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Effects of lockdown on human sleep and chronotype during the COVID-19 pandemic

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The COVID-19 pandemic [1] resulted in many countries imposing a lockdown, which in turn reduces sunlight exposure and alters daily social schedules. Since these are the main entrainment factors for biological rhythms [2], we hypothesized that the lockdown may have affected sleep and circadian rhythms. We indeed show that participants slept longer and later during lockdown weekdays, and exhibited lower levels of social jetlag. While this may seem to be an overall improvement of sleep conditions, chronotype was also delayed under the lockdown. This signature of a weaker light–dark cycle should be monitored attentively since it may progressively cause disruptive effects on sleep and circadian rhythms, affecting human performance and health [3].

We analyzed a database of 25,000 respondents of a detailed circadian/sleep survey in Argentina. We compared sleep duration, quality and timing, social jetlag and chronotype between control and lockdown conditions (Figure 1 and Table S1 in Supplemental Information, published with this article online) of 1,021 subjects that completed questionnaires both before and during the pandemic. Sleep onset and offset were delayed during the lockdown, but only on weekdays (Figure 1, Table S1). The delay in the offset was greater than the onset; thus, weekday sleep duration was longer during the lockdown. Only 37.30% of participants did not reach the recommended 7h of sleep [4] on weekdays during the lockdown compared to 60.24% under control conditions. Furthermore, social jetlag (the sleep timing difference between free and weekdays) decreased during the lockdown (Figure 1D, Table S1), indicating that sleep schedules became

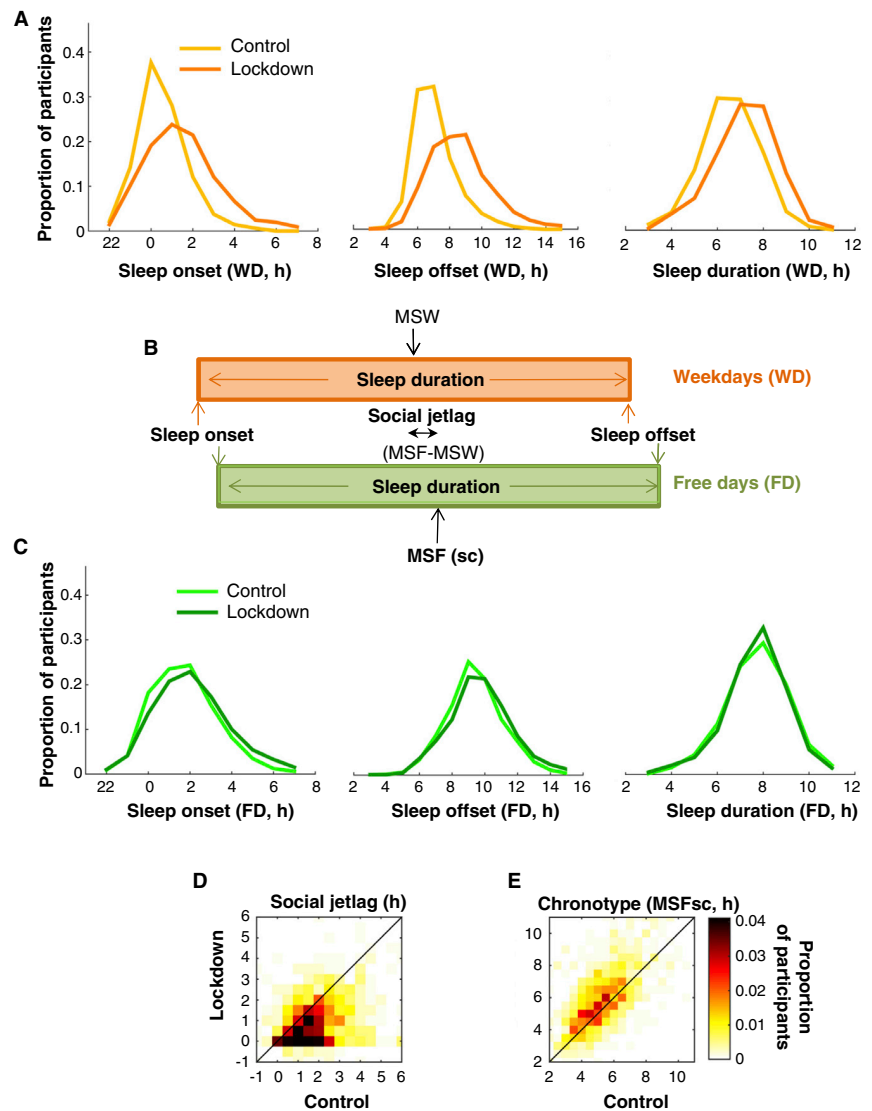


Figure 1. Lockdown is associated with later and longer sleep on weekdays, lower levels of social jetlag and a delayed chronotype.

