Supplemental Information: Effects of the COVID-19 lockdown on human sleep and rest-activity rhythms

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Table S1.

		Total		Men		Women		Diverse	
		n	%	*n*	%	*n*	%	*n*	%
Total		435	100	104	23.9	327	75.2	4	0.9
Age	18-25	118	27.1	19	4.4	99	22.8		
	26-35	159	36.6	38	8.7	119	27.4	2	0.5
	36-45	67	15.4	20	4.6	45	10.3	2	0.5
	46-55	54	12.4	12	2.8	42	9.7		
	56-65	33	7.6	14	3.2	19	4.4		
	> 65	4	0.9	1	0.2	3	0.7		
Socioeconomic status	low	23	5.3	7	1.6	15	3.5		
	medium	298	68.5	60	13.8	235	54	3	0.7
	high	114	26.2	37	8.5	77	17.7		
Highest educational level obtained	Lower secondary school	7	1.6	2	0.5	5	1.2		
	Apprenticeship	33	7.6	8	1.8	25	5.8		
	Higher education	78	17.9	22	5.1	56	12.9		
	University degree	317	72.9	72	16.6	241	55.4	4	0.9
Position	Student	119	27.4	19	4.4	99	22.8	1	0.2
	Employee	291	66.9	75	17.2	213	49	3	0.7
	Self-employed	21	4.8	9	2.1	12	2.8		
	House husband/wife	4	0.9	1	0.2	3	0.7		

Overview of the sociodemographic data of all participants.

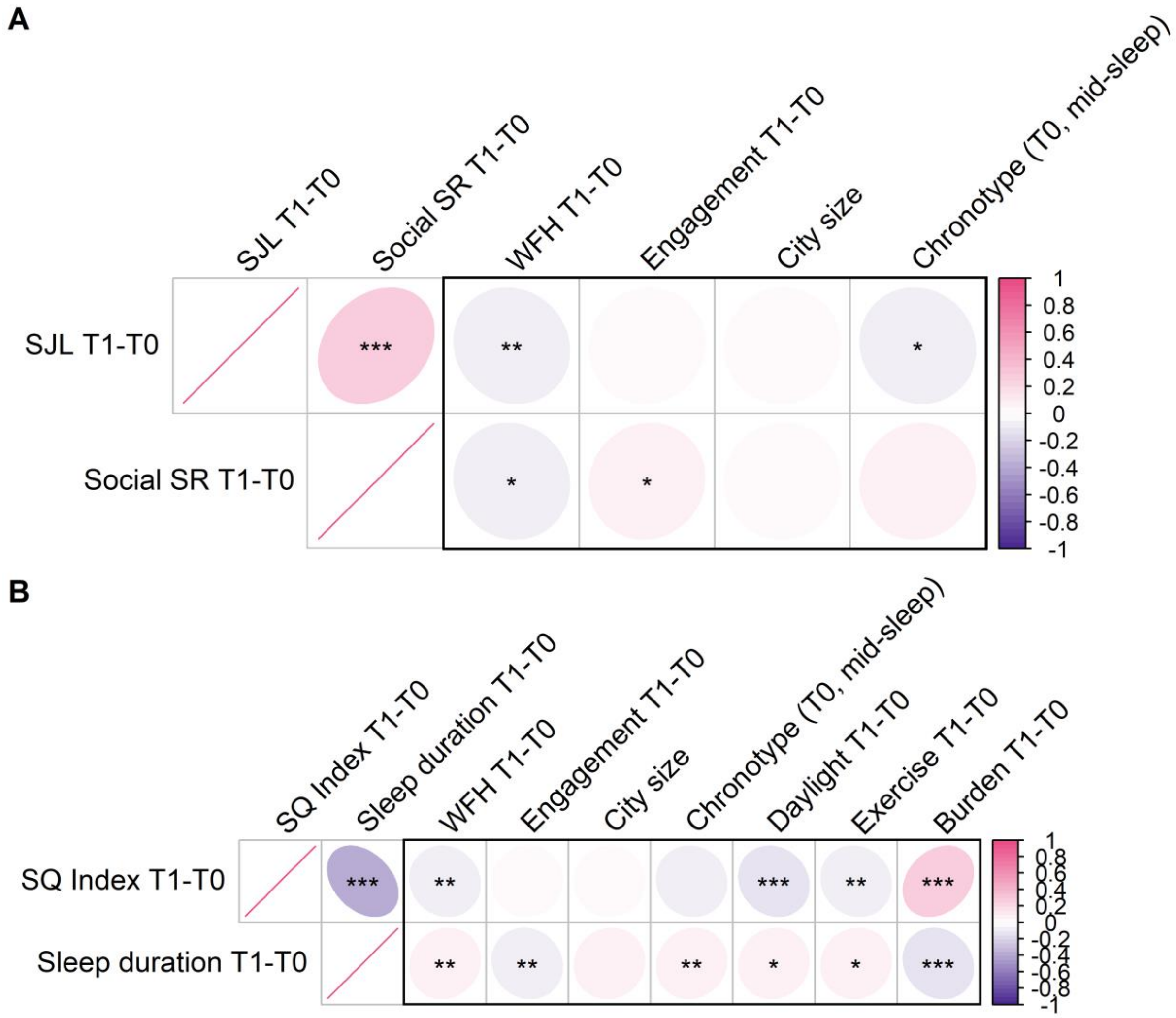

Figure S1. Confirmatory analyses of correlations as specified in the preregistration for (A) social jetlag (SJL) and social sleep restriction (SSR), and (B) for sleep quality (SQ) and sleep duration. All correlations are based on differences between T1 (during the ‘lockdown’) and T0 (pre ‘lockdown’, retrospectively assessed) except for chronotype and city size/ degree of urbanisation, which were assessed in reference to T0. More work from home at T0 compared to T1 relates to decreased social jetlag (SJL) and social sleep restriction (SSR) and to less decrease in sleep quality and longer sleep duration. More engagement, i.e. work-related and social activities, relates to increased SSR and decreased sleep duration. A later chronotype is associated with decreased SJL and increased sleep duration. More exposure to daylight and more exercise limited the decrease in sleep quality and prolonged sleep duration. An increase in perceived burden relates to shorter sleep duration and decreased sleep quality. The black box encircles the confirmatory analyses. Analyses outside these boxes are exploratory. * = *p*<.05; ** = p <.01; *** = *p* < .001 (uncorrected).

