Home confinement during the COVID-19: day-to-day associations of sleep quality with rumination, psychotic-like experiences and somatic symptoms

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Abstract

Due to the COVID-19 pandemic, populations from many countries have been confined at home for extended periods of time in stressful environmental and media conditions. Cross-sectional studies already evidenced deleterious psychological consequences, with poor sleep as a risk factor for impaired mental health. However, limitations of cross-sectional assessments are response bias tendencies, and the inability to track daily fluctuations in specific subjective experiences in extended confinement conditions. In a prospective study conducted across three European countries, we queried participants (N = 166) twice a day through an online interface about their sleep quality and their negative psychological experiences for two consecutive weeks. Focus was set on between-and within-person associations of subjective sleep quality with daytime experiences such as rumination, psychotic-like experiences, and somatic complaints about the typical symptoms of the coronavirus. Results show that daily reports of country-specific COVID-19 deaths predicted increased negative mood, psychotic-like experiences and somatic complaints during the same day, and decreased subjective sleep quality the following night. Disrupted sleep was globally associated with negative psychological outcomes during the study period, and a relatively poorer night of sleep predicted increased rumination, psychotic-like experiences, and somatic complaints the following day. This temporal association was unidirectional since daytime reports of negative mental experiences were not associated with poor sleep quality on the following night. Our findings show that night-to-night changes in sleep quality predict how individuals cope the next day with daily challenges induced by home confinement.

Keywords

Coronavirus, sleep, rumination, somatic symptoms, psychotic-like, stress.

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Methodological statement:

The methods were carried out in accordance with the relevant guidelines and regulations.

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Abbreviations

PTSD: Posttraumatic stress disorder

FDR: False discovery rate

PCL: PTSD Checklist

BDI: Beck Depression Inventory

PSQI: Pittsburgh Sleep Quality Index

O-LIFE: Oxford-Liverpool Inventory of Feelings and Experiences

GSQS: Groningen Sleep Quality Scale

PHQ: Patient Health Questionnaire

Introduction

In December 2019 a new coronavirus (SARS-CoV-2) was identified as the pathogen of an acute respiratory syndrome reported first in Wuhan, China¹. The World Health Organization announced the disease (eventually named COVID-19) as a public health emergency of international concern², and in the next three months, the COVID-19 continued to spread all over the world rapidly growing into a global pandemic. In order to slow the propagation of the virus as well as to attenuate the burden on health care systems, many countries introduced unprecedented measures of home confinement requiring individuals to stay at home and limit outdoor activities to the most necessary purposes. The restrictions drastically changed many individuals' daily routines that within the menacing context of the pandemic could lead to severe mental health complaints^{3,4}, urging health professionals to consider the psychological impact of COVID-19⁵⁻⁷.

A number of cross-sectional surveys conducted amongst front-line medical staff^{8,9}, university students^{10,11}, and the general population¹²⁻¹⁴ corroborated the concerns regarding mental health by reporting a pronounced increase in anxiety, depression, and symptoms of posttraumatic stress disorder (PTSD). Beyond these warning signs of psychological distress, a great proportion of the respondents reported frequent sleep difficulties^{6,12,14-16} and poor sleep emerged as an important risk factor for mental health complaints³. Additionally, disrupted sleep mediated the link between threat perception (measured by the COVID-19 death count) and negative emotions in a longitudinal study¹⁷, and those who reported more sleep difficulties during than before the confinement exhibited higher levels of depression, anxiety, and stress¹⁸. These findings are in line with previous studies showing the critical impact of poor sleep on the development and maintenance of mental health complaints¹⁹⁻²¹, and the putative role of healthy sleep in emotional adaptation²²⁻²⁵. During the confinement, reduced physical activity and lower exposure to daylight, irregular sleep-wake schedules, difficulties following good sleep habits, excessive and anxiety-provoking media use, increased levels of stress and social isolation may have deleterious impact on sleep

quality and render individuals more vulnerable to mental health problems²⁶. Therefore, monitoring sleep complaints during the pandemic is particularly relevant from a mental health perspective.

Limitations of the above studies are that sleep quality and daytime symptoms were measured retrospectively (e.g. asking participants to rate sleep quality during the previous weeks or month) and data were collected using cross-sectional designs. Although the approach allows quick and economical assessments in large samples, it is extremely difficult in such designs to address the directionality of the associations (i.e., whether sleep disruption temporally predicts daytime dysfunctions or the other way around). In addition, retrospective questionnaires might be more prone to biases^{27,28}, especially when individuals are queried in extremely unusual and stressful circumstances such as the COVID-19 pandemic. Studies indicate that retrospective self-reports are strongly biased by negative mood states²⁸, are subject to contamination between scales due to response bias tendencies²⁹, and show little agreement with prospectively assessed measures of similar variables³⁰. Furthermore, retrospective cross-sectional studies can only account for differences between individuals and neglect intra-individual variability (i.e. moment-to-moment changes in sleep and mental complaints within the same individuals), whereas prospective assessments point to considerable within-subject variability in sleep quality^{31,32}, daytime affective states^{33,34}, and even in states associated with personality traits that are considered to be stable over time³⁵.

To overcome these limitations, we conducted a two-week, prospective study investigating the associations between subjective sleep quality and daytime experiences during the confinement of the COVID-19 pandemic. Our prospective data collection allowed us to simultaneously examine associations across and within individuals. Hence, we tested whether individuals with poor sleep exhibited a higher level of mental health complaints during the two-week assessment period, and whether subtle night-to-night fluctuations in sleep quality were prognostic of increased negative experiences the next day (within

individuals). To address the temporal directionality of these associations, we examined whether subtle changes in daytime reports predicted changes in subjective sleep quality the following night.

Widely used measures of anxiety, depression, and stress provide efficient means to estimate the severity of negative affect and the prevalence of psychopathological conditions^{3,13,15}, but are not capable of capturing more specific and transient mental experiences that may impose an emotional burden on individuals during home confinement. Here, we focused on three factors particularly relevant within the context of the COVID-19 pandemic: rumination, psychotic-like experiences, and somatic complaints mimicking symptoms of COVID-19. Rumination refers to repetitive, intrusive, and hardly controllable thoughts about self-relevant situations and their underlying causes, and appears as a transdiagnostic factor in various psychopathological states^{36,37}. Rumination exhibits transient, state-like variations in healthy individuals and is associated with neurophysiological indices of impaired emotional adaptation³⁸. Psychotic-like experiences are unusual subjective experiences that phenomenologically resemble the symptoms of psychosis at a subclinical level (e.g., difficulties in controlling thoughts, cognitive anomalies, strange perceptions, and paranoid ideas), which are relatively common in the general population³⁹. Psychotic-like experiences also exhibit considerable moment-to-moment fluctuations^{40,41} and may increase under stressful circumstances^{40,42}. Coronavirus anxiety (the fear of obtaining the virus) emerged as a novel mental health issue of severe concern⁴³ that was associated with a number of psychological difficulties. Therefore, somatic complaints mimicking the most common symptoms of COVID-19 were examined as a measure of somatic symptom severity⁴⁴ possibly related to the health anxiety provoked by the pandemic. Although day-to-day (intra-individual) fluctuations of somatic symptoms were mainly evidenced in clinical populations^{45,46}, healthy individuals might also express pronounced variability in somatic symptoms in the context of the unprecedented coronavirus pandemic. We thus hypothesized that sleep disruptions would be associated with rumination, psychotic-like experiences, and somatic complaints during the study period, and that nights of poor sleep quality would eventually lead to worse

