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Dissociated profiles of sleep timing and sleep quality changes across the first and second wave of the COVID-19 pandemic

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ABSTRACT

Previous work showed a significant impact of the COVID-19 pandemic on Italians' sleep both during the first wave, when a total lockdown (TL) was imposed, and during the second wave, when a partial lockdown (PL) was mandated (autumn 2020). Here we complement these data by describing the profile of sleep across four time-points: the first and second lockdown (TL, PL) and the months preceding them (pre-TL, pre-PL).

An online survey was completed by 214 participants ($M_{age} = 36.78 \pm 14.2$ y; 159 F) during TL and again during PL. All sleep-related questions (including items of the Pittsburgh Sleep Quality Index) required a double answer, one referred to the current lockdown and one to the month preceding the lockdown.

Bedtime and rise time were delayed in TL and then advanced in pre-PL and PL. Similarly, time in bed increased in TL and then decreased in pre-PL and PL. Sleep quality worsened in the two lockdowns compared to the preceding periods and the proportion of poor sleepers correspondingly increased in both lockdowns.

Sleep habits and quality displayed different profiles across phases of the pandemic. Sleep timing was altered during the first lockdown and then returned towards baseline (likely due to normalized working schedules). Instead, sleep quality, which markedly worsened during both lockdowns, appears particularly sensitive to changes in life habits and psychological factors, independently of sleep habits. Our findings also point to a possible role of acute and chronic stress (experienced during the first and second wave, respectively) in modulating sleep changes across the pandemic waves.

Author contributorship

All authors contributed in a meaningful way to this manuscript. F.C., F.G. and G.F, conceptualization; F.C., N.C., O.D. and G.F, methodology; N.C. and O.D, formal analysis; O.D., M.L.R. and S.M, investigation; F.C., N.C., O.D., and M.L.R, writing—original draft preparation; F.C., N.C., M.L.R. and G.F, writing—review and editing; F.C., N.C., and S.M, visualization; F.G. and G.F, supervision; F.C., F.G. and G.F, project administration. All authors have read and agreed to the submitted version of the manuscript.

1. Introduction

The COVID-19 pandemic first arrived in Italy at the end of February 2020. By mid-March, cases had continued to rise throughout the country and the Italian government implemented a nationwide total lockdown which lasted 2 months before restrictions were relaxed (Istituto Superiore di Sanità, 2020).

The psychological impact on the Italian population as a result of the pandemic and related lockdown has been well documented (Cellini et al., 2020; Mazza et al., 2020; Moccia et al., 2020; Rossi et al., 2020). Compared to pre-pandemic European norms, Italians reported much

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higher levels of distress as early as six weeks into the pandemic (Mazza et al., 2020; Moccia et al., 2020). Additionally, many Italians endorsed higher rates of depression and anxiety symptoms, perceived stress, post-traumatic stress and adjustment disorder (Rossi et al., 2020).

Sleep habits and sleep quality were also adversely affected, a finding corroborated through surveys conducted in numerous countries, highlighting the global impact of the pandemic on sleep (Cellini et al., 2020; 2021; Gupta et al., 2020; Hisler and Twenge, 2021; Huang and Zhao, 2020; Kokou-Kpolou et al., 2020; Leone et al., 2020; Voitsidis et al., 2020). In the Italian population, impaired sleep quality, delayed bed- and rise times and increased time spent in bed were repeatedly reported during the lockdown (Cellini et al., 2020, 2021; Marelli et al., 2021).

The above findings refer to the initial pandemic-related lockdown (spring 2020). When restrictions in Italy were loosened, travel within Europe re-opened and people began traveling for summer holidays. However, this resulted in a new and larger wave of infections that started to spread in September, and, by November, the number of daily new cases (~34,000 positive cases/day) had increased five-fold compared to the number reported at the peak of the pandemic in March (~6500 positive cases/day) (Ministero della Salute, 2020). The Italian government quickly responded with partial lockdowns that were graded by severity based on the regional case rates. Indeed, since the Governmental Decree of November 3rd, 2020, Italian regions are being classified as colored zones (red, orange, yellow and white) on a weekly basis, according to a set of risk parameters including the number of Covid-19 cases per inhabitant and the pressure undergone by the regional healthcare systems. "Red zones" are the areas considered at highest risk and thus subjected to the greatest restrictions: movements outside of home are not allowed except for basic necessities (related to work, health, grocery shopping, assistance), with the requirement to carry documentation of essential travel at all times; moving across municipalities is prohibited in any case unless there are exceptional work- or health-related reasons. Only essential shops (such as pharmacies) are allowed to be open. Bars' and restaurants' services are limited to takeaway (until 10 p.m.) and home delivery. Cinemas, theaters, museums and gyms are also closed. All in-presence activities of schools, universities and team sports are suspended; religious services may continue in strict accordance with social distancing norms.

This set of restrictions is very similar to that adopted during the first, national lockdown (spring 2020), with the main difference being that limitations have been somewhat more relaxed during the "red zone" periods mandated since November: a higher number of work activities requiring physical presence are possible, police controls are less strict and a few public events (such as some religious services) are allowed to be organized with social distancing precautions. The fact that most Italian regions underwent "red zone" limitations for about a month in November–December 2020 allows to clearly identify, in Italy, a second wave of contagion, based both on number of Covid-19 cases and on severity of restrictions, and to compare sleep data across the waves.