Supplemental Experimental Procedures

Survey characteristics

Participants were recruited via the investigators' personal contacts, social media (i.e., Facebook, Instagram, and Twitter) profiles, and support from the public relations offices of the University of Basel, the Psychiatric Hospital of the University of Basel, and the University of Salzburg (Austria), which resulted in media coverage in printed media and on the radio. The completion of the one-time survey took approx. 20 minutes and ran on REDCap [1, 2]. The sampling period was between 23 March and 26 April 2020. Analyses confirmed that participants answered all questions within approx. 20 minutes (*median*; interquartile range [IQR] = 16-27 minutes) on the same day. It included (1) a questionnaire collecting background information, (2) a questionnaire about the ‘‘lockdown’-induced changes volunteers experienced in their personal lives (e.g. regarding work-related flexibility, work and social life-related activities, subjectively perceived burden, etc.), (3) a sleep-quality questionnaire, (4) the ultra-short version of the Munich Chronotype Questionnaire [μMCTQ; 3] to assess social jetlag (SJL) and social sleep restriction, (5) and a multidimensional questionnaire on life satisfaction. Importantly, questionnaires (3), (4), and (5) were answered twice in a row, once retrospectively referring to the time before the restrictions took effect (in the case of the sleep quality questionnaire the four weeks before the 'lockdown') and once referring to the time since participants noticed the effects of the restrictions. A code book detailing all questions as well as the scales used for the answers can be found in the pre-registration of this study [4]. Unfortunately, the code book is in German, but we kindly ask anyone interested to contact the lead author Dr. Christine Blume in case there are any questions.

Participant characteristics

A total of 513 participants provided us with their answers, 435 (327 women, four diverse; 18-25 years: 27%, 26-35 years: 37%, 36-45 years: 15%, 46-55 years: 12%, 56-65 years: 8%, >65 years: 1%) were included after application of exclusion criteria. Most (97.4%) of the participants reported a medium to high socioeconomic status and a high educational level (90.8%), which is probably a result of the recruitment strategies (i.e., investigators' own activities and support from universities' PR offices; for further details cf. Table S1). More than half of the volunteers (54.3%) lived in Switzerland, 27.6% in Germany, 15.6% in Austria and 2.5% (11 participants) in other countries. Please note that, according to the exclusion criteria, participants living in other (neighbouring) countries must also have been noticing the effects of the restrictions for at least five days to be included in the analyses. Of the participants, 60 (13.7%) lived in villages (<5.000 inhabitants), 108 (24.5%) in small cities (<20.000

inhabitants), 60 (13.8%) in medium-sized cities (<100.000 inhabitants), and 208 (47.6%) in large cities (>100.000 inhabitants). Regarding participants' chronotype, the median mid-sleep on free days (corrected for oversleep if necessary; MSF_{sc}) before the 'lockdown' occurred at 3:43 am with an interquartile range (*IQR*, 25th-75th quantile) of 2:32-4:05 am. During the 'lockdown', median MSF_{sc} occurred at 3:57 (*IQR* 2:40-4:15 am), which was significantly later than before ($F(1)=6.74$, $p = .009$, $RTE = 52.4\%$). Overall, participants indicated that they spent less time under the open sky than before the restrictions (*mdn* = -10; *IQR* -25-11 with a total range from -50 [much less than before] to 50 [much more than before] and zero indicating no change). Volunteers also said they exercised less than before the restrictions (*mdn* = -15; *IQR* -27-2 with a total range from -50 [much less than before] to 50 [much more than before] and zero indicating no change).

Information on the precise restrictions the ''lockdown' comprised and the dates when they took effect can be found online for Germany [5, 6], Austria [7], and Switzerland [8, 9]. The median time for which participants say they had been noticing the effects of the restrictions was 14 days with an *IQR* of 10-21 days. At the point of participation in the survey, participants felt their lives were affected by different measures to contain the COVID-19 epidemic to a varying degree. The closure of schools affected 105 (24.1%) of the participants, 240 (55.2%) were affected by universities being closed. Border closure affected 190 (43.7%) volunteers, the prohibition of assembly 207 (68.3%), and curfews affected 165 (60.9%). Almost all participants said they were affected by social/physical distancing (416; 95.6%) and a reduction of recreational activities (377, 86.7%). A majority was also affected by the closure of stores (346, 79.5%), 313 (72%) by working from home, 58 (13.3%) also by discontinuation of childcare. Self-quarantine and a ban on leaving the house had effects on 94 (21.6%) and 51 (11.7%) of the participants, respectively.

Generally, participants felt less busy than before the restrictions regarding meetings, travel, and appointments (*mdn* = -10; *IQR* -24-0 with a total range from -50 [much less than before] to 50 [much more than before] and zero indicating no change). Approximately 80.7% of the participants reported working more from home than before ($F_{ATS}(1)=536.5$, $p<.001$, $RTE=.81$), with the median proportion of work time spent working from home increasing from 10% prior to the ''lockdown' (*IQR* = 0-26%) to 100% during the 'lockdown' (*IQR* = 50-100%; mdn_{diff} = 63%, IQR_{diff} = 17-88%; $F_{ATS}(1)=678.9$, $p<.001$, $RTE=.83$). Along with more time spent working from home, work time also became more flexible. While prior to the 'lockdown', participants indicated moderate flexibility regarding their work times (*mdn* = 13 on a scale from -50 to 50, *IQR* = -10-24), during the 'lockdown' they indicated increased flexibility (*mdn* = 25, *IQR* = 7-40; mdn_{diff} = 10, IQR_{diff} = 0-23; $F_{ATS}(1)=157.3$, $p<.001$,