daytime functioning the following day within an individual. Likewise, we examined the inverse direction, i.e., whether daytime rumination, psychotic-like experiences, and somatization could predict worse sleep quality the following night. Additionally, we reasoned that trait-like characteristics such as proneness for a dysregulated stress-response after exposure to a stressor (as reflected by PTSD-like symptoms^{47,48}) and difficulties in controlling thoughts and attention (as reflected by cognitive disorganization^{49,50}) would be predictive of increased maladaptation during the pandemic. Therefore, we examined the association of these retrospectively assessed psychopathological indices with daytime functioning over and above the hypothesized association with sleep.

Results

Screening of participants and cross-sectional measures. In the first phase of the study, participants from three European countries in which restrictive confinement measures were adopted (Belgium, Hungary, and Spain) responded to a survey including items addressing cognitive disorganization, posttraumatic stress symptoms, sleep quality, depression and general demographic data that served us to screen and select individuals for the ensuing prospective study (*See Methods*). Thirteen participants reported that they were tested positive for COVID-19, and their data were not considered in the subsequent analyses. The prevalence rate of clinically relevant (moderate) depression⁵¹ in our sample (N = 717, 547 females) was 23 % (BE: 25.1 %, HU: 27 %, ESP: 18.4%), and 19.2 % of the respondents (BE: 21.1 %, HU: 25.6 %, ESP: 13.1 %) scored over the cut-off score to identify clinically relevant symptoms of PTSD⁵² corroborating previous reports about the substantial increase of mental health problems during the pandemic³. Although moderate differences emerged across the countries with respect to PTSD symptoms, school- and work related stress, and cognitive disorganization (*See Supplementary Materials*), the psychometric measures of mental health complaints exhibited similar patterns of correlations in our subsamples (**Figure 1**).

Figure 1. Cross-sectional survey. Pearson's correlation coefficients between the assessed variables among the Belgian, Hungarian, and Spanish sample of respondents (N = 717). The colors and numbers indicate Pearson's r- values, asterisks correspond to False Discovery Rate (FDR) corrected p-values (*** p < 0.001, ** p < 0.01, * p < 0.05). Stress: the increase of school-and job-related stress due to the confinement; Disorg: Cognitive Disorganization; Sleep: subjective sleep disturbances; BDI: Beck Depression Inventory; PCL: Posttraumatic stress disorder checklist.

Prospective study: Adherence to daily questionnaires. 184 individuals (146 (79 %) females, age 18-69 years, $M_{age} = 26.28$, $SD = 7.42$) were assigned for the second phase of the study assessing daily questionnaires during two-weeks. 22 % of the respondents completed all questionnaires, and 51 % completed more than 80 % of the daily questionnaires. Nine percent of the participants responded to less than 50 % of the morning or the evening questionnaires, and their data were excluded from further analyses yielding to the prospective data of 166 individuals.

COVID-19-related deaths and days since the introduction of confinement predict daytime functioning. The first analyses of the prospective study focused on the day-to-day associations of mental health indices with the perceived context of the confinement. COVID-19-related deaths and the time spent in confinement were the objective measures reflecting the circumstances of the pandemic during the study period. We explored whether daily reports of mental health indices were associated with the daily numbers of COVID-19-related deaths worldwide and in the country of the respondents. Moreover, since the number of deaths had not been independent of the time spent since the introduction of the restrictive measures, we also examined the influence of time (expressed as a fraction of weeks) spent in confinement on daily reports of mood, rumination, psychotic-like experiences, somatic complaints, sleep disruption, and sleep duration. The number of COVID-19-related deaths in the country predicted more negative mood ($b = -0.009$, CI: $-0.018 - -0.001$), psychotic-like experiences ($b = 0.004$, CI: $0.002 - 0.006$), and somatic complaints during the day ($b = 0.005$, CI: $0.003 - 0.007$), and worse subjective sleep quality during the following night ($b = 0.003$, CI: $0.001 - 0.005$), whereas the number of worldwide deaths predicted more somatic complaints during the day ($b = 0.020$, CI: $0.009 - 0.030$) and prolonged sleep duration the following night ($b = 0.054$, CI: $0.009 - 0.099$). The number of weeks since the introduction of confinement in the country had a negative linear and a positive quadratic effect on rumination (linear $b = -0.333$, CI: $-0.432 - -0.234$, quadratic $b = 0.023$, CI: $0.014 - 0.032$), psychotic-like experiences (linear $b = -0.376$, CI: $-0.483 - -0.269$, quadratic $b = 0.024$, CI: $0.015 - 0.034$) and somatic complaints (linear $b = -0.124$, CI: $-0.210 - -0.037$, quadratic $b = 0.009$, CI: $0.001 - 0.016$) (See Table 1). Further inspection of the plots of predicted values suggested that there was an

overall improvement of daytime functioning with time spent in confinement. Moreover, the steepness of the curve (reflecting the gradual amelioration of daily symptoms) was decreasing with time, indicating that the amelioration of mental health exhibited a slowing trend. These findings indicate that day-to-day fluctuations in mental health conditions were specifically associated with objective measures (number of deaths and days spent in confinement) reflecting the context of the confinement.

