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RESEARCH ARTICLE

Poor sleep hygiene practices are associated with a higher increase in sleep problems during the COVID-19 pandemic: A latent change score model

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Summary

The Coronavirus 2019 (COVID-19) pandemic significantly influenced physical and mental health worldwide. The present study aimed to investigate changes in sleep problems across three waves of the COVID-19 pandemic, and to identify potential predictors of the inter-individual variability around these changes, with a particular focus on the role of detrimental sleep hygiene practices. A total of 352 participants completed an online survey of self-report questionnaires at three different waves of the COVID-19 pandemic: T1 (Spring 2020); T2 (Autumn-Winter 2020); and T3 (Spring 2021). The questionnaires collected information on socio-demographic and COVID-19-related variables, psychological distress (i.e. the Depression Anxiety Stress Scale-21), sleep hygiene (i.e. the Sleep Hygiene Index) and sleep problems (i.e. the Medical Outcomes Study—Sleep Scale). Latent change score modelling revealed an average increase in sleep problems between T1 and T2 with significant inter-individual variability. No substantial changes were observed on average between T2 and T3. Notably, poorer sleep hygiene practices were associated with a more pronounced increase in sleep problems between T1 and T2 ($\beta = 0.191$, $p = 0.013$), even after controlling for relevant confounders such as demographic factors, COVID-19-related information and psychological distress. These findings expand on previous research regarding the detrimental effects of the pandemic on mental health, suggesting that interventions targeting sleep hygiene practices may be beneficial for mitigating its negative impact on sleep disruptions.

KEYWORDS
COVID-19, insomnia, longitudinal, sleep disturbances, sleep hygiene, sleep problems

1 | INTRODUCTION

The Coronavirus 2019 (COVID-19) pandemic significantly influenced physical and mental health worldwide. A considerable body of

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literature has highlighted that sleep quality and sleep habits undergo relevant changes during the pandemic (Jahrami et al., 2021; Scarpelli et al., 2022). Early studies showed that home confinement led to misalignment of circadian rhythms (Bottary et al., 2022; Merikanto et al., 2022) and sleep difficulties (Franceschini et al., 2020; Morin et al., 2021). On the one hand, people perceived some benefits from lockdown and restrictions as they could modulate sleep timing based on their chronotype (Korman et al., 2020). On the other side, the changes in light exposure, variations in daily activity and the elevated anxiety levels were closely associated with sleep disorders in patients with COVID-19 (Deng et al., 2021) and the general population (Limongi et al., 2023). In particular, Italy was one of the most affected countries and has faced various COVID-19 waves during the last years. In the first wave (Spring 2020), the Italian government, as per the stance of other European countries, implemented stringent measures such as home confinement and social distancing across all regions in Italy. In the second (Autumn-Winter 2020) and third (Spring 2021) waves, some restrictive measures were reintroduced, tailored to the varying levels of contagion risk and strain on the local healthcare systems in each Italian region.

It is important to note that most studies assessing sleep alterations during the pandemic were cross-sectional (Scarpelli et al., 2022), which limits their ability to establish causal relationships and examine longitudinal changes in sleep disturbances over time. Few longitudinal studies focused on establishing predictors of sleep problems during the pandemic, mostly employing a two-wave assessment. For instance, Ballesio et al. (2022) carried out a longitudinal study aimed at assessing the relationship between stress and sleep difficulties, revealing that higher levels of stress symptoms during the first lockdown significantly predicted sleep disorders after 8–10 months. To date, only a longitudinal study by Salfi and colleagues (2023) evaluated changes in sleep health in the Italian context through a three-time-point survey. The study showed reduced sleep disorders, decreased anxiety and depressive symptoms after 2 years of the pandemic. However, as previously shown in a two-time-point survey (Salfi et al., 2021), this study highlighted that sleep duration gradually decreased over the pandemic, especially in younger individuals and those with an evening chronotype (Salfi et al., 2023).

Additionally, cross-sectional findings demonstrated a significant association between sleep hygiene (i.e. a set of behavioural and environmental practices aimed at promoting healthy and restful sleep) and sleep quality during the COVID-19 pandemic, both in adolescents (Chehri et al., 2023) and adults (Bacaro et al., 2020). More in general, sleep hygiene has been considered a crucial factor impacting chronic insomnia both in behavioural (Spielman et al., 1987) and cognitive (Morin, 1993) approaches, as well as contributing to other sleep disturbances, for example, obstructive sleep apnea (Jung et al., 2019) or parasomnias (Sönmez & Aksoy Derya, 2018). Several cross-sectional studies conducted both on healthy and clinical samples have consistently found a significant correlation between poor sleep hygiene and disrupted sleep (Irish et al., 2015; Lacks & Rotert, 1986; Mastin et al., 2006). More directly, some prospective investigations explored the role of sleep hygiene in insomnia development (Gellis et al., 2014; Jansson-Fröjmark et al., 2019). Specifically, Jansson-Fröjmark et al. (2019) showed that different types of sleep hygiene habits (i.e. late evening nicotine use, light or noise disturbance, and having an irregular sleep schedule) were significantly associated both with concurrent and future insomnia.