RTE=.66). Additionally, the median amount of work time decreased from 40 hours per week prior to the ‘lockdown’ (IQR = 30-42 hours) to 35 hours during the ‘lockdown’ (IQR = 25-42 hours; mdn_{diff} = 63%, IQR_{diff} = 17-88%; $F_{ATS}(1)=35.4$, $p<.001$, RTE=.44). Furthermore, the median proportion of evenings spent with recreational activities (i.e., leisure activities) decreased from a median of three evenings per week prior to the ‘lockdown’ (IQR = 2-4 evenings) to a median of zero evenings per week during the ‘lockdown’ (IQR = 0-1 evenings; mdn_{diff} = -2.5, IQR_{diff} = -3- -1; $F_{ATS}(1)=1286.9$, $p<.001$, RTE=.11).

Beyond changes in work and social life as well as work-related flexibility, we also assessed to what extent participants experienced a change in perceived burden and wellbeing. During the ‘lockdown’, they indicated that they felt more burdened than before (mdn = 10 on a scale from -50 to 50 with zero indicating ‘no change’, IQR = 0-19). Of all participants, 49 (11%) felt more burdened than before the ‘lockdown’ due to childcare, 193 (44%) due to family-related issues, 81 (19%) due to household matters, 193 (44%) due to work/university, 144 (33%) due to health issues, 82 (19%) due to their own economic situation, and 155 (36%) indicated they were more afraid of the future. Of all participants, 48 (11%) also indicated there was no area due to which they felt more subjectively burdened than before the ‘lockdown’. When asked about areas that meant less burden during the ‘lockdown’ than before, 15 (3%) felt less burdened because of childcare, 39 (9%) because of family-related issues, 107 (25%) due to household matters, 102 (23%) due to work/university, 9 (2%) due to health issues, 27 (6%) due to their economic situation, and 16 (4%) indicated they were less afraid of the future. A total of 201 (46%) of the volunteers did not identify an area due to which they felt less burdened during the ‘lockdown’ than before. Median mental and physical wellbeing decreased from 10 on a scale ranging from 0 to 12 (IQR = 8-11) to 8 (IQR = 6-9; mdn_{diff} = -1, IQR_{diff} = -1-0; $F_{ATS}(1)=170.6$, $p<.001$, RTE=.33)

Data Reduction and Statistical Analyses

All hypotheses and the statistical approach were detailed in a pre-registration on Open Science Framework [4].

Data reduction.

In the following, we explain in detail how the values for aggregated scales were obtained, as well as any transformations of the data.

Sleep Quality.

The sleep-quality (SQ) questionnaire comprised nine different items, including questions about the average daily sleep duration, subjective sleep quality (4-point Likert scale, ranging from ‘very good’ [0] to ‘very bad’ [3]), sleep problems such as problems falling asleep, problems maintaining sleep, as well as sleep disturbances due to noise (4-point Likert scale, ranging from ‘never’ [0] to ‘3 or more times per week’ [3]). The SQ questionnaire also asked about the feeling of being refreshed and satisfaction with one’s sleep after waking up (4-point Likert scale, ranging from ‘very good’ [0] to ‘very bad’ [3]), and symptoms of daytime fatigue (5-point Likert scale, ranging from ‘never’ [0] to ‘always’ [4]). Furthermore, the number of nights per week during which participants used sleep medication was assessed (4-point Likert scale, ranging from ‘never’ [0] to ‘3 or more times per week’ [3]). The SQ questionnaire was designed to most parsimoniously assess sleep quality in the general population. To this end, we used items from the German ‘Studie zur Gesundheit Erwachsener in Deutschland’ [DEGS; 10], which included five items partly adapted from the Pittsburgh Sleep Quality Index [PSQI; 11]. Following discussions with experts in the field, we additionally included three items to assess daytime fatigue and the feeling of being refreshed when waking up as well as disturbances due to noise (because the ‘lockdown’ was associated with a reduction in traffic noise). Questions on these factors are also included in established sleep quality questionnaires such as the Karolinska Sleep Questionnaire [12] and the Sleep Quality Scale [13]. The SQ index was calculated based on the SQ questionnaire (range 0-25), with higher values indicating worse sleep quality. To calculate the sleep quality index, sleep duration was transformed according to the procedure used in the PSQI [11; less than/or 5 hours sleep = 3, less than/or 6 hours = 2, less than/or 7 hours = 1, more than 7 hours = 0]. If necessary, the scaling of questions was reversed so larger values would indicate decreased sleep quality. Subsequently, the coded answers of all items except sleep medication (which served as an exclusion criterion) were added up to a cumulative value (range 0-25).

Social Jetlag.

To calculate social jetlag (SJL), we used equation E1 provided by Wittmann, et al. [14], where MSF is the mid-sleep point on free days and MSW denotes the mid-sleep point on work days:

$$SJL = MSF - MSW \text{ (Equation E1)}$$

Prior to the calculation, sleep time entries were screened for implausible values and these were unified (e.g., 10am became 10pm).

Social Sleep Restriction.

To calculate Social Sleep Restriction (SSR) we used equation E3, where SD_f is the sleep duration on free days and SD_w the sleep duration on workdays:

$$SSR = SD_f - SD_w \text{ (Equation E3)}$$

Work from Home.

To calculate the proportion of Work from Home (WFH) we used equation E4:

$$\mathrm{WFH} = \left(\frac{\text{time working from home}}{\text{total worktime}}\right) * 100 \text{ (Equation E4)}$$

Prior to the calculation, we averaged values where participants had indicated a range (e.g., '5-10 h' became '7.5 h'). Furthermore, we screened for implausible entries, where in 28 cases we were certain that participants had swapped the number of hours they worked from home during the 'lockdown' and total work time during the 'lockdown'. In these cases, the time spent working from home exceeded the total worktime. These values were then exchanged to reflect the correct values. If participants reported a total worktime of zero hours before or during the 'lockdown', we replaced the resulting 'NaNs' by 0 % work from home.