Predicting daytime functioning and sleep from COVID-19-related variables												
Predictors	Positive mood		Rumination		Psychotic-like experiences		Somatic complaints		Sleep disruption		Sleep duration	
	Estimates	95% CI	Estimates	95% CI	Estimates	95% CI	Estimates	95% CI	Estimates	95% CI	Estimates	95% CI
Intercept	4.881 ***	3.422 – 6.339	1.101 ***	0.768 – 1.434	1.265 ***	0.892 – 1.638	0.477 **	0.176 – 0.779	0.439 *	0.096 – 0.782	7.672 ***	6.550 – 8.795
Age	-0.000	-0.019 – 0.019	0.005 *	0.000 – 0.010	0.003	-0.003 – 0.010	-0.001	-0.006 – 0.004	0.004	-0.000 – 0.008	-0.027 ***	-0.041 – -0.014
Gender (male)	-0.180	-0.487 – 0.127	-0.098 *	-0.181 – -0.016	-0.052	-0.156 – 0.052	-0.146 ***	-0.229 – -0.063	-0.077 *	-0.148 – -0.006	-0.410 ***	-0.630 – -0.190
PTSD-like symptoms	0.000	-0.011 – 0.012	0.008 ***	0.005 – 0.011	0.011 ***	0.007 – 0.015	0.008 ***	0.004 – 0.011	0.003 *	0.001 – 0.006	0.004	-0.004 – 0.013
Cognitive Disorganisation	-0.116 ***	-0.167 – -0.065	0.023 **	0.009 – 0.037	0.037 ***	0.019 – 0.054	0.032 ***	0.018 – 0.045	0.020 **	0.008 – 0.032	-0.034	-0.070 – 0.003
Deaths related to COVID-19 (in country, 10/day)	-0.009 *	-0.018 – -0.001	0.001	-0.001 – 0.003	0.004 **	0.002 – 0.006	0.005 ***	0.003 – 0.007	0.003 **	0.001 – 0.005	0.004	-0.003 – 0.010
Deaths related to COVID-19 (global, 1000/day)	-0.049	-0.107 – 0.010	0.011	-0.002 – 0.024	0.008	-0.005 – 0.022	0.020 ***	0.009 – 0.030	-0.008	-0.021 – 0.005	0.054 *	0.009 – 0.099
Weeks spent in confinement (linear)	0.263	-0.183 – 0.710	-0.333 ***	-0.432 – -0.234	-0.376 ***	-0.483 – -0.269	-0.124 **	-0.210 – -0.037	-0.058	-0.164 – 0.049	0.316	-0.034 – 0.665
Weeks spent in confinement (quadratic)	-0.024	-0.063 – 0.015	0.023 ***	0.014 – 0.032	0.024 ***	0.015 – 0.034	0.009 *	0.001 – 0.016	0.004	-0.005 – 0.013	-0.026	-0.056 – 0.004
Random Effects												
σ^2	1.7040		0.0805		0.0917		0.0559		0.0924		1.0179	
τ_{00}	0.5221 _{id}		0.0411 _{id}		0.0695 _{id}		0.0414 _{id}		0.0284 _{id}		0.2577 _{id}	
ICC	0.2345		0.3380		0.4314		0.4253		0.2348		0.2020	
N	166 _{id}		166 _{id}		166 _{id}		158 _{id}		166 _{id}		166 _{id}	
Observations	1984		1984		1984		1893		2011		2010	
Marginal R ² / Conditional R ²	0.053 / 0.275		0.175 / 0.454		0.245 / 0.571		0.252 / 0.570		0.062 / 0.282		0.056 / 0.246	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 1. The association of the number of deaths related to COVID-19 and of the days spent in confinement with daily indices of mental health, beyond the effects of age, gender, PTSD-like symptoms and cognitive disorganization. Daily reports of COVID-19 related deaths were associated with mood, psychotic-like experiences, and somatic complaints during the day, and worse subjective sleep quality the following night. The number of global deaths predicted more somatic complaints during the day and prolonged sleep duration the following night. The time spent in confinement was inversely related to the reported levels of rumination, psychotic-like experiences, and somatic complaints. σ^2 : residual variance; τ_{00} : variance of random intercept; τ_{11} : variance of random slope; ρ_{01} : correlation between random intercept and slope; ICC: intraclass correlation; N: number of participants. Marginal R²: variance explained by fixed effects; Conditional R²: variance explained by fixed and random effects. P-values were computed with Satterthwaite's approximation.

Figure 2. Mental health in the context of the confinement. Associations between the number of COVID-19-related deaths at the country level (linear, shown on the x-axis in figures in the top row) and days since the introduction of confinement (quadratic, shown on the x-axis in figures in the bottom row) with daytime functioning, sleep disruption, and sleep quality. Daily reports of COVID-19 deaths were predictive of increased negative mood, more psychotic-like experiences, and somatic complaints during the day, and worse subjective sleep quality the following night. Daily reports of rumination, psychotic-like experiences, and somatic symptoms decreased as time elapsed since the introduction of the confinement, but we also observed a quadratic effect indicating that the amelioration of mental health exhibited a slowing trend. In the plots, each point represents the average of the given measure for a day within a country and the trend lines are weighted for the number of observations for the given day in a country. Shades show 95% confidence intervals. Note that confidence intervals become wider due to a lower number of observations around later time points after the introduction of the confinement.

Night-to-night fluctuations in sleep quality predict daytime functioning. We examined if subjective sleep disruption (on average) was associated with increased rumination over the two-week study period, and whether night-to-night variations in sleep quality were associated with changes in daily rumination within individuals. Subjective sleep quality was associated with rumination in both cases: more disrupted sleep (on average) was associated with increased rumination over the two-week study period ($b = 0.027$, CI: 0.006–0.047, $p < 0.05$), and a relatively poorer night of sleep (i.e. reduction of sleep quality compared to the individual, two-week average) predicted relatively increased rumination the following day ($b = 0.010$, CI: 0.005 – 0.016, $p < 0.001$). In addition, trait-like, retrospective measures of posttraumatic symptoms

(assessed by the PCL-5), and cognitive disorganization were both predictive of increased rumination over the study period (PCL-5: $b = 0.007$, CI: $0.004 - 0.010$, $p < 0.001$, Cognitive Disorganization: $b = 0.019$, CI: $0.006 - 0.033$, $p = 0.006$). Figure 3/A illustrates the association between sleep disruption and rumination between- and within individuals, and statistical model parameters are specified in Table 2.

Next, we performed a similar analysis regressing the same variables on psychotic-like experiences. As expected, worse sleep quality was globally associated with increased reports of psychotic-like experiences ($b = 0.054$, CI: $0.029 - 0.079$, $p < 0.001$). Moreover, night-to-night changes in sleep quality within individuals were also linked to increased psychotic-like experiences the following day, that is, worse sleep quality predicted more psychotic-like experiences the next day ($b = 0.010$, CI: $0.004 - 0.016$, $p < 0.01$). PTSD-like symptoms (PCL-5: $b = 0.009$, CI: $0.006 - 0.013$, $p < 0.001$) and cognitive disorganization ($b = 0.03$, CI: $0.013 - 0.047$, $p < 0.001$) were both predictive of increased psychotic-like experiences (see Figure 3/B and Table 2).

Likewise, we investigated the links between sleep disruption and the daily experience of somatic symptoms of the COVID-19. At the between-subject level, subjective sleep disruption was positively associated with reports of somatic symptoms: the within-person average of sleep disruption was associated with a higher rate of somatic complaints over the course of the study ($b = 0.056$, CI: $0.036 - 0.076$, $p < 0.001$). Regarding daily fluctuations within individuals, relatively worse sleep quality on a given night was associated with more severe somatic symptoms the following day ($b = 0.007$, CI: $0.002 - 0.012$, $p < 0.01$). PCL-5 scores (PCL-5: $b = 0.005$, CI: $0.002 - 0.009$, $p < 0.001$) and cognitive disorganization ($b = 0.026$, CI: $0.013 - 0.039$, $p < 0.001$) both emerged as significant predictors of (increased) somatic symptoms in the statistical model (see Figure 3/C and Table 2).

In sum, disrupted sleep was associated with increased rumination, psychotic-like experiences, and somatic symptom severity as measured prospectively during the two-week study period. Moreover, night-

to-night variations in subjective sleep quality predicted next-day's functioning, indicating that a relatively worse night of sleep was more likely to lead to increased rumination, psychotic-like experiences, and somatic symptoms the following day.

