and predominantly males ($n = 297$, $r = 0.76$). Adolescents, younger adults, and older females did not show such tendencies.

The habit for regular napping significantly decreased in its frequency among adolescents (pre-lockdown 421 vs. two months of stay-at-home 28, $p = 0.001$). For adults, this habit became significantly more widespread (168 vs. 513, $p = 0.004$). Out if this 513 persons, 86 used two naps a day (16.8%) and three had three naps a day (0.6%). The correlation with newly introduced napping and desynchronized cases was strong ($r = 0.92$). Most of the desynchronized adults self-designed their own mental activity – fatigue – (meals) – nap–mental activity – fatigue – (meals) – nocturnal sleep daily rhythm as the most convenient sleep-wake cycle. However, the timing for naps and their duration were not fixed and broadly varied within early afternoon – late afternoon period of the day and from one to three hours (rarely even longer) of sleep. This tendency affected the evening bedtime that also became unfixed. Among the 617 desynchronized participants, 368 indicated their food intake patterns in the logs or during interviews. For 244 of them (66.3%), the "lunch – siesta" and "dinner/supper – nocturnal bedtime" patterns were clearly fixed to the end of the stay-at-home. The rest of 124 participants (33.7%) demonstrated two separate and desynchronized food intake and sleep-wake cycles both of them desynchronized with the light–dark cycle. Therefore, the prolonged napping divided the circadian

Table 1
Demographic and general data of the surveyed cohort (n = 3787) obtained from filled questionnaire forms, daily logs, and during interviews. M/F – male/female.

Variables↓/age groups→	Adolescence group	Adulthood group	Total/average
Questionnaire M/F	373/454	962/1072	2861
Daily log M/F	59/75	128/164	426
Interview M/F	93/88	167/152	500
Age group M/F TOTAL	525/617	1257/1388	1782/2005
Age group TOTAL	1142	2645	3787
Average stay-at-home	69 days	63 days	65 ± 9 days

Table 2
Data on sleep habits before and during the lockdown stay-at-home. P values are given against the pre-lockdown data.

Variables↓/age groups→	Adolescents	Adults	Average	P value
Before lockdown (obtained from 3787 participants)				
V1a Evening bedtime	22:15 ± 0:20	22:25 ± 0:45	22:22 ± 0:45	
V2a Morning get-up time	06:50 ± 1:00	07:05 ± 0:45	07:00 ± 0:40	
Free day bedtime	23:24 ± 0:40	23:55 ± 0:50	23:38 ± 0:50	
Free day get-up time	08:50 ± 0:40	08:50 ± 0:40	08:50 ± 0:45	
Regular napping (n)	421	168	589 (total)	
7 days stay-at-home (obtained from 926 participants)				
V1b Evening bedtime	23:30 ± 1:08	23:50 ± 0:50	23:44 ± 0:57	0.008
V2b Morning get-up time	08:50 ± 1:15	08:45 ± 0:55	08:48 ± 1:12	0.006
Regular napping (n)	65	217	282 (total)	
1 month stay-at-home (obtained from 3787 participants)				
V1c Evening bedtime	23:55 ± 1:15	23:45 ± 0:50	23:47 ± 1:10	0.008
V2c Morning get-up time	09:00 ± 1:24	08:45 ± 1:05	08:55 ± 1:13	0.005
Regular napping (n)	29	474	503 (total)	
2 months stay-at-home ((obtained from 3787 participants)				
V1d Evening bedtime	23:55 ± 1:15	23:35 ± 1:20	23:43 ± 1:15	0.008
V2d Morning get-up time	09:00 ± 1:25	08:45 ± 0:55	08:49 ± 1:20	0.006
Regular napping (n)	28	513	541 (total)	

Table 3
Sleep timing changes after two months in stay-at-home situation (n = 3787). Regular napping is presented as n before the lockdown/n after two months of stay-at-home.