Chronotype.

Chronotype was assessed from the answers given in relation to T0, that is, before the 'lockdown' and calculated according to Wittmann, et al. [14]. To determine chronotype, we used equation E5 (a or b), where SD is sleep duration, and index 'f' indicates free and index 'w' working days. MSF denotes the mid-sleep point on free days and MSF_{sc} the mid-sleep point corrected for oversleep on weekends. SD_{week} is the average weekly sleep duration:

If $SD_f \leq SD_w$

$$MSF_{sc} = MSF \text{ (Equation E5a)}$$

If $SD_f > SD_w$

$$MSF_{sc} = MSF - (SD_f - SD_{week})/2 \text{ (Equation E5b)}$$

Please note that the ultra-short version of the MCTQ used here [μMCTQ; 3] does not ask for the use of alarm clocks on free days. While we would like to mention this as a potential limitation, the authors of the validation study conclude that the μMCTQ represents a good alternative to the longer standard MCTQ to measure the point of entrainment or chronotype.

Degree of urbanisation/ City size.

City size was assessed in four categories: rural (0; <5.000 inhabitants), small city (1; 5.000-<20.000 inhabitants), medium-sized city (2; 20.000-<100.000 inhabitants), large city (3; >100.000 inhabitants).

Wellbeing.

For exploratory analyses, we also computed participants' wellbeing by summing up results from two items from the life satisfaction scale, i.e. 'satisfaction with physical health' and 'satisfaction with mental wellbeing (e.g., general mood, confidence, even temper)', which participants rated on a 7-point Likert scale ranging from 'not at all satisfied' (0) to 'very satisfied' (6). Please note that five out of the 435 participants did not complete the questions on life satisfaction, which were asked at the end of the survey. They were thus excluded from the analyses.

Background information: sociodemographic data.

We collected data regarding the sociodemographic characteristics of the participants (i.e., age, gender, country, socioeconomic status). Age was grouped into seven different groups (ranging from 'under 18' [1] to 'over 65' [7]).

Background information: measures to contain COVID-19.

We also asked about the different measures that were active while participants answered the questionnaires, that is, they were presented with a list of 12 measures participants could choose from. We also asked whether they were currently quarantined and/or suffered from COVID-19 themselves. Additionally, we were interested in the exact time window, for which participants had been noticing the measures in their personal lives at the point of answering the questionnaires.

Background information: occupation and work environment.

Furthermore, we gained insights in the work environment of the participants by asking about their occupational area as well as position, and if they work in shifts, where working night shifts served as an exclusion criterion.

Perceived burden.

Participants rated the change in self-perceived burden on a visual analogue scale ranging from 'much less than before' to 'much more than before'. The variable was centred on zero with zero indicating no change and a range between -50 and 50.

'Lockdown'-induced changes: Work.

We asked about worktime (in hours), time spent working from home (in hours), and flexibility regarding working hours (visual analogue scale ranging from 0-100, centred on zero for our analyses) before the 'lockdown' started (T0) and during the 'lockdown' (T1).

'Lockdown'-induced changes: Leisure activities.

To analyse how leisure activities decreased during the 'lockdown', we asked how many evenings per week volunteers spent with recreational activities (8-point Likert scale, ranging from 'no evening' [0] to 'seven evenings a week' [7]) before the 'lockdown' (T0) and during the 'lockdown' (T1). The values were transformed to a percentage of evenings spent with recreational activities.

'Lockdown'-induced changes: Engagement in work-related and leisure activities.

The changes in work and leisure activities were expressed as the mean of the 'lockdown'-induced changes regarding engagement at work and evenings spent with recreational activities (in percent).

'Lockdown'-induced changes: Daylight exposure.

The change in time spent under the open sky from T0 to T1 was captured with a visual analogue scale ranging from 'much less' ('0') to 'much more' ('100'). The variable was centred on zero with a range between -50 and 50.

'Lockdown'-induced changes: Exercising.

The change in exercising from T0 to T1 was captured with a visual analogue scale ranging from 'much less' ('0') to 'much more' ('100'). The variable was centred on zero with a range between -50 and 50.

Changes in variables.

All difference or change measures, which served as an input to the correlation analyses, were computed as T1 ('lockdown') - T0 (pre 'lockdown').

Hypotheses.

The following confirmatory hypotheses were tested according to the pre-registration on Open Science Framework [4]. They concerned four parameters: (1) sleep duration, (2) sleep quality, (3) social jetlag [SJL; 14][1], and (4) social sleep restriction (SSR). For sleep duration, we expected a shorter sleep duration before than during the 'lockdown'. We likewise expected a lower sleep quality before than during the 'lockdown' due to a larger mismatch between social and biological rhythms. For SJL and SSR, we expected a decrease during the 'lockdown' as compared to before the 'lockdown'. Furthermore, for sleep duration, sleep quality, social jetlag indices, and 'social sleep restriction', we expected effects to be more pronounced:

[1] Please note that in an earlier version, we had also planned to include SJL corrected for oversleep on weekends (sleep-corrected SJL; SJLsc according to Jankowski et al. (2017)) as a second SJL measure with the same hypotheses as for SJL. However, during the implementation of this measure we noticed that the computation SJLsc is not straightforward as different sleep patterns have to be taken into account and rules for categorisation may be conflicting. A valid implementation thus seemed questionable, wherefore we decided to only compute 'classic' SJL and use SSR as a measure of sleep restriction during the work week.

- The more working hours volunteers spend working from home during the ‘lockdown’ compared to before
- The stronger the decrease in work and social life-related activities and tasks during the ‘lockdown’ compared to before
- The more densely populated the area volunteers live in is
- For later chronotypes (before the ‘lockdown’).