Indeed, one Italian study has investigated sleep features during this second pandemic wave through a web-based survey and compared sleep and psychological wellbeing between two assessments conducted during the first and the second Italian lockdowns (Salfi et al., 2021). The authors found reduced insomnia and anxiety symptoms during the second wave as well as improvements in subjective sleep quality, sleep latency and sleep disturbances (measured through subscales of the Pittsburgh Sleep Quality Index, PSQI; Buysse et al., 1989), despite the fact that the global PSQI score remained unchanged between assessments. Also, they observed earlier bed- and rise times during the second wave relative to the first wave. These data suggest that, though the impact of the pandemic on sleep and wellbeing remained high (as shown, e.g., by the stable prevalence of depressive symptoms and poor sleepers across both lockdowns), the population underwent some sort of adaptation to the stressful circumstances of the second lockdown compared to what experienced under the similar conditions of the first lockdown.

The aim of our study is to complement these findings (Salfi et al., 2021) by integrating two additional time-points in the longitudinal design adopted by the authors. Specifically, through a web-based survey administered during the first and second Italian lockdowns, we collected sleep data regarding both the current lockdowns and the months preceding them, resulting in four time-points: 1. Pre-Total Lockdown (pre-TL), 2. Total Lockdown (TL), 3. Pre-Partial Lockdown (pre-PL), 4. Partial Lockdown (PL). Although the data on pre-TL and pre-PL should be considered explorative given the risks of response bias, this method of data collection provides a broader and more detailed picture of the evolution of sleep features over time across multiple phases of the pandemic.

2. Materials and Methods

2.1. Participants and procedure

During the first lockdown, a sample of 1622 participants (age range: 18–79 years, mean age = 34.1 ± 13.6; 1171 F) residing in Italy completed an anonymous online survey from April 1st to April 20th, 2020, advertised across the whole nation via social media. The only inclusion criterion was age >18 years.

Participants were asked to read the aims of the study and to explicitly agree to participate in the survey by filling in the consent form. The survey took approximately 25 min to be completed. There was no money or credit compensation for participation.

At the end of the survey, participants were asked to leave their e-mail address if they were willing to be re-contacted for a further assessment of their sleep habits. Out of the 1622 participants, 443 provided consent to take part in the follow-up study. These were contacted again on November 10th with the request to complete the second survey. A reminder was sent after one week (when 168 participants had responded) and after two weeks (when 38 additional participants had responded); data collection was ended on December 1st. The final sample of the follow-up survey consists of 214 participants (age range: 18–73 years, mean age = 36.1 ± 14.2; 159 F).

The Ethical Committee of the Department of Psychology, University of Campania "Vanvitelli", approved the research protocol. All methods were carried out in accordance with relevant guidelines and regulations.

Data reported here are part of a wider research project designed to assess several aspects of sleep during the lockdown; other data with different research purposes are presented elsewhere (Cellini et al., 2021; Conte et al., 2021a).

2.2. The instrument

The survey administered during the Total Lockdown (TL, spring 2020) was made up of several sections containing questions on: current working condition and daily habits, problems and worries related to the ongoing COVID-19 pandemic, health status, sleep and dreams. The section on sleep included the PSQI (Italian version, Curcio et al., 2013) and four additional, ad hoc questions regarding night awakenings ("How often do you wake up during the night?" - "Never", "1–2 times", "3–4 times", "5 or more times"; "How long do your nocturnal awakenings usually last?" - "I do not wake up during the night", "Less than 5 min", "5–10 min", "15–20 min", "20–30 min", "more than 30 min") and napping habits ("How often do you take a daytime nap?" – "Never", "1–2 times a week", "3–4 times a week", "5–6 times a week", "every day"; "For how long do you usually nap?" – "I do not take naps", "less than 10 min", "10–30 min", "30 min to 1 h", "more than 1 h").

A heading at the beginning of the sleep section explicitly instructed participants to provide a double answer to each sleep item: one referring to his/her condition during the current lockdown and another referring to the month preceding the lockdown. Correspondingly, answer spaces to each sleep item (i.e., those of the PSQI and the four items on night awakenings and napping) were also double: one was labeled "during the current lockdown" and the other "during the month preceding the lockdown".

As for psychological variables, they were assessed through single ad hoc items regarding mood ("In the current situation, how is your prevalent mood?" "Very Positive", "Moderately Positive", "Neutral", "Moderately Negative", "Very Negative"), stress ("In the current situation, how stressed do you generally feel?" "Not at all stressed", "Moderately stressed", "Extremely stressed"), general fear ("In the current situation, how afraid do you generally feel?" "Not at all afraid", "Moderately afraid", "Extremely afraid"), fear of Covid-19 contagion ("In the current situation, how afraid do you feel of being personally infected or that any of your dear ones could be infected?" "Not at all afraid", "Moderately afraid", "Extremely afraid").

The same survey was administered as a follow-up during the Partial Lockdown (PL, autumn 2020).

2.3. Data analysis

First, we compared sample characteristics between drop-out (DR, N = 1408) and follow-up (FU, N = 214) participants, using Mann-Whitney's *U* test and χ^2 test for ordinal and categorical variables, respectively. For Mann-Whitney's *U* test we reported the rank-biserial correlation coefficient as a measure of effect size (ES).