Variables↓/Age groups→	Adolescents (n = 1142)	Adults (n = 2645)	Total
Evening bedtime			
Remained unchanged	212 (18.6%)	388 (14.7%)	600 (15.8%)
About 1 h earlier	18 (1.6%)	27 (1.0%)	45 (1.2%)
About 2 h earlier	0 (0%)	9 (0.3%)	9 (0.2%)
About 1 h later	467 (40.9%)	857 (32.4%)	1324 (35.0%)
About 2 h later	195 (17.0%)	711 (26.9%)	906 (23.9%)
More than 2 h later	94 (8.2%)	206 (7.8%)	300 (7.9%)
Variable time	56 (4.9%)	547 (20.7%)	603 (15.9%)
Morning get-up time			
Remained unchanged	144 (12.6%)	364 (13.8%)	508 (13.4%)
About 1 h earlier	5 (0.4%)	41 (1.6%)	46 (1.2%)
About 2 h earlier	0 (0%)	31 (1.2%)	31 (0.8%)
More than 2 h earlier	0 (0%)	17 (0.6%)	17 (0.5%)
About 1 h later	432 (37.8%)	849 (32.1%)	1281 (33.8%)
About 2 h later	467 (40.9%)	644 (24.3%)	1111 (29.3%)
More than 2 h later	53 (4.6%)	96 (3.6%)	149 (3.9%)
Variable time	41 (3.6%)	603 (22.8%)	644 (17.0%)
Regular napping	421/28	168/513	589/541

cycle of the involved individuals into two mental activity-fatigue-(meals)-sleep cycles during the day with unfixed bedtimes for both periods of sleep because mental fatigue arrived at different times each day.

Involvement in physical/locomotor activity did not produce such changes. Various types of regular physical activity such as sports, cleaning, cooking, gardening, active playing with children, small home repairs, and dancing were indicated in the logs and during the interviews by 715 participants out of 926 (77.2%). Most of them (n = 514, 71.9%) shifted their evening bedtime to one hour later or did not shift it at all and none of them was desynchronized to the end of stay-at-home. During interviews, some of these participants indicated that while they were not involved in work-from-home activities they were not at constant leisure during the stay-at-home and actually had various tasks to perform. Numerous home-related activities that were procrastinated because of limited free time during employment could be performed now. It included general cleaning of the house, cleaning closets from outdated clothes and shoes, minor home repairs, and additional gardening activities. The positive effect of these activities can be seen not only in lack of desynchronized cases but also in lack of complaints about insomnia or disturbed sleep even during the first two weeks of the stay-at-home.

Table 3 also indicates that 508 (13.4%) participants did not change their morning get-up time and, therefore, continued to use alarm clocks. Only 186 of them were interviewed and no sound conclusions are possible, however the “force of habit” was indicated by only six volunteers (3.2%) while the rest indicated various social obligations such as little children at home, pets, and morning prayers as reasons to keep the wake time unchanged.

4. Discussion

Most probably, Robinson Crusoe was a natural lark, otherwise, even without candles he could use an open fire for lighting and spent pleasant long evening hours looking at a bonfire. He appeared to be a good sleeper during his stay-on-the-island situation. With bedtime at 7 p.m. with the sunset, wake-up time around 5 a.m. with sunrise, and daily naps from 12 a.m. to 2 p.m., his total sleep duration was 12 h a day. Or, maybe, Daniel Defoe missed something.