For sleep duration and sleep quality, we expect effects to be more pronounced:

- The larger the increase in time spent under the open sky during the ‘lockdown’ compared to before
- The larger the increase in physical exercise during the ‘lockdown’ compared to before
- The stronger the decrease in subjectively perceived burden during the ‘lockdown’ compared to before.

Data exclusion.

A total of 78 (from 513) participants were excluded prior to data analyses as they presented with characteristics, which we assumed to prevent a valid assessment of sleep-wake patterns. More precisely, we excluded unemployed/retired participants and shift workers who also work night shifts. Moreover, we excluded those, who reported using sleep medication >2x/week as well as volunteers suffering from sleep disorders other than insomnia [e.g., restless legs, sleep apnoea]. Last, we also excluded volunteers who indicated they had been noticing the effects of the ‘lockdown’ for less than five days or repeatedly participated in the study.

Statistical analyses.

All statistical analyses were done in R version 3.6.1 [16]. As all data were non-normally distributed according to Shapiro-Wilk tests for normality (all $p < .001$), we exclusively used non-parametric statistical approaches. All hypotheses detailed in the pre-registration were tested in a one-sided manner against a critical *p*-value of $p = .05$, while exploratory analyses (which are labelled as such) were tested in a two-sided fashion. Besides uncorrected *p*-values, we also report *p*-values adjusted for multiple comparisons for all confirmatory analyses [17] using the ‘False Discovery Rate’ (FDR) method [18] as implemented in R’s ‘p.adjust’ function. Please note that the interpretation of the results is based on the consistent *general pattern* of associations and *not* single results (or ‘cherry-picking’) as recommended by Wasserstein, et al. [19], wherefore the interpretation may, in rare occasions, also take into account uncorrected *p*-values or ‘trends’. Results with $.05 \leq p \leq .06$ are denoted trends and for analyses with $.05 \leq p \leq .1$, we report the direction of the correlations to provide a comprehensive picture of the data.

For the analyses of differences between the two time points, that is, before and during the 'lockdown', we used advanced non-parametric analyses of longitudinal data as implemented in the 'nparLD' package for R [20]. The methods used do not require distributional assumptions and are thus advantageous in this case. We here report the ANOVA-type statistic (ATS) along with the Relative Treatment Effect (RTE) as measure of the effect size. For the RTE, the distribution of the two groups is compared on the basis of mean ranks and can thus be related to each other. More precisely, an RTE of $p = 0$ indicates that the values of the first group (here: pre 'lockdown') are very certainly higher than those of the second group (here: during 'lockdown'). A relative effect of $p = 1$ would indicate that the values of the first group are very certainly lower than those of the second group and a $p = .5$ indicates that none of the distributions tends to have higher values. We report interpolated medians (of difference values) calculated from the 'psych' package as measures of central tendency [21]. Interpolated medians are especially useful when distributions are skewed as well as for Likert-scale data or in cases where the total range of answers to a question is relatively narrow.

The interpolated median gives a measure within the upper bound and lower bound of the median, in the direction that the data is more heavily weighted

For the correlation analyses, we likewise used non-parametrical approaches. More precisely, we computed Kendall's tau as a measure for correlations. As this approach is not free from distributional assumptions, we confirmed the *p*-values using permutation tests as implemented in the 'coin' package for R [22]. As the permutation tests confirmed the *p*-values in all cases, we refrain from reporting these *p*-values here. Moreover, as effect sizes have an important informative value here too., we also report Cohen's *d* as a measure of effect size for the correlation analyses. To this end, we have transformed the correlation coefficients according to the formulae proposed by Walker [23]. Small, medium, and large effect sizes are denoted by $d = 0.2.$, $d = 0.5$, and $d = 0.8$, respectively.

Results

Confirmatory analyses.

For an overview of all confirmatory correlation analyses please see Figure S1.

Social jetlag (SJL).

During the 'lockdown', SJL was reduced compared to before the 'lockdown' (*mdn* reduction = 13 minutes, *IQR* = -31-17 minutes; $F_{ATS}(1)=124.6$, $p<.001$, $p_{corr}<.001$, $RTE=.36$; cf. Figure 1A). A decrease in SJL was related to an increase in the amount of work accomplished from home during the 'lockdown' compared to before ($p=.006$, $p_{corr}=.014$, $tau=-.08$, $d=0.27$). Moreover, especially in later chronotypes, SJL was reduced during the 'lockdown' compared to before ($p=.02$, $p_{corr}=.037$, $tau=-.07$, $d=0.22$). Changes in SJL were unrelated to changes in work and leisure-related activities (p=.08, p_{corr}=.095, tau=.05, d=0.15) and unrelated to the degree of urbanisation as measured by the city size (p=.25, p_{corr}=.27).

Social sleep restriction (SSR).

The 'lockdown' was also associated with a decrease in SSR (*mdn* = 25 minutes, *IQR* = -51-5 minutes; $F_{ATS}(1)$=44.6, p<.001, p_{corr}<.001, *RTE*=.41; cf. Figure 1B). A decrease in SSR from before to during the 'lockdown' was associated with a higher proportion of work done from home (p=.029, p_{corr}=.047, tau=-.06, d=0.20) as well as less engagement in work and leisure time activities (p=.032, p_{corr}=.049, tau=.06, d=0.20). The decrease in SSR was not significantly stronger for earlier chronotypes (p=.068, p_{corr}=.084, tau=.05, d=0.16). Changes in SSR were unrelated to the degree of urbanisation/ city size (p=.30, p_{corr}=.31).

Sleep duration.