In summary, previous investigations have suggested that different factors may predict changes in sleep health over the course of the pandemic. However, little is known about longitudinal evidence on the impact of sleep hygiene practices. To provide additional insights into this matter, we aimed to examine inter-individual differences in sleep changes during the COVID-19 pandemic by employing an innovative latent change score (LCS) modelling approach (McArdle, 2009; McArdle & Hamagami, 2001). Namely, our study had a twofold aim: (1) to identify average changes in sleep disturbances that occurred over the course of three waves of the pandemic; and (2) to investigate potential predictors of the inter-individual variability around these changes. In accordance with cross-sectional findings linking sleep alterations to poor sleep hygiene during COVID-19 (Bacaro et al., 2020), we hypothesized that detrimental sleep hygiene practices could contribute to a higher increase in sleep problems throughout the pandemic. Moreover, we controlled for relevant sociodemographic (i.e. gender and age differences) and COVID-19-related (e.g. positivity to SARS-CoV-2, loss of someone close due to COVID-19) variables, as well as psychopathological symptoms (i.e. stress, anxiety and depression), in order to disentangle the unique contribution of sleep hygiene.

2 | METHODS

2.1 | Procedure

The current investigation is part of a larger project on the effects of the pandemic on Italian people. The study was approved by the Ethics Committee of the Centre for Research and Psychological Intervention (CERIP) of the University of Messina (protocol #12106/2021), and was conducted in line with the Declaration of Helsinki and its later amendments.

Participants were requested to complete a web survey designed through the Microsoft Azure platform at three different time-points: T1 (Spring 2020); T2 (Autumn-Winter 2020); and T3 (Spring 2021). Survey promotion was made through university platforms, social networks and online blogs. After signing an informed consent, participants were asked to complete a set of questionnaires, which took approximately 30 min to fill out. The questionnaires collected information on socio-demographic factors, COVID-19-related information, psychological distress and sleep parameters. To facilitate follow-up assessments at each of the three time-points, participants provided their email addresses with explicit consent. We used non-anonymous data collection later de-identified, as commonly applied in behavioural science (Audette et al., 2020). Specifically, participants provided their e-mail addresses during the first wave of data collection with explicit

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consent to be contacted again twice in the second and third waves. After data collection, data were anonymized.

2.2 | Participants

The baseline sample (T1) of the present study consisted of 6516 participants. Among them, 640 participants completed both T1 and T2, while 354 participants completed all three measurement occasions (T1, T2 and T3). Little's (1988) MCAR test, conducted on the constructs selected for this study, indicated that the missing data were missing completely at random ($p > 0.05$). Additionally, participants who completed all three measurements differed negligibly from those assessed only at T1 in terms of gender (Phi coefficient = 0.032), education (Cramer's $V = 0.024$), marital status (Cramer's $V = 0.035$), age (Cohen's $d = -0.063$), sleep problems (Cohen's $d = -0.088$) and sleep hygiene (Cohen's $d = 0.024$). The high dropout rate was consistent with other longitudinal studies conducted during the initial phase of the pandemic (Markovic et al., 2021; Martínez-de-Quel et al., 2021; Nyberg et al., 2023; Salfi et al., 2021; 2023). To avoid introducing a high level of uncertainty through multiple imputation procedures, we utilized a case-complete approach, which is compatible with the MCAR missing data mechanism, as suggested by Hair et al. (2019). Specifically, after excluding two participants under the legal age of 18 years, the final sample comprised 352 individuals. Details regarding socio-demographic characteristics and COVID-19-related information are reported in Table 1.

TABLE 1 Baseline socio-demographic characteristics of the sample ($n = 352$)

	n	%
Age (years)		
18–25	162	46
26–30	53	15.1
31–40	46	13.1
41–50	46	13.1
51–60	38	10.8
> 60	7	2
Gender		
Female	280	79.5
Male	72	20.5
Marital status		
Single	130	36.9
Engaged/Married	210	59.7
Divorced/Separated/Widower	12	3.4
Occupation		
Student	163	45.9
Employed	170	47.9
Unemployed	18	5.1
Retired	4	1.1
Education		
Until middle school	8	2.3
High school	153	43.5
Bachelor's degree	71	20.2
Master's degree	91	25.9
PhD/postgraduate school	29	8.2
Having tested positive for COVID-19		
Yes	4	1.1
No	348	98.9
Having close contacts who tested positive for COVID-19		
Yes	56	15.9
No	296	84.1
Having lost someone close due to COVID-19		
Yes	14	4.0
No	338	96.0

Abbreviation: COVID-19, Coronavirus 2019.