Figure 3. Prospective data analyses. *Left column:* Individual differences in subjective sleep disruption are associated with increased rumination, psychotic-like experiences, and somatic complaints during the two-week study period. The scatterplots of the left column represent the two-week averages of sleep disruption (x-axes) and daytime experiences (y-axes). Points with brighter and darker colors indicate positive and negative ratings of mood, respectively. Note that the brighter colored points (reflecting more positive mood) are more prominent in case of lower rumination, psychotic-like experiences, and somatic

symptoms. *Right column:* Day-to-day associations between subjective sleep disruption and next day's rumination, psychotic-like experiences, and somatic complaints. Subjective sleep disruption as compared to the individual two-weekly averages, that is, relatively worse nights of sleep during the study period are associated with increased rumination, psychotic-like experiences, and somatic complaints the following day. Grey lines indicate the regression slopes of each individual fitted to their day-to-day reports of sleep quality and daytime experiences (individual means and slopes). The red lines show the regression slopes fitted to all data points (overall mean and slope). Points with brighter and darker colors indicate positive and negative ratings of mood respectively. As indicated by the color of the data points, more positive daily mood is associated with lower rumination, psychotic-like experiences, and somatic symptoms (See Table 2).

Associations between sleep disruption and subsequent daytime functioning

<i>Predictors</i>	Rumination		Psychotic-like experiences		Somatic complaints	
	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>
Intercept	0.164 *	0.014 – 0.313	0.125	-0.056 – 0.306	0.166 *	0.018 – 0.314
Age	0.000	-0.004 – 0.005	-0.003	-0.009 – 0.003	-0.003	-0.007 – 0.002
Gender (male)	-0.080	-0.162 – 0.002	-0.001	-0.100 – 0.098	-0.099 *	-0.179 – -0.019
PTSD-like symptoms	0.007 ***	0.004 – 0.010	0.009 ***	0.006 – 0.013	0.005 ***	0.002 – 0.009
Cognitive Disorganisation	0.019 **	0.006 – 0.033	0.030 ***	0.013 – 0.047	0.026 ***	0.013 – 0.039
Sleep disruption (within-person mean)	0.027 *	0.006 – 0.047	0.054 ***	0.029 – 0.079	0.056 ***	0.036 – 0.076
Sleep disruption (within-person centered)	0.010 ***	0.005 – 0.016	0.010 **	0.004 – 0.016	0.007 **	0.002 – 0.012
Random Effects						
σ^2	0.0835		0.0963		0.0567	
τ_{00}	0.0383 id		0.0595 id		0.0363 id	
τ_{11}	0.0002 id.gsqs_sum_centered		0.0002 id.gsqs_sum_centered		0.0002 id.gsqs_sum_centered	
ρ_{01}	0.1754 id		-0.3809 id		0.2269 id	
ICC	0.3208		0.3884		0.4003	
N	166 id		166 id		158 id	
Observations	1884		1884		1800	
Marginal R^2 / Conditional R^2	0.142 / 0.417		0.232 / 0.530		0.268 / 0.561	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 2. Summary of mixed models examining associations between sleep quality and subsequent daytime functioning. σ^2 : residual variance; τ_{00} : variance of random intercept; τ_{11} : variance of random slope; ρ_{01} : correlation between random intercept and slope; ICC: intraclass correlation; N: number of participants. Marginal R^2 : variance explained by fixed effects; Conditional R^2 : variance explained by fixed and random effects. P-values were computed with Satterthwaite's approximation.

Subjective sleep quality predicts next day functioning regardless of mood fluctuations. Sleep disruption was linked to negative mood based on the averages of the study period (between-individuals; $b = -0.1$, CI: $-0.18 - -0.02$, $p = 0.01$), and daily changes in sleep disruption were temporally associated with more negative mood the next-day (within-individuals; $b = -0.05$, CI: $-0.07 - -0.02$, $p < 0.001$). To rule out that the associations of sleep disruption with rumination, psychotic-like experiences, and somatic symptoms (between-and within individuals) were not merely explained by the covariance of sleep disruption with negative mood, we entered the variable mood as an additional predictor into our models focusing on the links between sleep quality and daytime functioning. Although negative mood was associated with increased rumination, psychotic-like experiences, and somatic symptoms on both the between- and within-individual levels, the two-week averages of, as well as the daily variations in subjective sleep disruption remained significant predictors of the outcome variables beyond the variance explained by negative mood (See Table S1 - Supplementary Materials). These findings suggest that negative mood did not fully account for the associations of sleep disruption with rumination, psychotic-like experiences, and somatic symptoms.

Daily reductions in sleep duration are followed by increased rumination the next day. To examine the links between subjective reports of sleep duration and negative psychological experiences, we regressed sleep duration on average, and daily changes in sleep duration on reports of rumination, psychotic-like experiences and somatic complaints. Average sleep duration was not significantly associated with rumination. On the other hand, daily fluctuations in sleep duration (more specifically, relatively shorter durations of sleep) within-individuals were associated with increased rumination the following day. Average sleep duration or the daily changes in sleep duration within-individuals were not significantly predictive of psychotic-like experiences and somatic complaints. In sum, these findings do not indicate that individual differences in sleep duration are linked to individual differences in negative daytime

experiences, but within the same individuals, daily reductions in sleep duration are predictive of increased rumination on the following day (See Table 3). Daily reductions in sleep duration remained significant predictors of rumination ($b = -0.014$, $CI: -0.027 - -0.001$, $p < 0.05$) even when controlling for the confounding effects of mood (See Table S2 in Supplementary Materials).

Associations between sleep duration and subsequent daytime functioning

<i>Predictors</i>	Rumination		Psychotic-like experiences		Somatic complaints	
	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>
Intercept	0.523	-0.016 – 1.062	0.394	-0.289 – 1.076	0.553	-0.008 – 1.115
Age	0.000	-0.005 – 0.005	-0.002	-0.008 – 0.005	-0.001	-0.006 – 0.004
Gender (male)	-0.114 **	-0.199 – -0.030	-0.054	-0.161 – 0.054	-0.163 ***	-0.252 – -0.074
PTSD-like symptoms	0.008 ***	0.005 – 0.011	0.011 ***	0.007 – 0.015	0.007 ***	0.004 – 0.011
Cognitive Disorganisation	0.022 **	0.008 – 0.036	0.038 ***	0.020 – 0.055	0.032 ***	0.017 – 0.046
Sleep duration (within-person mean)	-0.037	-0.094 – 0.021	-0.023	-0.096 – 0.049	-0.037	-0.096 – 0.023
Sleep duration (within-person centered)	-0.014 *	-0.028 – -0.001	-0.011	-0.027 – 0.004	-0.011	-0.024 – 0.003
Random Effects						
σ^2	0.0853		0.0979		0.0574	
τ_{00}	0.0396 _{id}		0.0675 _{id}		0.0439 _{id}	
τ_{11}			0.0007 _{id.sleep_duration_centered}		0.0011 _{id.sleep_duration_centered}	
ρ_{01}			0.2451 _{id}		0.0341 _{id}	
ICC	0.3173		0.4102		0.4390	
N	166 _{id}		166 _{id}		158 _{id}	
Observations	1884		1884		1800	
Marginal R^2 / Conditional R^2	0.128 / 0.405		0.193 / 0.524		0.210 / 0.557	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 3. Summary of mixed models examining associations between sleep duration and subsequent daytime functioning. Note that the model predicting rumination does not include a random slope as the model with the random slope had a singular fit (random slope and intercept were perfectly correlated). σ^2 : residual variance; τ_{00} : variance of random intercept; τ_{11} : variance of random slope; ρ_{01} : correlation between random intercept and slope; ICC: intraclass correlation; N: number of participants. Marginal R^2 : variance explained by fixed effects; Conditional R^2 : variance explained by fixed and random effects. P-values were computed with Satterthwaite's approximation.