Median sleep duration increased by 13 minutes (*IQR* = -25-51 min) during the 'lockdown' ($F_{ATS}(1)$=26.57, p<.001, p_{corr}<.001, *RTE*=.56). Increased sleep duration during the 'lockdown' compared to before was associated with an increased proportion of work accomplished from home (p=.005, p_{corr}=.014, tau=.09, d=0.29), decreased engagement with work and leisure-related activities (i.e., working hours and the number of evenings spent with social activities; p=.005, p_{corr}=.014, tau=-.09, d=0.28), an increase in time spent under the open sky (p=.02, p_{corr}=.037, tau=.07, d=0.23) as well as an increase in exercising (p=.036, p_{corr}=.052, tau=.06, d=0.20). Moreover, later chronotypes experienced a stronger increase in sleep duration (p=.006, p_{corr}=.014, tau=.09, d=0.28). Furthermore, a major factor that was associated with less increase or a decrease in sleep duration was an increase in perceived burden (p<.001, p_{corr}<.001, tau=-.13, d=0.43). The changes in sleep duration seemed, by trend, to be more pronounced in more urbanised areas (p=.058, p_{corr}=.075, tau=.06, d=0.19).

Sleep quality.

Sleep quality slightly decreased during the 'lockdown' ($F_{ATS}(1)$=3.76, p=.026, p_{corr}=.045, *RTE*=.53). The difference in median sleep quality was 0.25 points on a scale ranging from 0-25 (higher values indicate worse sleep quality; *IQR* = -1.6-2.8). Less decrease or an increase in sleep quality during the 'lockdown' compared to before was associated with an increased proportion of work accomplished from home (p=.007, p_{corr}=.015, tau=-.08, d=0.26), an increase in the time spent under the open sky (p<.001, p_{corr}<.001, tau=-.13, d=0.42), as well as an increase in the amount participants exercised (p=.002, p_{corr}=.007, tau=-.09, d=0.30). As for sleep duration, the change in sleep quality was heavily dependent on changes in perceived burden with increased burden being associated with decreased sleep quality (p<.001, p_{corr}<.001, tau=.26, d=0.87). Moreover, later chronotypes experienced, by trend less of a decrease or an increase in sleep quality (p=.05, p_{corr}=.068, tau=-.06, d=0.18). Changes in sleep quality were unrelated to the engagement in work and leisure-related activities (p = .24, p_{corr}=.27) and to the degree of urbanisation (p = .41, p_{corr}=.41).

Exploratory analyses.

Daylight and exercising.

The difference (during ‘lockdown’ vs. before) between time spent under the open sky and exercising is highly correlated (p<.001, *tau*=.39, d=1.4) suggesting that many people went outside to exercise. This is not surprising given that during the ‘lockdown’ the weather in central Europe was extremely dry, sunny, and warm and fitness centres and sports clubs were closed.

Flexibility and work from home.

A higher proportion of work accomplished from home during the ‘lockdown’ compared to before was associated with higher flexibility of working hours (p=.007, *tau*=.09, d=0.28).

Social jetlag (SJL).

Changes in SJL were, by trend, related to changes in workload (i.e., hours per week; p=.054, *tau*=.07, d=0.22), where decreased SJL was associated with less working hours. Changes in SJL were also related to changes in social sleep restriction (SSR; p<.001, *tau*=.25, d=0.83). More precisely, decreased SSR was associated with decreased SJL. A decrease in SJL was also associated with an increase in sleep duration (p<.001, *tau*=-.12, d=0.37). Moreover, decreases in SJL were associated with decreased physical and mental wellbeing (p=.038, *tau*=.07, d=0.23). This effect may be attributed to the situation during the ‘lockdown’ generally being detrimental for wellbeing. Perhaps, even the loss of social contact with colleagues at work is an explanatory factor behind this correlation, which a decrease in SJL cannot outweigh. Changes in SJL were unrelated to changes in the amount of leisure activities (p=.99) or sleep quality (p=.43).

Social sleep restriction (SSR).

A decrease in SSR, that is more equal sleep durations on work days and free days, from before to during the ‘lockdown’ was associated with a decrease in working hours (p=.014, *tau*=.09, d=0.28) but not with a decrease in leisure activities (p=.92). Changes in SSR were unrelated to changes in physical and mental wellbeing (p=.43). Besides, a decrease in SSR was associated with a less pronounced decrease in sleep quality (p<.001, *tau*=.12, d=0.37). Moreover, a decrease in SSR was also associated with an increase in sleep duration (p<.001, *tau*=-.21, d=0.68).

Sleep duration.

Sleep duration on work days was longer during the ‘lockdown’ (*mdn* = 7.5h, *IQR* = 7-8.3h) compared to before (*mdn* = 7.7h, *IQR* = 6.7-8.3h; mdn_{diff} = 18 min; IQR_{diff} = 10-25 min;

F_{ATS}(1)=25.25, p<.001, RTE=.56) while sleep duration on free days was marginally reduced (mdn_{pre} = 8.3h, IQR = 7.6-9.2h, mdn_{post} = 8.2h, IQR = 7.8-9.2h; mdn_{diff} = -6 min; IQR_{diff} = -33-19 min; F_{ATS}(1)=3.31, p=.069, RTE=.48).

Increased sleep duration during the ‘lockdown’ compared to before was associated with decreased engagement with work-related activities (p<.001, tau=-.14, d=0.46) but not with a change in engagement in leisure activities (p=.47). Besides, an increase in sleep duration was related to an increase in physical/ mental wellbeing (p<.001, tau=.13, d=0.43), an decrease in subjective burden (p<.001, tau=-.13, d=0.43), and an increase in sleep quality (p<.001, tau=-.36, d=1.25). An increase in sleep duration was also associated with a decrease in SJL (p<.001, tau=-.12, d=0.37) and SSR (p<.001, tau=-.21, d=0.68).

Mid-sleep on work days and free days.

Before the ‘lockdown’, mid-sleep on work days occurred at 2:39 am (mdn, IQR = 2:11-3:34 am), on free days at 4:06 am (mdn, IQR = 3:04-4:18 am). When the restrictions were effective, mid-sleep on work days occurred at 3:03 am (mdn, IQR = 3:06-3:41 am), on free days at 3:52 am (mdn, IQR = 3:05-4:27 am). While mid-sleep on work days occurred significantly later during the ‘lockdown’ than before (F(1) = 90.89, p_{ATS} < .001, RTE = 59.6%), there was no change on free days (F(1) = .06).