All other analyses were conducted on the 214 participants who responded to the follow-up survey, in order to describe the profile of sleep changes across the four time-points using a longitudinal approach. Analyses were performed using JAMOVI 1.6.16 (The jamovi project, 2021) and JASP 1.4.1 (JASP Team, 2020).

To assess the changes of sleep parameters across different periods, we employed linear mixed models (LMM), which take into account factors whose levels are randomly extracted from a population (i.e., participants), allowing for more generalizable results (Baayen et al., 2008). We built separate models for global PSQI score, sleep timing (bedtime and rise time), time in bed, and sleep onset latency, using Participant as crossed random effects, Period (pre-TL, TL, pre-PL, PL) and Gender (Female/Male) as fixed effects, and Age as a covariate. The Holm test was used for post-hoc comparisons.

As for the PSQI global score, higher values indicate worse sleep quality. Poor sleepers are identified by scores >5 (Buysse et al., 1989).

Non-parametric statistics were employed to assess the ordinal variables. Specifically, the Friedman test was used to assess differences across the four periods in PSQI subscales (Sleep Quality, Sleep Duration, Habitual Sleep Efficiency, Sleep Disturbances, Use of Sleep Medication, and Daytime Dysfunction, Buysse et al., 1989), night awakenings (number and duration) and napping habits (frequency and duration). We reported Kendall's W as a measure of ES and, in case of significance, the Durbin-Conover test was used as post-hoc analysis.

Finally, Wilcoxon signed-rank test was used to assess the difference between Total Lockdown and Partial Lockdown in psychological variables (mood, stress, general fear, fear of the Covid-19). The rank-biserial correlation coefficient is reported as a measure of ES.

Statistical significance was set at $p \leq .05$.

3. Results

3.1. Sample characteristics

Demographics of the whole initial sample (N = 1622) and of DR (N = 1408) and FU (N = 214) participants are reported in Table 1. The FU participants were on average older than the DR participants (U = 129719.5, p < .001, ES = 0.139) and had a higher educational level (χ^2_2 = 10.60, p = .005), i.e., they included a higher proportion of participants who had graduate and postgraduate degrees and a lower proportion of participants who had a middle/high school education. The proportion of females and males did not differ between groups (χ^2_1 = 0.544, p = .496) nor did working condition (χ^2_3 = 0.715, p = .870) and marital status (χ^2_3 = 1.933, p = .582). Also, there was no difference in the proportion of participants who knew someone infected with Covid-19 (χ^2_1 = 0.526, p = .468) or had experienced the death of someone close due to Covid-19 (χ^2_1 = 0.681, p = .409).

Table 1
Demographic characteristics and experience with Covid-19 in the whole initial sample, in the drop-out participants and in the follow-up participants.

	Whole sample (N = 1622)	Drop-out (N = 1408)	Follow-up (N = 214)
Age, year	34.07 ± 13.58	33.65 ± 13.44	36.79 ± 14.194
Gender			
Female	1171 (72.2%)	1012 (71.88%)	159 (74.29%)
Male	451 (27.8%)	396 (28.12%)	55 (25.71%)
Occupation			
Students	591 (36.4%)	515 (36.6%)	76 (35.5%)
Workers	846 (52.2%)	733 (52.1%)	113 (52.8%)
Unemployed	34 (2.1%)	28 (2.0%)	6 (2.8%)
Retired	151 (9.3%)	132 (9.4%)	19 (8.9%)
Marital Status			
Unmarried	1113 (68.6%)	972 (69.0%)	141 (65.9%)
Married	404 (24.9%)	345 (24.5%)	59 (27.6%)
Divorced	88 (5.4%)	75 (5.3%)	13 (6.1%)
Widowed	17 (1.0%)	16 (1.1%)	1 (0.5%)
Education			
Middle/High school	883 (54.4%)	788 (56%)	95 (44.4%)
Graduate	474 (29.2%)	401 (28.5%)	73 (34.1%)
Postgraduate	265 (16.3%)	219 (15.6%)	46 (21.5%)
Knowing someone infected with Covid-19	608 (37.5%)	523 (37.1%)	85 (39.7%)
Having a relative/close friend deceased of Covid-19	178 (11%)	151 (10.7%)	27 (12.6%)

3.2. Differences between TL and PL in psychological measures

The Wilcoxon test showed that general fear for the pandemic situation and fear of Covid-19 contagion significantly increased from TL to PL (W = 722, p = .045, ES = −0.261, and W = 876, p = .003, ES = −0.321, respectively), consistent with the strikingly higher percentage, in PL, of participants who reported to know someone who was positive to Covid-19 (37.5% in TL vs. 91.09% in PL). No difference was found for mood (W = 5831, p = .508, ES = −0.60), whereas stress levels showed a trend to increase from TL to PL (W = 966, p = .100, ES = −0.200).

3.3. Differences in sleep schedules and sleep quality across the four time-points

Table 2 displays average scores of sleep timing and sleep quality variables in the four time-points; comparisons of these variables across time-points are shown in Figs. 1 and 2.

The LMM on bedtime showed a significant effect of Period ($F_{3,636}$ = 38.81; p < .001, Fig. 1a), with delayed bedtimes in TL relative to pre-TL (p < .001), pre-PL (p < .001), and PL (p < .001), indicating an

Table 2
Mean and standard deviation of sleep timing variables and PSQI global scores across the four time-points.