Negative daytime experiences do not predict sleep disruption or sleep duration the next night. To investigate bidirectional relationships regarding day-to-day associations between sleep and daytime

experiences, we also examined the temporal associations between daytime experiences and sleep on the following night. Daily rates of rumination, psychotic-like experiences, somatic complaints, or negative mood did not significantly predict subjective sleep disruption and sleep duration the following night. On the other hand, older age was associated with poorer sleep quality (on average) during the two-week assessment period (See Table 4). In sum, whereas sleep disruption and sleep duration predicted daytime negative experiences the following day, no signs of such temporal association were observed in the other direction.

Associations between daytime functioning and subsequent sleep

<i>Predictors</i>	Sleep disruption		Sleep duration	
	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>
Intercept	0.349 **	0.106 – 0.592	8.566 ***	7.782 – 9.350
Age	0.005 *	0.001 – 0.010	-0.028 ***	-0.041 – -0.015
Gender (male)	-0.065	-0.139 – 0.009	-0.442 ***	-0.681 – -0.204
PTSD-like symptoms	-0.000	-0.003 – 0.003	0.006	-0.004 – 0.016
Cognitive Disorganisation	0.007	-0.005 – 0.020	-0.026	-0.067 – 0.015
Psychotic-like experiences (within-person mean)	0.004	-0.006 – 0.015	0.030	-0.003 – 0.063
Psychotic-like experiences (within-person centered)	0.000	-0.004 – 0.005	0.008	-0.007 – 0.024
Rumination (within-person mean)	0.004	-0.015 – 0.024	-0.051	-0.115 – 0.012
Rumination (within-person centered)	0.003	-0.005 – 0.010	-0.007	-0.032 – 0.018
Somatic complaints (within-person mean)	0.021 **	0.007 – 0.035	-0.021	-0.067 – 0.025
Somatic complaints (within-person centered)	-0.006	-0.014 – 0.001	0.014	-0.010 – 0.038
Mood (within-person mean)	-0.029	-0.065 – 0.008	0.091	-0.027 – 0.209
Mood (within-person centered)	-0.005	-0.018 – 0.007	0.007	-0.035 – 0.048
Random Effects				
σ^2	0.0916		0.9900	
τ_{00}	0.0251 _{id}		0.2556 _{id}	
τ_{11}	0.0000 _{id.rumination_sum_centered}			
ρ_{01}	0.4755 _{id}			
ICC	0.2176		0.2052	
N	158 _{id}		158 _{id}	
Observations	1683		1682	
Marginal R ² / Conditional R ²	0.096 / 0.292		0.067 / 0.259	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 4. Summary of mixed models examining associations between daytime functioning and subsequent (next night's) sleep quality and duration. σ^2 : residual variance; τ_{00} : variance of random intercept; τ_{11} : variance of random slope; ρ_{01} : correlation between random intercept and slope; ICC: intraclass correlation; N: number of participants. Marginal R²: variance explained by fixed effects; Conditional R²: variance explained by fixed and random effects. P-values were computed with Satterthwaite's approximation.

Discussion

The aim of our study was to prospectively investigate the associations between subjective sleep quality and psychological health in the context of home confinement due to the COVID-19 pandemic. More specifically, 166 individuals from three different countries (out of 717 respondents in a cross-sectional survey) filled in daily reports during two consecutive weeks. We focused our analyses on the associations at the between-individual level, as well as on the bidirectional temporal links between day-to-day variations of sleep quality and daytime rumination, psychotic-like experiences, and somatic complaints. Our findings indicate that disrupted sleep during the assessment period was associated with more negative psychological conditions such as increased rumination, more psychotic-like experiences, and somatic complaints resembling the most common symptoms of the coronavirus. Furthermore, day-to-day fluctuations covaried within individuals: a relatively poorer night of sleep predicted increased rumination, psychotic-like experiences, and somatic complaints the following day. This association appeared to be unidirectional, since daytime reports of such mental experiences were not associated with poor sleep quality on the following night.

A growing number of studies have reported an alarming increase in the prevalence of mental health complaints during the COVID-19 pandemic^{6,10,11,15,16,53}. The cross-sectional findings in our samples are in line with these first cross-sectional observations indicating clinically relevant signs of depression and posttraumatic symptomatology in approximately 20 % of our respondents. Likewise, impaired sleep quality exhibited moderate associations with retrospectively assessed psychopathological measures^{3,14,15} such as depression, posttraumatic symptoms, and cognitive disorganization. Since our aim was to include only healthy participants free from severe psychological conditions in our prospective study, we excluded individuals showing clinically relevant signs of depressive symptoms. Nevertheless, we retained and included in our models the scores of PTSD-like symptoms and cognitive disorganization as proxies of

psychopathological conditions that were consistently linked to impaired sleep quality^{54–57}, negative emotionality and reduced resilience^{47–50}. This way, by controlling the effects of the levels of more general psychopathological traits, we could disentangle the associations of sleep quality with daytime reports that reflect rather specific mental experiences such as rumination, psychotic-like experiences, and somatic complaints during the confinement.

To evaluate if the perceived circumstances of the pandemic and the confinement influenced our variables of interest, we examined whether the country-specific and global number of deaths, as well as the time spent confined at home were predictive of daily measures of psychological functioning. Country-specific, daily numbers of deaths related to COVID-19 were predictive of worse mood, more psychotic-like experiences and somatic complaints during the same day, and poorer sleep quality the following night. As for the worldwide daily number of deaths, a less general pattern was observed. There was a positive link with more somatic complaints (the same day) and longer sleep duration the following night. Beyond the associations with COVID-19-related number of deaths, daily variations in rumination, psychotic-like experiences and somatic complaints were related to the time spent in confinement. On the one hand, we highlight a general improvement in psychological functioning with days elapsed from the introduction of the confinement, but a quadratic (U-shaped) relationship was also observed, indicating that negative psychological states seem to reappear with prolonged confinement. Although we abstain from drawing conclusions regarding the causal relationship of death rates and confinement days with psychological functioning, our results suggest that day-to-day variations of negative mental experiences were not independent of the context of the confinement and the pervasive information about the negative consequences of the COVID-19. Previous studies indicate that social media exposure⁵⁸ and 'local' COVID-19 death counts¹⁷ during the outbreak are risk factors for mental health problems. Our findings are in line with these reports and extend these observations by evidencing a link between death rates and

psychological functioning on a day-to-day basis. The gradual amelioration of mental health as a function of time elapsed since the introduction of the confinement is also in line with a previous study showing a reduction of the negative psychological impact of the pandemic four weeks after its initial outbreak⁵⁹. Although the number of our observations were relatively lower at later time points (>60 days after the introduction of the confinement) these data indicate that a further prolongation of the confinement period could be associated with negative psychological outcomes⁷.