Sleep quality.

An increase in sleep quality was related to a decrease in working hours (p=.04, tau=.07, d=0.23), but unrelated to changes in the amount of leisure activities (p=.23). Sleep quality during the ‘lockdown’ was strongly correlated with subjectively perceived burden during this time (p<.001, tau=.27, d=0.92), where less perceived burden was associated with a less strong decrease in sleep quality. Moreover, decreases in sleep quality were associated with decreased physical and mental wellbeing (p<.001, tau=-.34, d=1.18) and decreased sleep duration (p<.001, tau=-.36, d=1.25). Besides, the decrease in sleep quality was limited by a decrease in SSR, that is more equal sleep durations on work days and free days (p<.001, tau=.12, d=0.37). Changes in sleep quality were unrelated to changes in SJL (p=.43).

Transition to daylight saving time.

On 28 March, Europe switched to daylight saving time (DST). Following the transition to DST, we had added an additional question to our survey, where participants could indicate (i) how much they usually suffer from the transition to DST and (ii) how much they currently suffer on a visual analogue scale ranging from ’not at all‘ (-50) to ’very much‘ (50). Sixty-one percent of the participants (n=265) completed the survey following the transition to DST, 48 participants (11%) completed the survey between 29 and 31 March [three days, which has previously been suggested to be the time frame during which the majority of people subjectively adjust; cf. 24]. Generally, participants did not indicate suffering a lot from the transition to DST. More specifically, the interpolated median for the responses from the 48 participants was -18 (*IQR* -42.5 – 13). The interpolated median of all 265 participants' responses (n=265) was -15.3 with an *IQR* of -43.5 to 12.3. This suggests that neither did the 48 nor the 265 participants suffer a lot from the transition. Additionally, there was no significant difference between how much volunteers indicated they usually suffered from the transition and how much they suffered from the spring transition in 2020 ($F(1) = 2.6$, p_{ATS}=.11).

Limitations

Although we aimed at recruiting a heterogeneous sample, particularly with the help of our institutions' PR departments, the sample is a convenience sample, which limits the generalisability of the findings. Specifically, as often in such samples [cf. also 25], the majority of respondents were women, and educational level and socioeconomic status were generally rather high. Additionally, flexibility regarding working hours had been moderate even before the 'lockdown' and sleep quality was rather good compared to what has been reported in representative studies [10]. While the latter aspect suggests that the main motivation for study participation was *not* respondents' own troubles with sleeping, there was of course less scope for a potential 'lockdown'-induced improvement of sleep quality than in a sample with worse sleep quality/more sleep problems. Likewise, the effects of increased flexibility of social schedules (e.g. working hours) were probably less pronounced as flexibility had been moderate even before the lockdown. Last, the moderate to high socioeconomic status may have cushioned the increase in subjective burden. In sum, we think the sample characteristics may have contributed to an underestimation rather than overestimation of the effects in the general population.

Besides this, while looking back at the development of the situation one could have expected the 'lockdown', we did not do so until a week before the restrictions took effect. Therefore, in a one-time survey we were only able to assess the participant's situation before the lockdown (T0) by retrospective self-report, which may have introduced a recall bias. We did our best to limit these effects by introducing the questions on sleep quality and chronotype with the repeated instruction "please relate your answers to the time ***before*** COVID-19 caused changes in your life (i.e., work from home, social distancing)" or "[…] ***since*** COVID-19 caused changes […]", where the terms 'before' and 'since' were even in a different colour than the rest of the text. Additionally, the time span the questions referred to were rather short, as recommended by Althubaiti [26]. Although effects of a recall bias cannot be excluded, we would like to argue that it seems unlikely that such a bias was so systematic that it had a major effect on the validity of the results in 435 participants.

One further possible limitation is that the study period included the transition to DST, which took place in Europe on 28 March. In this context, a negative impact of clock change on sleep quality and sleep timing has previously been reported [27, 28]. However, participants generally indicated they did not suffer a lot from the transition to DST, neither in the past nor during the lockdown. This may be explained by a moderate flexibility regarding working hours even before the lockdown, which may smoothen the transition. Even in a subsample of 48 respondents taking the survey within three days following clock change, participants did not feel strongly affected by the transition to DST. Therefore, we do not assume that clock change had a relevant impact on the results. Besides this, clock change took place 7-14 days after the start of the 'lockdown', wherefore we assume that participants were able to separate effects of the 'lockdown' and the transition to DST on sleep timing and quality.

Last, due to the situation and the nature of this study, we were only able to include subjective self-report data. One may argue that this may have introduced a bias, for example with regard to perceived sleep duration, which has previously been reported for insomnia patients [29]. However, such a misperception bias should have been the same for both the time before the 'lockdown' and the time since the restrictions took effect. As statistical analyses relied on within-subject comparisons, such a bias would not have affected the results. Additionally, it seems unlikely that a bias, even if different for the two time periods the questions referred to (i.e., before and during the lockdown) was systematic enough to affect results in a large sample of 435 participants. Furthermore, also seemingly 'objective' methods such as wrist actigraphy do not reliably assess sleep duration in comparison to polysomnography [30] And the increase in sleep duration is in the range of what has been reported for consumer devices [31]. Besides this, we would like to argue that established questionnaires such as the PSQI [11] or the MCTQ [14] have a long tradition of subjectively assessing sleep-related variables as do sleep quality questionnaires such as the Karolinska Sleep Questionnaire [12]. It seems important to emphasise though that subjective and objective measures, especially of sleep quality, should rather be seen as complementing than mirroring each other.

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Author Contributions

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Declaration of Interests

The authors do not declare any competing interests.

Ethical Approval

Ethical approval was provided by the cantonal ethics commission (Ethikkommission Nordwest- und Zentralschweiz; 2020-00593). The study was conducted in accordance with Swiss law and the Declaration of Helsinki.