	Pre-TL	TL	Pre-PL	PL
Bedtime (hh: mm)	23:40 ± 01:22	24:36 ± 01:39	23:58 ± 01:21	23:51 ± 01:21
Rise time (hh: mm)	07:46 ± 01:25	09:08 ± 01:39	08:16 ± 01:33	08:00 ± 01:21
Time in Bed (h)	8.10 ± 1.47	8.53 ± 1.64	8.30 ± 1.55	8.16 ± 1.43
Sleep Latency (min)	17.10 ± 20	27.10 ± 29.10	21 ± 22.70	21.80 ± 27
PSQI global score	5.37 ± 2.28	6.33 ± 3.37	5.28 ± 2.93	6.02 ± 3.03

Notes. PSQI: Pittsburgh Sleep Quality Index; TL: Total Lockdown; Pre-TL: month preceding TL; PL: Partial Lockdown; Pre-PL: month preceding PL.

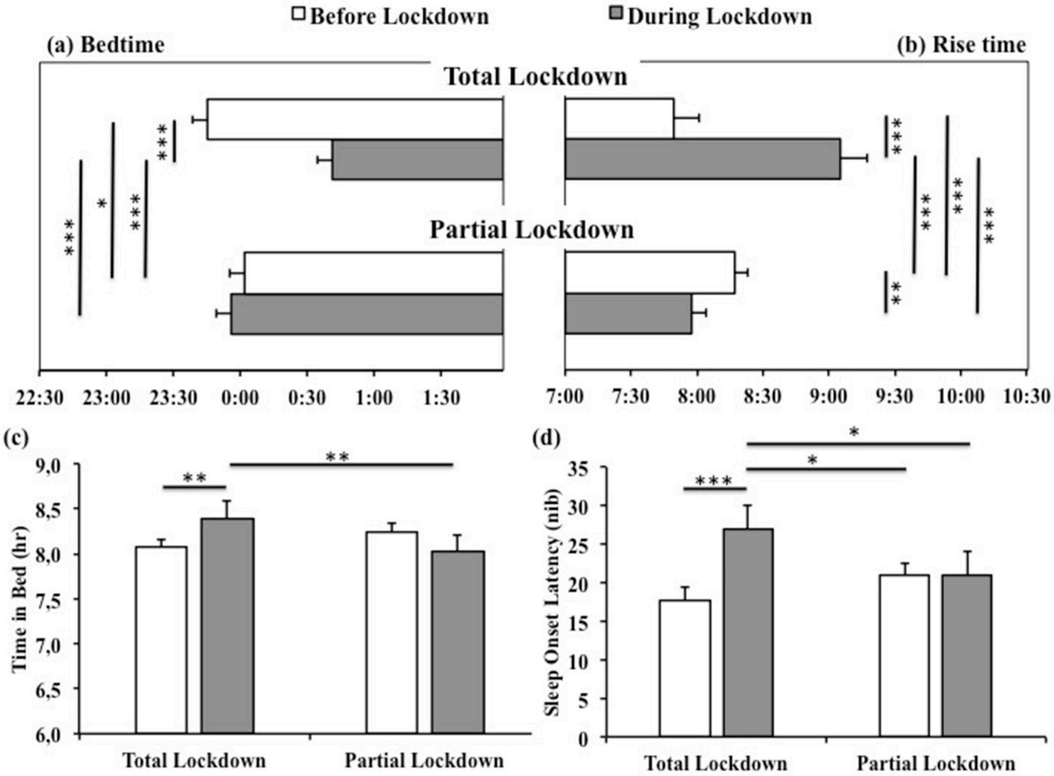

Fig. 1. Differences in **(a)** Bedtime, **(b)** Rise time, **(c)** Time in Bed, and **(d)** Sleep Onset Latency across the four time-points. Significant comparisons are indicated with asterisks (***: $p \leq .001$; **: $p \leq .01$; *: $p \leq .05$). Error bars represent standard errors of the means.

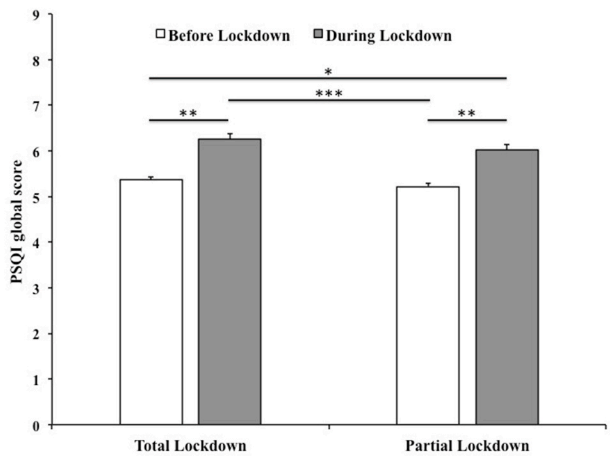

Fig. 2. Differences in Pittsburgh Sleep Quality Index (PSQI) global scores across the four time-points. Significant comparisons are indicated with asterisks (***: $p \leq .001$; **: $p \leq .01$; *: $p \leq .05$). Error bars represent standard errors of the means.

advancement of bedtimes after the delay appeared in the first lockdown. Pre-PL showed later bedtimes than pre-TL ($p = .013$), while it did not differ from PL ($p = .280$). No effect of Age was observed ($p = .278$), whereas males tended to go to bed later than females ($p = .054$). No interaction effect emerged.