Our results unambiguously indicate that poor subjective sleep quality during the two-week assessment period was associated with increased rumination, psychotic-like experiences and somatic complaints about the most typical symptoms of the coronavirus. That is, individuals who exhibited poor subjective sleep quality on average were also more likely to exhibit negative psychological outcomes during the confinement. The outbreak of the pandemic and the extreme circumstances produced by the confinement seem to have had a profound negative impact on subjective sleep quality, and sleep problems consistently correlated with impaired psychological functioning^{3,14,18,60}. Our findings based on the prospective assessment of sleep quality and mental health indices corroborate these previous results as well as the well-established role of sleep in emotional adaptation^{22,25,61}. Furthermore, our data indicate that sleep disruption was associated with rumination, psychotic-like experiences and somatic complaints over and above the influence of psychopathological traits (PTSD-like symptoms and cognitive disorganization) as well as inter-and intra-individual variations in daily mood. This suggests that the association of sleep quality with more specific mental experiences during the confinement are not merely attributable to general levels of psychopathology and negative affect. At variance with subjective sleep quality, we did not observe similar links between sleep duration and psychological functioning. Whereas sleep deprivation and sleep restriction have been consistently associated with increased negative affect⁶¹, pain sensitivity⁶², and psychotic-like phenomena^{20,63}, links between individual differences in sleep duration and negative health outcomes have only been reported in much larger samples and specifically

in the case of extremely short and long sleep durations^{64,65}. Moreover, studies suggest that home confinement provided more freedom to schedule bed-and wake-up times leading to an increase in the time spent in bed^{18,66}. Time in bed however does not necessarily correlate with sleep duration, and what is more, it may reduce the perceived quality of sleep, especially in those individuals who are vulnerable to sleep problems²⁶.

Our participants exhibited remarkable intra-individual variability in psychological measures and sleep quality during the two-week study period, allowing for the analyses of day-to-day associations between sleep and daytime mental experiences. Night-to-night variations in sleep quality predicted mental experiences the upcoming day, i.e., worse nights were predictive of increased rumination, psychotic-like experiences, and somatic complaints. Moreover, these associations remained significant after controlling for associations with daytime mood. Whereas average sleep duration was not associated with daytime psychological functioning, daily reductions in sleep durations (within-individuals) were associated with increased rumination the following day regardless of the influence of daytime mood. Noticeably, temporal associations between sleep and daytime psychological measures were not observed in the reverse direction. Simply put, worse days were not followed by worse nights. Such associations (i.e., daytime stress leading to sleep disruption the following night) have been reported in some studies^{67–69}, but others found only unidirectional links between sleep quality and next day's psychological functioning^{33,70,71}. Although a bidirectional relationship between sleep and daytime functioning seems plausible⁶¹, future studies and meta-analyses should corroborate if associations are present in both directions.

The global atmosphere of anxiety and the unusual circumstances of home confinement after the outbreak of the COVID-19 imposed an overwhelming mental health burden on the population. Intrusive and recurrent thoughts, cognitive disorganization and unusual experiences, and dysfunctional anxiety about contracting the coronavirus were common experiences all over the globe. Our findings indicate that

restorative sleep could be an important factor to counteract the depletion of cognitive resources required for efficient emotional coping strategies during the challenging days of the confinement. Although our results call out for the development of sleep quality-promoting strategies to help individuals to cope better with stressful situations, their impact remains to be investigated.

Methods

Participants. Individuals (N = 728, 556 (76%) females, age = 18-69 years, Mean_{age} = 28.5, SD_{age} = 10.09) willing to participate in our study were selected from three European countries in which restrictive confinement measures were adopted. The majority of the respondents were young, university students and their family members. Participants were contacted by advertisements placed on social media, and through the web pages and mailing services of the participating universities (Université Libre de Bruxelles, Belgium, Eötvös Loránd University, Hungary, and Autonomous University of Madrid, Spain). In the first phase of the study, participants were asked to complete an online questionnaire including self-report scales of standardized questionnaires measuring sleep quality⁷², depression⁷³, schizotypy⁷⁴, and symptoms of PTSD⁵². Demographic variables and items related to events (e.g. tested positive for COVID-19) and experiences related to the confinement (e.g. household, school- and work-related stress) were also assessed. This cross-sectional questionnaire served us to screen and select the participants for the second, prospective phase of the study. Individuals with current or prior history of neurological, psychiatric, or chronic somatic diseases, scoring above 12 on the short form of the Beck Depression Inventory (BDI-13⁷³), or taking medication (except contraceptives) were excluded. In addition, we excluded participants who reported to be previously diagnosed with COVID-19 or believed that they currently suffered or had suffered but recovered from the virus. Individuals fulfilling the inclusion criteria and willing to continue participation (N = 246) were selected for the prospective study phase. 184 individuals (146 (79 %) females, age 18-69 years, M_{age} = 26.28, SD = 7.42) were assigned for the second phase of the study assessing daily questionnaires during two weeks. Informed consents were obtained, and the study was approved by the corresponding local ethical committees of the three participating universities, the local Ethics Committee of the Université Libre de Bruxelles, the Ethics Committee of the Eötvös Loránd University, and the Ethics Committee of the Autonomous University of Madrid, respectively.

Procedure. The study consisted of three phases: 1) the administration of the cross-sectional questionnaire to screen and enroll potential participants, 2) the prospective study phase asking participants to complete short questionnaires twice a day during two consecutive weeks, and 3) the debriefing phase. The same questionnaire-batteries were used for the Belgian, Hungarian, and Spanish samples using the standardized or available versions in English, Hungarian, and Spanish, respectively. Items that were not available in Spanish or Hungarian were translated by the authors. Research assistants invited the selected participants to sign up for the prospective phase of the study through a dedicated website where only the invited participants could register and approve their registration via a two-step authentication process.