Supplemental References

S1. Harris, P.A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., and Conde, J.G. (2009). Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. Journal of Biomedical Informatics *42*, 377-381.

S2. Harris, P.A., Taylor, R., Minor, B.L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., Kirby, J., et al. (2019). The REDCap consortium: Building an international community of software platform partners. Journal of Biomedical Informatics *95*, 103208.

S3. Ghotbi, N., Pilz, L.K., Winnebeck, E.C., Vetter, C., Zerbini, G., Lenssen, D., Frighetto, G., Salamanca, M., Costa, R., Montagnese, S., and Roenneberg T. (2019). The µMCTQ: An Ultra-Short Version of the Munich ChronoType Questionnaire. Journal of Biological Rhythms.

S4. Blume, C., Schmidt, M., and Cajochen, C. (2020). Sleep & Social Jetlag during COVID-19. Open Science Framework.

S5. Bundesregierung Deutschland (2020). Vereinbarung zwischen Bundesregierung und den Bundesländern: Leitlinien zum Kampf gegen die Corona-Epidemie. Volume 2020. (Berlin).

S6. Bundesregierung Deutschland (2020). Besprechung der Bundeskanzlerin mit den Regierungschefinnen und Regierungschefs der Länder. Volume 2020. (Berlin).

S7. Österreichisches Bundesministerium für Soziales Gesundheit Pflege und Konsumentenschutz (2020). Coronavirus - Rechtliches. Volume 2020. (Vienna).

S8. Swiss Federal Council (2020). Coronavirus: Federal Council declares ‘extraordinary situation’ and introduces more stringent measures. Volume 2020. (Bern).

S9. Swiss Federal Council (2020). Bundesrat verschärft Massnahmen gegen das Coronavirus zum Schutz der Gesundheit und unterstützt betroffene Branchen. Volume 2020. (Bern).

S10. Schlack, R., Hapke, U., Maske, U., Busch, M., and Cohrs, S. (2013). Häufigkeit und Verteilung von Schlafproblemen und Insomnie in der deutschen Erwachsenenbevölkerung. (Robert Koch-Institut, Epidemiologie und Gesundheitsberichterstattung).

S11. Buysse, D.J., Reynolds, C.F., Monk, T.H., Berman, S.R., and Kupfer, D.J. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. Psychiatry Research *28*, 193-213.

S12. Nordin, M., Åkerstedt, T., and Nordin, S. (2013). Psychometric evaluation and normative data for the Karolinska Sleep Questionnaire. Sleep and Biological Rhythms *11*, 216-226.

S13. Hyeryeon, Y., Kyungrim, S., and Chol, S. (2006). Development of the Sleep Quality Scale. Journal of Sleep Research *15*, 309-316.

S14. Wittmann, M., Dinich, J., Merrow, M., and Roenneberg, T. (2006). Social jetlag: misalignment of biological and social time. Chronobiology international *23*, 497-509.

S15. Jankowski, K.S. (2017). Social jet lag: Sleep-corrected formula. Chronobiology International *34*, 531-535.

S16. R Core Team (2015). R: A Language and Environment for Statistical Computing. (Vienna, Austria: R Foundation for Statistical Computing).

S17. Rubin, M. (2017). Do p Values Lose Their Meaning in Exploratory Analyses? It Depends How You Define the Familywise Error Rate. Review of General Psychology *21*, 269-275.
S18. Benjamini, Y., and Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. Journal of the Royal Statistical Society. Series B (Methodological) *57*, 289-300.
S19. Wasserstein, R.L., Schirm, A.L., and Lazar, N.A. (2019). Moving to a World Beyond “$p < 0.05$”. The American Statistician *73*, 1-19.
S20. Noguchi, K., Gel, Y.R., Brunner, E., and Konietschke, F. (2012). nparLD: An R Software Package for the Nonparametric Analysis of Longitudinal Data in Factorial Experiments. Journal of Statistical Software *50*, 1-23.
S21. Revelle, W. (2019). psych: Procedures for personality and psychological research. R package version 1.9.12.
S22. Hothorn, T., Hornik, K., van de Wiel, M.A., and Zeileis, A. (2008). Implementing a Class of Permutation Tests: The coin Package. 2008 *28*, 23.
S23. Walker, D.A. (2003). JMASM9: converting Kendall’s tau for correlational or meta-analytic analyses. Journal of Modern Applied Statistical Methods *2*, 26.
S24. Blume, C., Hauser, T., Winkler, T., Heib, D.P., Gruber, W.R., and Schabus, M. (2019). "How does Austria sleep?" Self-reported sleep habits and complaints in an online survey. Sleep and Breathing.
S25. de Quervain, D., Aerni, A., Amini, E., Bentz, D., Coynel, D., Gerhards, C., Fehlmann, B., Freytag, V., Papassotiropoulos, A., and Schicktanz, N. (preprint 2020). The Swiss Corona Stress Study. Open Science Framework.
S26. Althubaiti, A. (2016). Information bias in health research: definition, pitfalls, and adjustment methods. Journal of multidisciplinary healthcare *9*, 211.
S27. Roenneberg, T., Kumar, C.J., and Merrow, M. (2007). The human circadian clock entrains to sun time. Current Biology *17*, R44-R45.
S28. Harrison, Y. (2013). The impact of daylight saving time on sleep and related behaviours. Sleep Medicine Reviews *17*, 285-292.
S29. Edinger, J.D., and Fins, A.I. (1995). The distribution and clinical significance of sleep time misperceptions among insomniacs. Sleep *18*, 232-239.
S30. Ameen, M.S., Cheung, L.M., Hauser, T., Hahn, M.A., and Schabus, M. (2019). About the Accuracy and Problems of Consumer Devices in the Assessment of Sleep. Sensors *19*.
S31. Fitbit Inc. (2020). The Impact Of COVID-19 On Global Sleep Patterns. Volume 2020.