Rise time showed a similar pattern, with a significant effect of Period ($F_{3,636} = 60.97$; $p < .001$, Fig. 1b): indeed, rise times were delayed in TL compared to pre-TL ($p < .001$), pre-PL ($p < .001$) and PL ($p < .001$). Also, pre-PL showed later rise times than pre-TL ($p < .001$) and PL ($p = .004$), indicating, again, a progressive advancement after the first lockdown. No effect of Gender was observed ($p = .962$), whereas Age was a significant covariate ($t = -8.49$, $p < .001$), with younger participants reporting later rise times. No interaction effect emerged.

The analysis on time in bed (Fig. 1c) and sleep latency (Fig. 1d) showed similar profiles of these variables (Period effects: $F_{3,636} = 5.23$; $p < .001$ and $F_{3,636} = 7.50$; $p < .001$, respectively) to those of sleep timing, with significant increases in TL followed by a return towards pre-pandemic levels. In fact, time in bed was greater during TL compared to pre-TL ($p = .009$) and PL ($p = .009$), whereas there was no difference between pre-PL and PL ($p = .160$) or between pre-TL and pre-PL ($p = .259$). We also observed an effect of Gender ($F_{1,211} = 4.71$; $p = .031$) and Age ($t = -10.15$, $p < .001$), with females and younger participants spending more time in bed, but no significant interaction. Similarly, participants took longer to fall asleep during TL compared to pre-TL ($p < .001$), pre-PL ($p = .013$) and PL ($p = .013$), and no difference between pre-PL and PL ($p = .999$) or between pre-TL and pre-PL ($p = .313$). We also observed a significant effect of Age ($t = -3.54$, $p < .001$), indicating longer sleep latency in younger participants, but not of Gender ($F_{1,211} = 0.02$; $p = .894$), and no interaction effect emerged.

A different pattern was displayed, instead, by PSQI global scores. There was a significant effect of Period ($F_{3,636} = 0.705$; $p < .001$, Fig. 2), with higher PSQI scores (i.e., worsened sleep quality) in TL compared to pre-TL ($p = .003$) and pre-PL ($p < .001$), and in PL compared to pre-TL ($p = .037$) and pre-PL ($p = .009$). No difference was observed either between the two pre-lockdown periods or between the two lockdowns (both p's = 0.721). Age and Gender were not associated with changes in PSQI scores ($p = .736$ and $p = .690$, respectively) and there was no interaction effect.

The proportion of poor sleepers (PSQI>5) was 39.7%, 48.1%, 36.9%, and 47.7% for pre-TL, TL, pre-PL, and PL, respectively.

3.4. Differences in night awakenings and napping habits across the four time-points

Fig. 3 displays the differences in night awakenings and napping habits across the four time-points. Friedman test showed a significant difference across periods in the number of awakenings occurring during sleep ($\chi^2_3 = 17.03$, $p < .001$, ES = 0.547), with a higher number in TL compared to pre-TL ($p < .001$) and pre-PL ($p = .010$), but no differences between pre-PL and PL ($p = .108$) or between either lockdown or pre-lockdown periods (all p's > 0.204). Similarly, duration of awakenings ($\chi^2_3 = 21.04$, $p < .001$, ES = 0.572) increased from pre-TL to TL ($p < .001$) and from pre-PL to PL ($p = .048$). Also, it was higher in pre-PL compared to pre-TL ($p = .029$), while it did not differ between TL and PL ($p = .709$).

No significant differences across periods were observed, instead, in the number ($\chi^2_3 = 6.16$, $p = .104$, ES = 0.691) and duration ($\chi^2_3 = 2.14$, $p = .543$, ES = 0.704) of daytime naps.

3.5. Differences in PSQI sub-scores across the four time-points

Fig. 4 displays the differences in scores at the seven PSQI subscales across the four time-points.

Scores at the Sleep Quality subscale (higher scores correspond to lower sleep quality) showed significant oscillations across time-points ($\chi^2_3 = 16.68$, $p < .001$, ES = 0.315), with higher scores in TL compared to pre-TL ($p = .002$) and pre-PL ($p = .010$), and in PL compared to pre-PL ($p = .006$). No differences were observed between PL and TL ($p = .888$) or between the pre-lockdown periods ($p = .640$).

A similar profile was observed for Sleep Disturbances ($\chi^2_3 = 39.20$, $p < .001$, ES = 0.363), which were higher during TL compared to pre-TL and pre-PL (both p's < 0.001) and in PL compared to pre-PL ($p < .001$). No differences emerged between the lockdown or pre-lockdown periods (all p's > 0.951).

Habitual Sleep Efficiency (higher scores correspond to lower sleep efficiency) showed the same pattern ($\chi^2_3 = 8.18$, $p = .043$, ES = 0.364), with an increase in TL compared to pre-TL ($p = .015$), a trend to increase from pre-PL to PL ($p = .078$), and no differences between PL and TL ($p = .785$) or pre-TL and pre-PL ($p = .502$).

Sleep Latency ($\chi^2_3 = 23.22$, $p < .001$, ES = 0.356) was higher in TL compared to pre-TL ($p < .001$), pre-PL ($p < .001$) and PL ($p = .003$), whereas there were no differences between pre-PL and PL ($p = .232$) or pre-TL and pre-PL ($p = .097$).