Analyzing the obtained results, the sleep-related elements of the owls-larks concept can be assessed under somewhat different angle. The ongoing development in the classification of human chronotypes expanded the owls-larks classification to the seven-item “extreme early” to “extreme late” scale [21]. In the 1990s, biological rhythms were defined as circadian, ultradian, and infradian rhythms that are the cycles that operate on a period of a day, less than a day, and more than a day, respectively [22]. Later, these rhythms were defined as tidal (0.517 day), daily (1 day), lunar (29.53 days), and annual (365.256 days) rhythms [23]. Genetics, age, gender, and environmental stimuli influence the expression of chronotype [7,9,10,12,17]. Specifically for genetics, researchers indicate from ten to 36 genes that may be involved in human chronobiology [24,25]. How all these variables interact to produce seven different human chronotypes is difficult to say. Can we say that a person with a habit of prolonged midday napping and shortened nocturnal sleep decided to follow the tidal rhythm instead of daily rhythm? Can we say that a person with a newly introduced habit for two or three naps a day shifted into the infant-type temporal daily pattern? The concept of circadian rhythm misalignment or disruption is widely used to explain the extreme variability of sleep habits [26]. Without a precise definition of normality, it is not yet clear do we speak about synchronized and desynchronized circadian cycles and daily rhythms or about organized and disorganized people. Another approach to the problem was to label certain sleep habit variations as disorders [27]. The International Classification of Sleep Disorders (ICSD-2) recognizes nine different circadian rhythm sleep disorders! No clear borderlines between owls and larks as variations of normality and the delayed sleep phase disorder and the advanced sleep phase disorder can be detected in this classification. Recently, some chronobiology approaches were severely criticized with ironic mention of “owls, larks, swifts, and woodcocks” [28]. A failure to develop a unidimensional scale for scoring chronotypological differences and lack of objective markers of chronotype were indicated as the main weaknesses of these approaches.

The authors realize that their results question some accepted opinions. If data on different chronotypes are collected from participants living their ordinary daily routine, the results indicate the significant prevalence of morning-type persons, from 40% to 56% of all participants [10,15,29]. Our results indicate that if self-selected sleep timing is possible, the majority of humans are evening-type persons. Morningness tendencies among older adults were well-documented [30,31] but many of them cannot be called real larks if napping is taken into account. Some human professions may stimulate a tendency towards eveningness [32,33]. Since people introduced open fire for cooking and lighting, the environmental light–dark cycle has been losing its importance in human life. Such invention led to the phenomenon of wisdom teeth as an observable evolutionary change. One may assume that human chronobiology, while less observable, underwent some evolutionary changes as well. In 2018, Putilov et al. investigated 1665 polymorphisms in 36 chronobiology-related genes and found out that such evolutionary changes are actually took place as a part of general adaptation [34]. We doubt that various peculiarities of human sleep habits should be called disorders. Changes in daily rhythm and sleep habits were detected in patients suffering from psychosis, bipolar I disorder, and other mental illnesses [35,36]. Some of our volunteers exercised the same sleep habits but did not suffer from bipolar disorder. Some participants moved toward eveningness, some participants moved toward morningness, and some participants accepted almost infant-type daily napping way of life, but while these changes occurred due to their self-adjustment to new realities, almost none presented any sleep-related complaints. It is difficult to label such temporary changes as disorders.

Specifically for napping, this topic was researched in application to infants and young children as their natural sleep habit [37,38] and to pregnant women as a beneficial change in their daily pattern [39]. The topic remained understudied for the general population until recently when Mairesse et al. introduced the “Napping type” as an additional chronotype [40]. Our results demonstrated that an introduction of regular midday naps changes bedtime and wake-up time of nocturnal sleep almost inevitably and may significantly change the whole sleep-wake cycle of an individual.

The large number of participants who were completely desynchronized ($n = 617$, 16.3%) is not alarming. It was a tendency to estimate circadian sleep dysrhythmia as a sleep disorder [41]. It was demonstrated that mental activity with individual working schedule may produce chronic desynchronization in older adults [42]. That is exactly what had happened during the stay-at-home period but our desynchronized participants presented no complaints. The patients with circadian rhythm sleep disorders typically describe chronic excessive daytime sleepiness and/or insomnia symptoms, impacting their daytime functioning [43]. In a stay-at-home condition, daytime functioning was not impaired and no complaints followed. In other words, circadian rhythm sleep disorders exist, but chronotype disorders do not exist.