(A) Histograms of sleep onset, offset and duration on weekdays (WD) during control and lockdown conditions. On weekdays, sleep onset occurs 56min later and sleep offset occurs 1h35min later during lockdown. On average, subjects slept from 00:35 to 07:13h on control weekdays and from 01:31 to 08:48h on lockdown weekdays. Sleep duration on weekdays is 39min longer under lockdown (6.631h versus 7.277h). (B) Schema of main variables analyzed on both week and free days (FD). (C) Histograms of sleep onset, offset and duration on free days under control and lockdown conditions. (D) Two-dimensional histogram of social jetlag during control and lockdown conditions. Social jetlag decreases by 54min during lockdown (1.790h versus 0.885h). (E) Two-dimensional histogram of chronotype (midpoint of sleep on free days, sleep corrected, or MSFsc) during control and lockdown conditions. Chronotype is 36min later during lockdown (05:16 versus 05:52). Sleep onset, offset and MSFsc chronotype are presented as local time, whereas sleep duration and social jetlag are presented as number of hours. Only statistically significant and relevant differences are reported ($p < 0.001$ and Cohen's $d < 0.4$; Table S1).

more consistent throughout the week. In keeping with this, the number of subjects using alarm clocks (36.14% versus 73.16%, $p < 0.0001$) or taking naps (48.09% versus 58.08%, $p < 0.0001$) decreased during lockdown

weekdays (Supplemental Results). The lockdown, however, did not affect sleep quality, measured through the Pittsburgh Sleep Quality Index (PSQI score) ($Z = 2.722$, $p = 0.0065$, $r = 0.0602$). Finally, we measured chronotype using the



MSFsc (midpoint of sleep on free days, sleep corrected), which was found to be significantly delayed during the lockdown (Figure 1E, Table S1). A second proxy, the MEQ (Morningness-Eveningness Questionnaire) score, did not change, but this could be predicted since effects on diurnal preferences (MEQ score) are expected to lag behind those in sleep timing (MSFsc).

We then measured how demographic and social factors affect sleep. Younger subjects exhibited both later sleep onset and offset on weekdays, longer sleep duration on weekdays, higher social jetlag and later chronotype. The effects of lockdown on sleep and chronotype were much larger on younger subjects (Figure S1). This is quantified by main effects of age and an interaction with condition (lockdown or control) on all variables. With regard to working status, this factor had main effects and interacted with condition for all dependent variables (Figure S1F–J). Participants who changed their working status exhibited larger differences in sleep and chronotype. The percentage of subjects not reaching the minimum recommended levels of sleep duration on weekdays decreased from 61.01% to 35.01% in the group who worked from home during lockdown, but continued to be high for those who worked outside in both conditions (72.92% versus 68.42%). Those who did not work outside during the lockdown improved their sleep, but their chronotype became more delayed. Finally, while we found that both cohabitation status and longitude had main effects on sleep onset on weekdays and chronotype, the effect was comparable during lockdown and control conditions (Supplemental Results).

Our results demonstrate a significant effect of the lockdown imposed during the COVID-19 pandemic on sleep and chronotype parameters. While some parameters appear to be improved, with longer sleep duration on weekdays and a decreased social jetlag (indicating a less variable sleep timing), chronotype was significantly delayed. One could speculate that this might be associated with changes in lifestyle associated with weaker social cues (e.g. mainly work and school schedules, which became more flexible, delayed or even absent) and a lower exposure to light in the morning (and/or a higher exposure in the evening hours) reflecting a drift

from regular entrainment. While people significantly decreased their sleep debt by about 40 minutes a day on weekdays, the sleep duration during free days did not shorten at all. It is possible that sleep debt was smaller but not completely absent during the lockdown; however, our results suggest there was no direct compensation between sleep debt on weekdays and recovery on free days. Objective measures of sleep and circadian rhythms, as well as light exposure, seem imperative to determine the consequences of all these simultaneous changes.

Sleep and chronotype exhibit developmental changes: sleep duration decreases, and social jetlag and chronotype show a peak at the end of adolescence [5,6]. Our results support these main effects, showing that age interacts with lockdown: younger subjects experienced larger changes in sleep and chronotype than older ones. The magnitude of the lockdown-induced changes depended on subjects' working status: changes in the working schedule regulated how much sleep and chronotype were affected during the lockdown. Those subjects who started to work from home or those who stopped working slept more and exhibited less social jetlag and later chronotypes than those who continued working outside during lockdown. This result is important because the COVID-19 outbreak offers the unique opportunity to evaluate how sleep is affected depending on working schedules, since it is likely that work and school schedules will be affected chronically after the lockdown period is completed.

A recent survey in Italy indicated that sleep timing was significantly changed during the lockdown, with longer sleep times, a clear phase delay and a lower sleep quality [7]. This correlated with higher levels of depression and anxiety, which was also found in China during the enforced lockdown period [8]. An important strength of our work is that we evaluated not only sleep but also chronotype in the same subjects under both control and lockdown conditions. Additionally, the whole country was equally and globally enforced to adopt the mandatory confinement on the same date (March 20th, 2020). Finally, the large size and the distribution of ages, geographical locations and characteristics of work and cohabitation

status of our sample also allow us to evaluate which predictors modulate the impact of lockdown on the general population. Since sleep and circadian entrainment affect the immune system [9,10], the maintenance of healthy sleep and circadian rhythms might serve as a protective strategy against infectious diseases. It is quite likely that these quarantine measures will extend into the coming months, and even years, making this analysis necessary and timely for psychological and physical wellbeing recommendations.

SUPPLEMENTAL INFORMATION

Supplemental Information contains one figure, one table, results, and experimental procedures, all of which can be found with this article online at <https://doi.org/10.1016/j.cub.2020.07.015>.

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