Daytime Dysfunction sub-scores showed an interesting oscillation across time ($\chi^2_3 = 11.89$, $p < .001$, ES = 0.325), with greater dysfunctions during pre-TL compared to TL ($p = .012$) and pre-PL ($p = .01$), and during PL compared to pre-PL ($p = .018$) and TL ($p = .020$).

No differences were observed for Sleep Duration ($\chi^2_3 = 4.42$, $p = .220$, ES = 0.287) and Use of Sleep Medication sub-scores ($\chi^2_3 = 1.26$, $p = .740$, ES = 0.393).

4. Discussion

This study addresses the evolution of sleep features over the course of the Covid-19 pandemic in an Italian sample. Specifically, we present longitudinal data from a survey administered during the first wave of the pandemic and related total lockdown (spring 2020) as well as data from a follow-up survey administered to the same sample in autumn 2020, when Italy underwent a resurgence of Covid-19 cases (reaching a higher rate than that attained in spring) and the government responded with a second, partial lockdown. The use, in both surveys, of additional questions referring to the month preceding the lockdown allowed us to investigate sleep characteristics across four time-points: 1. Pre-Total Lockdown, 2. Total Lockdown, 3. Pre-Partial Lockdown, 4. Partial Lockdown.

First of all, our data are basically in accordance with those from Salfi et al. (2021), who compared subjective reports of sleep features between the first and the second pandemic waves in a large Italian sample and observed that the negative impact of the pandemic on sleep and mental health persisted during the second wave. As in Salfi et al. (2021), we found that subjective sleep quality was equally low in both lockdowns, as indexed both by the PSQI global score and by the prevalence of poor sleepers. Also, consistent with Salfi et al. (2021), we observed greater daytime consequences of sleep disruption (Daytime Dysfunction subscale of the PSQI), as well as an advancement of sleep timing, during the second relative to the first lockdown.

As for the evolution of sleep features across the four time-points, our

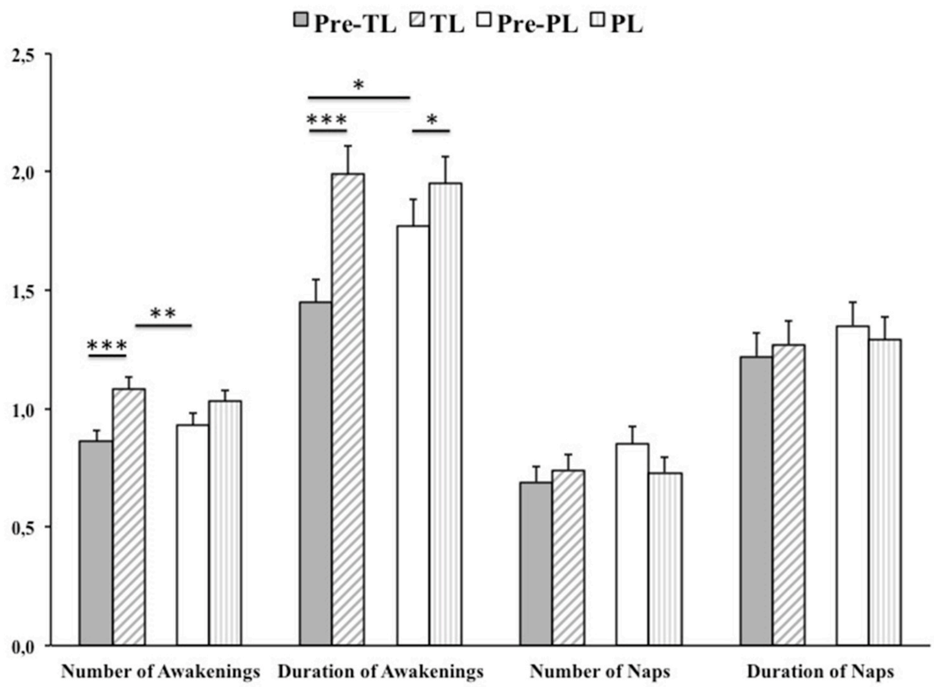

Fig. 3. Differences in number and duration of night awakenings and of naps across the four time-points. TL: Total Lockdown; Pre-TL: month preceding TL; PL: Partial Lockdown; Pre-PL: month preceding PL. Scores correspond to ratings on a 0–5 ordinal scale, with 0 indicating the absence of the characteristic and 5 its maximum expression (see Materials and Methods section for specific descriptors). Significant comparisons are indicated with asterisks (***: $p \leq .001$; **: $p \leq .01$; *: $p \leq .05$). Error bars represent standard errors of the means.