Various major changes in how animals fill their days, depending on what demands are being made on them, were reported within the field of animal behavior [44]. The routine daily use of alarm clocks presented the problem of sleep debt accumulated on workdays and raised a question of “social jet-lag” [20,45]. The broader question is: what is natural and what is unnatural in the human way of life? The internal clock is not the only factor determining what people do at different times of the day, because humans can also adjust their sleep habits and temporal daily patterns according to circumstances. Theoretical and methodological shortcomings in the existing literature on sleep habits were noted and the necessity for in-depth study of intraindividual variability was stressed [46]. The authors also indicated a necessity to study sleep habits “across multiple days” [46]. We hope that our 65-day study will add relevant data to the topic.

4.1. Limitations

Any “catch-the-moment” research may have certain weaknesses both in study design and data collection. While a questionnaire-based survey is an established technique to study sleep patterns, any self-report survey has its limitations because of the method of data collection and a discrepancy between the self-reported and non-self-reported (digital sleep-tracking devices, wrist-activity monitors) sleep habits is possible. The geographical analysis was not performed because of the uneven distribution of respondents across the involved countries, from tens to thousands per country. Geographical locations, however, could have a different number of hours of sunlight per day that could affect circadian rhythms. The topic of religious practices was not touched in the survey because of the Ethics Committee requirements as well as the topic of alcohol and other recreational substance use. However, certain religions require time-specific prayers that might affect sleep-wake patterns of some participants forcing them to keep their fixed daily temporal patterns even during the lockdown. The survey took place during the lockdown period as a one-time effort and, therefore, test-retest reliability was not calculated. Our results cannot be generalized to the whole human population that may include individuals with sleep disorders, mood-related disorders, pregnant women, and individuals older than 60 years.

5. Conclusion

In self-selected sleep conditions, the timing of sleep and sleep habits significantly differ from those of socially and economically fixed daily routine conditions. The changes in daily temporal patterns of humans during a prolonged stay-at-home situation indicate that human sleep habits may change according to existing living conditions.

Author contributions

MS, the head of the AMHSI Research Team, had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: AMHSI RT, MRT, and YR. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: AMHSI RT, MV, JB. Critical revision of the manuscript for important intellectual content: AMHSI RT, MRT, LN, and MV. Statistical analysis: YR, MV, and NB. Supervision: AMHSI RT, MRT, and MS. All authors have approved the paper and are personally accountable for their own contributions.

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Conflict of interest

The authors and collaborators declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare that they have no competing interests.