Participants signed up between the 9th of April 2020 and the 14th of May 2020 for the two-week assessment period (See Figure 4 showing the two-week assessment period within the timeline of the pandemic). Daily questionnaires requiring approximately 3-5 minutes per day were sent to participants via the online interface. A morning questionnaire was available between 5:00 and 12:30 am, and an evening questionnaire was accessible between 18:00 pm and 03:00 am. Participants were instructed to complete the morning questionnaire upon awakening, and to complete the second questionnaire always before going to sleep. A reminder email of the morning questionnaire was sent between 7:00-9:00 am, and a reminder of the second questionnaire was sent between 19:00-20:00 pm. The two-week long prospective study period started with the first morning questionnaire the day after the participant completed the registration and ended on the 14th day with the last evening questionnaire. Morning questionnaires assessed subjective sleep quality and sleep schedules (bedtime, sleep latency, and wake up time). The evening questionnaires consisted of items measuring mood, rumination, psychotic-like experiences and somatic complaints comprising the most typical symptoms of the COVID-19. Participants were also asked to report daily caffeine intake and alcohol consumption and their overall satisfaction with daily activities (work, physical activity, social interactions, media use, etc.). After finishing the last questionnaire, participants were instructed to access the debriefing that consisted of a final phase providing the possibility for the participants to ask questions regarding the study and to report any issue that they considered important. Moreover, they were asked to report if they had been tested positive for COVID-19 and if they assumed that they had contracted the virus during the study period.

Cross-sectional measures. The PTSD Checklist from the DSM-5 (PCL-5) was used to assess PTSD-like symptoms⁵². This 20-item self-report questionnaire that assesses DSM-5 symptoms of PTSD is suitable to screen individuals for PTSD, but it can also be applied from a dimensional point of view to quantify the severity of symptoms of stress in clinical and subclinical populations⁷⁵. Symptoms of depression were assessed with the short form of the Beck Depression Inventory (BDI-13). The questionnaire is suitable to screen individuals with mild, moderate, or severe symptoms of depression⁷³. Sleep disturbances were measured by the respective subscale of the Pittsburgh Sleep Quality Index (PSQI⁷²), a questionnaire used widely to evaluate subjective sleep quality. The sleep disturbances subscale focuses on subjective sleep complaints, such as having difficulties falling asleep, nocturnal awakenings, pain and discomfort during bedtime, as well as daytime sleepiness and fatigue. We used the Cognitive Disorganization scale of the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE) to evaluate the cognitive aspects of trait-like schizotypy⁷⁴. The 11 yes/no items of the scale assess difficulties in attention, concentration, decision making, and social functioning. The levels of school- and/or work-related stress experienced as a consequence of the confinement were assessed by seven-point Likert-scales (e.g. 0 – I experience much less stress since the introduction of the confinement, 6 – I experience much more stress...).

Morning questionnaire. Participants completed the Groningen Sleep Quality Scale (GSQS)⁷⁶ each morning. The questionnaire consists of 14 binary items that measure the extent of subjective sleep fragmentation. Previous studies indicate that the questionnaire is an adequate tool for assessing subjective sleep disruption⁷⁷. Additionally, participants were asked to report their bedtime, sleep latency (the time they needed to fall asleep) and wake up time. These responses were used to compute subjective sleep duration (i.e. the time elapsed between sleep onset and morning awakening).

Evening questionnaire. To measure ruminative, perseverative and intrusive thoughts, items assessing state-rumination (developed by Kocsel and colleagues³⁸) were adapted to the context of the confinement. Three statements (“I was not able to get certain thoughts out of my mind.”; “I kept thinking about something over and over again.”; “I had difficulties in suppressing my thoughts about the current situation.”) were rated on a 4-point Likert scale. Psychotic-like experiences were assessed with a scale

consisting of eight items that were originally adapted from two validated instruments^{40,78}. The items (rated on an 8-point Likert scale) covered perceptual anomalies (e.g. “Familiar things have seemed strange or unusual”), cognitive disorganization (e.g. “I have found it difficult to think clearly”) and paranoid ideation (e.g. “I think people have been saying or doing things to annoy me.”). The scale showed good psychometric properties and proved to be effective for the daily assessment of psychotic-like experiences in a previous study⁴¹. Somatic complaints were measured by items adopted from the Patient Health Questionnaire (PHQ-15)⁴⁴. The PHQ-15 was designed to measure the prevalence of the most common body symptoms (e.g., headache, nausea, etc.). Here, we used items that overlapped with the most typical symptoms of the coronavirus such as stomach pain, headache, chest pain, dizziness, low energy, muscle pain, shortness of breath, and we added an extra item concerning the experience of dry cough or sore throat. Daytime mood was assessed by a single item (“Throughout the day my mood was...”) rated on an 8-point Likert scale (0 – Extremely negative: sad, negative, distressed; 7 – Extremely positive: happy, joyful, relaxed).

Statistical analyses. In order to account for the nested structure of the data (repeated measures within participants), linear mixed models were fitted using the lme4 package⁷⁹ in R (v3.6.3). Every model included a random intercept and random slope per participant for the within-person centered time-varying predictor. In case of convergence issues, random slopes were removed, and a random intercept-only model was fitted. We disentangled between- and within-person effects of time-varying variables obtained from the prospective study⁸⁰. Within-person averages over the two-week study period were entered to assess between-person effects (i.e. to capture differences between participants scoring high or low on a measure on average), while within-person centering was applied to examine within-person effects (i.e. to capture correlates of day-to-day deviation from the participant’s average on a measure). When we fitted models that included somatic complaints, we excluded data from eight participants who indicated at debriefing phase that they believed they had contracted the coronavirus during their participation in the study.

First, we investigated how events associated with the pandemic predicted daytime functioning, sleep disruption, and sleep duration. Predictors were country-wise and worldwide numbers of COVID-related deaths for the given day (accessed from <https://www.worldometers.info/coronavirus/coronavirus-death-toll/> as of 19th May 2020). In order to facilitate interpretation of coefficient estimates, the number of country-wise and global deaths per day were scaled with a division by 10 and 1000, respectively. Additionally, we calculated the number of days since the introduction of confinement in the country of the participant (Belgium: 14th March 2020, Hungary: 28th March 2020, Spain: 17th March 2020). Time spent in confinement was expressed in weeks (number of days / 7) in order to have this variable on a scale comparable to the other predictors (this was done to facilitate model fitting and interpretation of coefficients). In order to capture non-linear effects, time spent in confinement was entered as a linear and as a quadratic term as well. Age, gender, PTSD-like symptoms (PCL-5 sum score) and cognitive disorganization were entered as person-specific time-invariant predictors. Dependent variables were the sum scores derived from the prospective measurements of rumination, psychotic-like experiences and somatic complaints during the day, and sleep disruption and sleep duration the following night.

Figure 4. The plot shows the progress - confirmed cases and deaths - of the COVID-19 pandemic in three European countries. Dashed lines show the introduction of specific countermeasures. The blue line segment shows when the data collection took place. Data from: Hale, Thomas, Sam Webster, Anna Petherick, Toby Phillips, and Beatriz Kira (2020). Oxford COVID-19 Government Response Tracker, Blavatnik School of Government. <https://covidtracker.bsg.ox.ac.uk/>

Then, we analyzed the relationship between sleep disruption / duration and functioning on the next day. Dependent variables were the sum scores derived from the prospective measurements of rumination, psychotic-like experiences, and somatic complaints. As diagnostic plots suggested that model residuals were not normally distributed, each dependent variable was log10-transformed, after which model residuals did not appear to strongly violate normality. Age, gender, PTSD-like symptoms (PCL-5 sum score), cognitive disorganization and within-person mean of subjective sleep disruption (GSQS sum score) / duration were entered as level-2 predictors, and within-person centered subjective sleep quality / duration were entered as a level-1 predictor in the models.