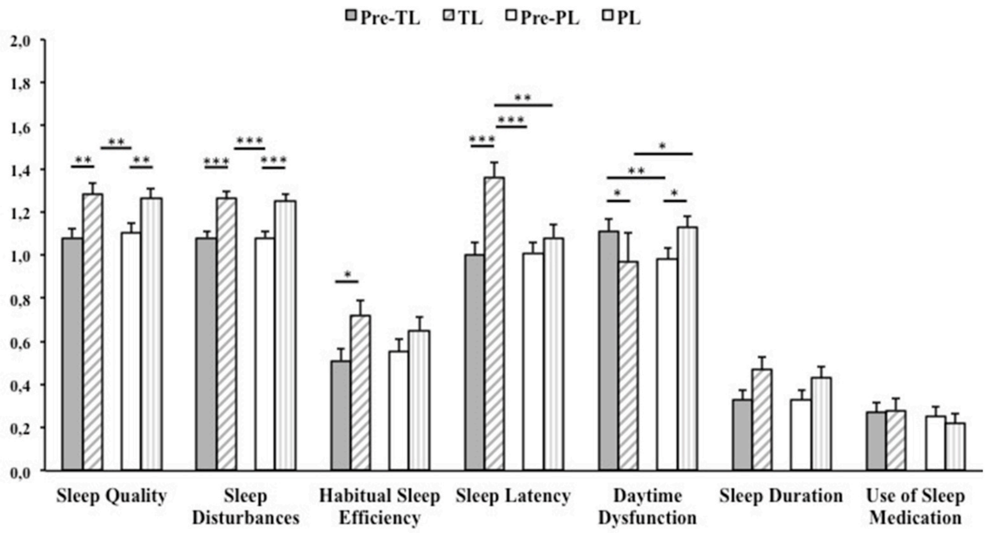

Fig. 4. Differences in scores at the PSQI subscales across the four time-points. Higher Sleep Quality and Habitual Sleep Efficiency sub-scores indicate lower sleep quality and lower sleep efficiency, respectively. Significant comparisons are indicated with asterisks (***: $p \leq .001$; **: $p \leq .01$; *: $p \leq .05$). Error bars represent standard errors of the means.

most interesting finding is the dissociated profile of sleep quality and sleep timing variables. After the significant worsening observed during the first pandemic wave relative to the pre-pandemic period (also reported by Cellini et al., 2020, 2021; Gualano et al., 2020; Franceschini et al., 2020; Casagrande et al., 2020), sleep quality (indexed by the PSQI global score and by the Sleep Quality subscale of the PSQI) returned to baseline and then deteriorated again in PL to the same extent as in TL. The proportion of poor sleepers in the sample showed the same sinusoidal curve. A quite different pattern was displayed, instead, by bed- and rise times, which were significantly delayed from pre-TL to TL (as in Cellini et al., 2020, 2021; Marelli et al., 2021), then advanced in pre-PL and were even earlier in PL. A similar profile emerged for time in bed, which increased from pre-TL to TL (Cellini et al., 2020, 2021; Marelli et al., 2021), decreased in pre-PL and was further reduced in PL, returning to baseline level.

This striking difference between the two types of curve suggests that subjective sleep quality and sleep schedules are at least partially independent and may be modulated by different factors. On one hand, sleep habits appear to be strongly affected by the time constraints linked to daily activities, notwithstanding the psychological effects of the pandemic emergency. In fact, it appears that, although the abrupt introduction of strict limitations during TL determined a relevant disruption of habitual sleep-wake schedules (with people being able to spend more time in bed and delay their bed- and rise times), these sleep variables tended to gradually return towards their pre-pandemic baseline when the first lockdown was interrupted as well as during the second lockdown, when restrictions were much weaker and many daily routines and work activities were allowed, at variance with TL. As also pointed out by Salfi et al. (2021), social jet lag, which was substantially reduced during the first lockdown (Korman et al., 2020; Leone et al., 2020; Blume et al., 2020), returned to exert its effects on sleep in the second lockdown. Also, it is worth noting that greater time spent in bed during TL was not reflected in longer sleep duration, as indexed by the absence of differences in the Sleep Duration subscale of the PSQI across the four time-points (in line with Cellini et al., 2021, who found only a slight, non-significant increase of sleep duration during the first lockdown compared to the pre-pandemic period). On the other hand, the profile of PSQI scores across 2020 more closely reflects, instead, the changes in the general pandemic situation (e.g., number of daily cases) and in social rather than work-related restrictions, which are plausibly the main determinants of emotional wellbeing. Indeed, the substantial reduction, during the summer, of daily Covid-19 cases, accompanied by the suspension of all the main restrictions, has probably determined a sort of rebound of daytime wellbeing which had been so relevantly impaired at the beginning of the pandemic outbreak with the first home confinement period. In this perspective, the return to a high level of sleep impairment during the second wave is not surprising, considering that the number of daily Covid-19 cases in autumn 2020 reached a higher rate than that observed during the first wave (Ministero della Salute, 2020). In fact, a much higher percentage of our participants reported knowing someone who was positive to Covid-19 during PL relative to TL, a finding that was also reflected in the increase of scores in psychological measures (especially fear of contagion and fear for the general pandemic emergency) in PL compared to TL.

Also our findings on sleep onset latency deserve a comment. Its profile across the four time-points appears aligned to that of sleep timing variables, with a significant increase during TL followed by a return towards baseline in the last two periods. In other words, changes in sleep latency in our sample are more related to sleep schedules rather than global sleep quality judgments, suggesting that, at least during pre-PL and PL, sleep latency did not play a major role in sleep satisfaction. Instead, our findings on sleep fragmentation measures are coherent with literature on the determinants of subjective sleep quality. In fact, number of night awakenings and average duration of awakenings (as well as the Sleep Disturbances and Habitual Sleep Efficiency subscales of the PSQI) showed a profile of changes parallel to that of subjective sleep quality (both PSQI global score and the Sleep Quality sub-score), in line with previous studies consistently pointing to number of awakenings (Baekeland and Hoy, 1971; Della Monica et al., 2018; Conte et al., 2020) and wake after sleep onset time (Hoch et al., 1987; Kryger et al., 1991) as main determinants of perceived sleep quality.