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References

[1] De Manacéíne, Sleep M. Its physiology, pathology, hygiene, and psychology. London: Walter Scott, Ltd.; 1897.
[2] Binns E. The anatomy of sleep. London: John Churchill; 1845.
[3] Hammond WA. Sleep and its derangements. Philadelphia: J.B. Lippincott & Co.; 1869.
[4] Horne JA, Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. Int J Chronobiol 1976;4:97–100.
[5] Webb WB, Bonnet MH. The sleep of 'morning' and 'evening' types. Biol Psychol 1978;7(1–2):29–35.
[6] Adan A, Almirall H. Horne & Östberg morningness-eveningness questionnaire: a reduced scale. Pers Indiv Differ 1991;12(3):241–53. https://doi.org/10.1016/0191-8869(91)90110-W.
[7] McEnany G, Lee KA. Owls, larks and the significance of morningness/eveningness rhythm propensity in psychiatric-mental health nursing. Issues Ment Health Nurs 2000;21(2):203–16.
[8] Allebrandt KV, Roenneberg T. The search for circadian clock components in humans: new perspectives for association studies. Braz J Med Biol Res 2008;41(8):716–21.
[9] Magee C, Gopaldasani V, Bakand S, et al. The physical work environment and sleep: a latent class Analysis. J Occup Environ Med 2019;61(12):1011–8. https://doi.org/10.1097/JOM.0000000000001725.
[10] Magee CA, Blunden S. Sleep timing during adolescence: a latent transition analysis approach. Behav Sleep Med 2020;18(1):131–46. https://doi.org/10.1080/15402002.2018.1546180.
[11] Pagani L, Semenova EA, Moriggi E, et al. The physiological period length of the human circadian clock in vivo is directly proportional to period in human fibroblasts. PloS One 2010 Oct 15;5(10):e13376. https://doi.org/10.1371/journal.pone.0013376.
[12] Merrow M, Spoelstra K, Roenneberg T. The circadian cycle: daily rhythms from behaviour to genes. EMBO Rep 2005;6(10):930–5.
[13] Kumar V, editor. Biological timekeeping: clocks, rhythms and behaviour. New Delhi: Springer; 2017.
[14] Hittle BM, Gillespie GL. Identifying shift worker chronotype: implications for health. Ind Health 2018;56(6):512–23. https://doi.org/10.2486/indhealth.2018-0018.
[15] National Sleep Foundation. Sleep Diary/Sleep Log. www.sleepfoundation.org.
[16] National Sleep Foundation. 2005 Sleep in America poll: adult sleep habits and styles. Washington, DC: National Sleep Foundation; 2005.
[17] Bixler EO, Papaliaga MN, Vgontzas AN, et al. Women sleep objectively better than men and the sleep of young women is more resilient to external stressors: effects of age and menopause. J Sleep Res 2009;18(2):221–8.
[18] Smith CS, Reilly Q, Midkiff K. Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. J Appl Psychol 1989;74:728–38.
[19] Gale C, Martyn C. Larks and owls and health, wealth, and wisdom. BMJ 1998;317(7174):1675–7. https://doi.org/10.1136/bmj.317.7174.1675.
[20] Putilov AA, Verevkin EG, Donskaya OG, et al. Model-based simulations of weekday and weekend sleep times self-reported by larks and owls. Biol Rhythm Res 2018. https://doi.org/10.1080/09291016.2018.1558735.
[21] Roenneberg T, Wirz-Justice A, Merrow M. Life between clocks: daily temporal patterns of human chronotypes. J Biol Rhythm 2003;18(1):80–90.
[22] Monk TH, Folkard S. Making shiftwork tolerable. New York: Taylor & Francis; 1992.
[23] Floessner T, Hut RA. Basic principles underlying biological oscillations and their entrainment. In: Kumar V, editor. Biological timekeeping: clocks, rhythms and behaviour. New Delhi: Springer; 2017. p. 47–58.
[24] Putilov AA, Dorokhov VB, Poluektov MG. How have our clocks evolved? Adaptive and demographic history of the out-of-African dispersal told by polymorphic loci in circadian genes. Chronobiol Int 2018;35(4):511–32. https://doi.org/10.1080/07420528.2017.1417314.
[25] Garbazza C, Benedetti F. Genetic factors affecting seasonality, mood, and the circadian clock. Front Endocrinol (Lausanne) 2018 Aug 23;9:481. https://doi.org/10.3389/fendo.2018.00481.