In the analysis of the relationship between daytime functioning and sleep disruption / duration the following night, the dependent variables were sleep quality (GSQS sum score) and sleep duration. Age, gender, PTSD-like symptoms (PCL-5 sum score), cognitive disorganization and within-person means of mood, rumination, psychotic-like experiences and somatic complaints were entered as level-2 predictors, and within-person centered mood, rumination, psychotic-like experiences and somatic complaints (of the day before sleep) were entered as level-1 predictors.

Open data and analysis scripts

Anonymized data and analysis scripts can be found on the project's OSF page:

https://osf.io/xabwe/?view_only=f319528ac4c54e08bb041c788dcb6339

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Supplementary Materials

S1. Cross-sectional comparisons across the three sites, Belgium (N = 227), Spain (N = 283) and Hungary (N = 207). Age showed the most pronounced difference across the three countries (BE vs ESP: $t = -5.41$, $d = -0.41$, $p < 0.0001$; BE vs HUN $t = 6.14$, $d = 0.71$, $p < 0.0001$; ESP vs HUN $t = 11.73$, $d = 1.11$, $p < 0.0001$). Posttraumatic symptoms (PCL), Cognitive Disorganization (Disorg), and the increase in perceived stress due to the COVID-19 (Stress) exhibited significant differences across countries. Depression (BDI), and Sleep disturbance (Sleep) did not significantly differ across countries. The effect size (Cohen's d) of the differences marked as significant ranged between 0.3 and 0.47). *** - FDR corrected $p < 0.001$, ** - FDR corrected $p < 0.01$.

Associations between sleep quality and subsequent daytime functioning controlled for mood

<i>Predictors</i>	Rumination		Psychotic-like experiences		Somatic complaints	
	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>
Intercept	0.430 **	0.166 – 0.693	0.380 *	0.055 – 0.705	0.417 **	0.161 – 0.673
Age	0.000	-0.004 – 0.005	-0.003	-0.009 – 0.002	-0.003	-0.007 – 0.002
Gender (male)	-0.093 *	-0.174 – -0.012	-0.017	-0.117 – 0.083	-0.110 **	-0.190 – -0.030
PTSD-like symptoms	0.007 ***	0.004 – 0.010	0.009 ***	0.005 – 0.013	0.006 ***	0.003 – 0.009
Cognitive Disorganisation	0.014 *	0.000 – 0.029	0.025 **	0.007 – 0.042	0.021 **	0.007 – 0.035
Sleep quality (within-person mean)	0.022 *	0.001 – 0.042	0.051 ***	0.026 – 0.076	0.051 ***	0.031 – 0.071
Sleep quality (within-person centered)	0.007 **	0.002 – 0.013	0.005 *	0.000 – 0.010	0.005 *	0.000 – 0.010
Positive mood (within-person mean)	-0.049 *	-0.090 – -0.009	-0.045	-0.095 – 0.005	-0.046 *	-0.085 – -0.007
Positive mood (within-person centered)	-0.061 ***	-0.071 – -0.051	-0.088 ***	-0.098 – -0.077	-0.050 ***	-0.058 – -0.041
Random Effects						
σ^2	0.0775		0.0852		0.0528	
τ_{00}	0.0374 id		0.0596 id		0.0355 id	
τ_{11}	0.0001 id,gsqs_sum_centered				0.0002 id,gsqs_sum_centered	
ρ_{01}	0.2212 id				0.1885 id	
ICC	0.3312		0.4116		0.4104	
N	166 id		166 id		158 id	
Observations	1884		1884		1800	
Marginal R ² / Conditional R ²	0.193 / 0.460		0.293 / 0.584		0.309 / 0.593	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table S1. Summary of mixed models examining associations between sleep quality and subsequent daytime functioning, controlled for mood. σ^2 : residual variance; τ_{00} : variance of random intercept; τ_{11} : variance of random slope; ρ_{01} : correlation between random intercept and slope; ICC: intraclass correlation; N: number of participants. Marginal R²: variance explained by fixed effects; Conditional R²: variance explained by fixed and random effects. P-values were computed with Satterthwaite's approximation.

Associations between sleep duration and subsequent daytime functioning controlled for mood

<i>Predictors</i>	Rumination		Psychotic-like experiences		Somatic complaints	
	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>	<i>Estimates</i>	<i>95% CI</i>
Intercept	0.760 **	0.209 – 1.311	0.667	-0.034 – 1.369	0.811 **	0.244 – 1.379
Age	0.000	-0.005 – 0.005	-0.002	-0.008 – 0.004	-0.001	-0.006 – 0.004
Gender (male)	-0.122 **	-0.205 – -0.039	-0.063	-0.169 – 0.043	-0.171 ***	-0.258 – -0.084
PTSD-like symptoms	0.008 ***	0.005 – 0.011	0.011 ***	0.007 – 0.015	0.007 ***	0.004 – 0.011
Cognitive Disorganisation	0.016 *	0.002 – 0.030	0.030 **	0.012 – 0.049	0.024 **	0.010 – 0.039
Sleep duration (within-person mean)	-0.029	-0.085 – 0.028	-0.016	-0.088 – 0.056	-0.027	-0.085 – 0.031
Sleep duration (within-person centered)	-0.014 *	-0.027 – -0.001	-0.012	-0.026 – 0.003	-0.011	-0.024 – 0.001
Positive mood (within-person mean)	-0.058 **	-0.098 – -0.018	-0.064 *	-0.115 – -0.012	-0.065 **	-0.106 – -0.023
Positive mood (within-person centered)	-0.062 ***	-0.072 – -0.052	-0.089 ***	-0.099 – -0.078	-0.052 ***	-0.060 – -0.043
Random Effects						
σ^2	0.0787		0.0848		0.0529	
τ_{00}	0.0382 _{id}		0.0662 _{id}		0.0418 _{id}	
τ_{11}			0.0004 _{id.sleep_duration_centered}		0.0010 _{id.sleep_duration_centered}	
ρ_{01}			0.2756 _{id}		0.1100 _{id}	
ICC	0.3268		0.4397		0.4471	
N	166 _{id}		166 _{id}		158 _{id}	
Observations	1884		1884		1800	
Marginal R^2 / Conditional R^2	0.185 / 0.452		0.264 / 0.588		0.263 / 0.592	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table S2. Summary of mixed models examining associations between sleep duration and subsequent daytime functioning, controlled for mood. Note that the model predicting rumination does not include a random slope as the model with the random slope had a singular fit (random slope and intercept were perfectly correlated). σ^2 : residual variance; τ_{00} : variance of random intercept; τ_{11} : variance of random slope; ρ_{01} : correlation between random intercept and slope; ICC: intraclass correlation; N: number of participants. Marginal R^2 : variance explained by fixed effects; Conditional R^2 : variance explained by fixed and random effects. P-values were computed with Satterthwaite's approximation.