Incidentally, it is also worth noting that negative dream emotionality also displayed the same oscillations as subjective sleep quality across the four time-points of the pandemic (Conte et al., 2021a), with significant increases in negative emotionality during both lockdowns compared to the periods before them. This observation lends further support to the existence of a strong link between sleep quality and dream affect proposed in previous studies (e.g., Schredl et al., 1998; Pérusse et al., 2016; Conte et al., 2021b), although the direction of this relationship remains to be ascertained.

As for napping habits, no difference emerged across the four time-points either regarding napping frequency or their average duration, at variance with what observed in an Indian study (Gupta et al., 2020), finding increased napping frequency during the first pandemic lockdown, which was interpreted by the authors as a factor contributing to delayed sleep timing. To our knowledge, only another study addressed napping during the Covid-19 pandemic (Dai et al., 2021): the authors showed that habitual nappers who maintained their habit unchanged during the first lockdown showed the lowest variation in sleep schedules and the lowest emotional impact of the pandemic emergency. Further investigations are warranted to clarify changes in napping habits during the pandemic as well as their relationships with other sleep variables.

The use of sleep medications (assessed through the corresponding PSQI subscale) was also unchanged across time-points, in line with results from by Salfi et al. (2021), who observed only a trend to increase of this variable during the second compared to the first pandemic wave.

Finally, the Daytime Dysfunction subscale of the PSQI displayed a very interesting profile, with daytime functioning improving significantly during the first lockdown, maintaining this improvement in pre-PL and returning to baseline levels (i.e., worsening) in PL. This peculiar pattern could be explained by the relevant differences in daily habits (and possibly in the nature of experienced stress) between the two lockdowns. Indeed, the imposition of the Total Lockdown in March 2020 abruptly interrupted most daytime routines and provided individuals with a large amount of "free time", to be spent in the home setting. Most of this "earned" time has probably been occupied in leisure activities or activities not requiring the same amount of concentration and energy requested by usual everyday life tasks (either work-related or not, i.e., driving), resulting in a lower perception of difficulties with staying awake or having enough energy to perform. In addition, although sleep quality was significantly impaired, social jet lag was reduced during the first lockdown (Korman et al., 2020; Leone et al., 2020; Blume et al., 2020), as previously pointed out. Possibly, this general effect was carried over to pre-PL, even though normal daily routines were mostly recovered. Instead, during the Partial Lockdown, the perception of daytime dysfunction was increased probably due to the additive effects of several interrelated factors, i.e., the resumption of work-related but not social activities, the reappearance of social jet lag effects and the worsening of general psychological wellbeing. As for the latter factor, it should be considered that the quality of psychological distress has probably changed over the course of the pandemic, with that experienced during the first wave being more acute and that characterizing the second wave being more chronic. This is probably reflected in differences in sleep and sleep-related measures between the two periods, as suggested by literature pointing to differential effects of acute and chronic stress on sleep (reviewed in Lo Martire et al., 2020).

A few caveats impose caution in the interpretation of our results. First, our method of data collection entails a certain risk of response bias due to demand characteristics. In other words, the participants' responses regarding their sleep during the current lockdown could have had a carry-over effect on their retrospective responses regarding the month preceding the lockdown. However, the choice of this method should be considered in light of the evolution of the pandemic emergency, in which the unpredictable instantiation of lockdown periods did not allow for an a priori planning of research procedures. Furthermore, concerning our follow-up assessment, our limited sample size and the use of non-probabilistic sampling limit the generalizability of our findings. Nevertheless, although our follow-up participants were slightly older and more educated than those who dropped out, we found that the two groups did not differ in the other demographic characteristics (e.g., proportion of males and females, working condition and marital status) or in their experience with Covid-19 (knowing individuals infected or deceased by Covid-19). Finally, the under-representation of male participants in both the original and the follow-up sample should be acknowledged. The significantly impaired sleep quality found in this study could be mostly attributed to females rather than males, in line with the fact that women report disrupted sleep more frequently than men in a wide range of studies (see Mong and Cusmano, 2016, for a review). Still, the higher proportion of females compared to males is common to most other sleep surveys conducted during the pandemic (e.g., Cellini et al., 2020; Voitsidis et al., 2020; Kokou-Kpolou et al., 2020).

In conclusion, our study highlights that distinct sleep features have evolved differently across four time-points of the Covid-19 pandemic. While sleep timing variables appear to have been strongly affected by the time constraints linked to daily activities, regardless of oscillations in psychological aspects, the profile of subjective sleep quality, instead, more closely reflects the changes in psychological wellbeing linked to the general pandemic situation (e.g., number of daily cases) and to the social rather than work-related restrictions. In addition, our general pattern of findings suggests that the evolution of sleep measures across the four periods may also depend on a transformation in the nature of psychological distress, from the first, more acute phase, to the second phase, characterized by lower restrictions in the face of prolonged stress.

Declaration of competing interest

The authors declare no financial conflicts of interest and no personal or financial support or involvement with any organization having financial interest in the subject matter of the paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychires.2021.09.025.

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