[26] Deibel SH, McDonald RJ, Kolla NJ. Are owls and larks different when it comes to aggression? Genetics, neurobiology, and behavior. Front Behav Neurosci 2020 Mar 17;14:39. https://doi.org/10.3389/fnbeh.2020.00039.
[27] Reid KJ. Assessment of circadian rhythms. Neurol Clin 2019;37(3):505–26. https://doi.org/10.1016/j.ncl.2019.05.001.
[28] Putilov AA. Owls, larks, swifts, woodcocks and they are not alone: a historical review of methodology for multidimensional self-assessment of individual differences in sleep-wake pattern. Chronobiol Int 2017;34(3):426–37. https://doi.org/10.1080/07420528.2017.1278704.
[29] Taillard J, Philip P, Bioulac B. Morningness/eveningness and the need for sleep. J Sleep Res 1999;8(4):291–5.
[30] Duffy JF, Czeisler CA. Age-related change in the relationship between circadian period, circadian phase, and diurnal preference in humans. Neurosci Lett 2002;318(3):117–20.
[31] Biss RK, Hasher L. Happy as a lark: morning-type younger and older adults are higher in positive affect. Emotion 2012;12(3):437–41. https://doi.org/10.1037/a0027071.
[32] Gjermunds N, Brechan I, Johnsen SÅK, et al. Musicians: larks, owls or hummingbirds? J Circadian Rhythms 2019 May 7;17:4. https://doi.org/10.5334/jcr.173.
[33] Chin-Quee AL, Yaremchuk K. Medical residents' circadian preferences across specialties. Laryngoscope 2017;127(10):2236–8. https://doi.org/10.1002/lary.26449.
[34] Putilov AA, Dorokhov VB, Poluektov MG. How have our clocks evolved? Adaptive and demographic history of the out-of-African dispersal told by polymorphic loci in circadian genes. Chronobiol Int 2018;35(4):511–32. https://doi.org/10.1080/07420528.2017.1417314.
[35] Salvatore P, Ghidini S, Zita G, et al. Circadian activity rhythm abnormalities in ill and recovered bipolar I disorder patients. Bipolar Disord 2008;10(2):256–65. https://doi.org/10.1111/j.1399-5618.2007.00505.x.
[36] Leufstadius C, Eklund M. Time use among individuals with persistent mental illness: identifying risk factors for imbalance in daily activities. Scand J Occup Ther 2008;15(1):23–33.
[37] Araki A, Ohinata J, Suzuki N, et al. Questionnaire survey on sleep habit of 3-year-old children in Asahikawa City. No Hattatsu 2008;40(5):370–4.
[38] Chaput JP, Gray CE, Poitras VJ, et al. Systematic review of the relationships between sleep duration and health indicators in the early years (0-4 years). BMC Publ Health 2017 Nov 20;17(Suppl 5):855. https://doi.org/10.1186/s12889-017-4850-2.
[39] Wang W, Li M, Huang T, et al. Effect of nighttime sleep duration and midday napping in early pregnancy on gestational diabetes mellitus. Sleep Breath 2020 Apr 8. https://doi.org/10.1007/s11325-020-02076-3 [Epub ahead of print].
[40] Mairesse O, Delwiche B, Neu D, et al. There is more to chronotypes than larks and owls. Evidence of two additional chronotypes in humans from a large scale community-based survey. Pers Indiv Differ 2019;148:77–84. https://doi.org/10.1016/j.paid.2019.05.017.
[41] D'Alonzo GE, Krachman SL. Circadian rhythm sleep disorders. J Am Osteopath Assoc 2000;100(8 Suppl):S15–21.
[42] Opalovskaya GM. Circadian rhythms of autonomic parameters during mental and physical activity. Bull Exp Biol Med 2001;132(5):1029–33.
[43] Luca G, Van Den Broecke S. Circadian rhythm sleep disorders: clinical picture, diagnosis and treatment. Rev Med Suisse 2020;16(698):1237–42.
[44] Meddis R. The evolution of sleep. In: Mayes A, editor. Sleep mechanisms and functions. London: Van Nostrand; 1983. p. 57–106.
[45] Phillips ML. Circadian rhythms: of owls, larks and alarm clocks. Nature 2009;458(7235):142–4. https://doi.org/10.1038/458142a.
[46] Bei B, Wiley JF, Trinder J, et al. Beyond the mean: a systematic review on the correlates of daily intraindividual variability of sleep/wake patterns. Sleep Med Rev 2016;28:108–24. https://doi.org/10.1016/j.smrv.2015.06.003.