2.3 | Measures

After collecting socio-demographic (i.e. age, gender, education, marital status, occupational status) and COVID-19-related (i.e. having tested positive for COVID-19, having close contacts who tested positive for COVID-19, and having lost someone close due to COVID-19) data, participants completed the following self-report questionnaires.

- The Medical Outcomes Study-Sleep Scale, Italian version (MOS-SS; Palagini & Manni, 2016) was employed to assess specific sleep parameters (sleep disturbance, awakening short of breath or with headache, quantity of sleep, optimal sleep, sleep adequacy and somnolence) through 12 items. Specifically, in the current investigation, we focused on the Sleep Problems Index defined as a composite measure of sleep alterations. For descriptive analyses, we computed the Sleep Problem Index as a raw sum of Items 1, 3, 4, 5, 6, 7, 8, 9 and 12 of the MOS-SS (Table S1), with scores ranging from 9 to 45. The higher the score, the higher the sleep problems.
- The Sleep Hygiene Index, Italian version (SHI; Zagaria et al., 2021) was employed to assess sleep hygiene practices. The scale consists of 13 items (Table S2), in which participants rate the frequency of their habits on a five-point Likert scale from "never" to "always". Scores range between 13 and 65, where higher scores indicate poor sleep hygiene.
- The Depression Anxiety Stress Scale-21, Italian version (DASS-21; Bottesi et al., 2015) was employed to evaluate psychological distress. The questionnaire comprises three subscales that measure anxiety, depression and stress symptoms. Subscale scores are calculated as the sum of the responses to the seven items from each subscale multiplied by 2 to suit the original 42-item scale. In the present investigation, we focused on the General Distress—an index of general psychopathology—calculated as the sum of the anxiety, depression and stress scores.

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2.4 | Data analytic strategy

Data were analysed using IBM SPSS version 25 (IBM, Armonk NY, USA) and Mplus 8.6 (Muthén & Muthén, 1998–2017).

Preliminarily, to ensure that sleep problems were measured consistently over time and that any observed changes were due to true construct differences and not to measurement artefacts, we conducted longitudinal measurement invariance tests adhering to the stepwise framework proposed by Meredith (1993) and Little et al. (2013). We started with a configural invariance model specifying the same fixed and free loadings pattern across time. Subsequently, we assessed weak factorial invariance by imposing equality constraints on items' loadings across time, followed by strong factorial invariance, where the intercepts of indicators were constrained to be equal across measurement occasions. With the aim of evaluating the tenability of invariance constraints, we computed changes in absolute and incremental fit indices between these nested models. Namely, a change in comparative fit index (CFI) and Tucker–Lewis index (TLI) less than 0.01, along with a change in root mean square error of approximation (RMSEA) less than 0.015, suggests that the more constrained model was not substantially worse than the less constrained model (Chen, 2007; Cheung & Rensvold, 2002). Solely in the presence of strong factorial invariance, even if partial, sleep problem scores can be longitudinally compared at their latent level (Little, 2013).

A parcelling strategy was applied to define the latent factors of sleep problems, which demonstrates several advantages over using single indicators (see Little et al., 2013 for an extensive discussion). Specifically, the balancing approach was employed by assigning items to parcels based on the corrected item-total correlations (Little et al., 2013). Four indicators (i.e. parcels) were defined for each factor (Kenny, 1979; Kline, 2011), and the same item-to-parcel assignments were used for each measurement occasion, ensuring consistency across time. Moreover, residual covariances among the same parcels across waves were freely estimated.

As a subsequent step, we employed a LCS modelling approach (Geiser, 2021; McArdle, 2009; McArdle & Hamagami, 2001) to investigate inter-individual differences in true state changes across time. Multiple-indicator LCS models are a class of longitudinal structural equation models (SEM) that, unlike conventional approaches that rely on observed differences, offer the advantage of modelling occurred changes through latent variables while partialling out measurement error, thereby mitigating the risk of biased estimates (Matusik et al., 2021). Prior to specifying LCS models, observed scores were linearly transformed into *z*-scores using the means and the standard deviations observed at Wave 1 (Alessandri et al., 2017). In the first phase, a multiple-indicator univariate LCS model was implemented by re-parameterizing the strong invariance model in order to quantify the latent mean changes and the variability around these changes. The following main steps were taken (Cerutti et al., 2022): (1) the non-directional associations between adjacent latent state factors (i.e. T1 and T2 sleep problems, as well as T2 and T3 sleep problems) were transformed into a direct effect and fixed at 1; (2) the latent residual variances of T2 and T3 sleep problems were fixed at 0; (3) two LCS variables, reflecting changes between neighbourhood occasions ($\tau 2 - \tau 1$ and $\tau 3 - \tau 2$), were defined by specifying covariances with the T1 latent state variable and direct effects, constrained to unity, on the subsequent latent state variables; (4) a non-directional relationship was specified between the two LCS variables. Each LCS variable had its own mean, i.e. the average extent of change between adjacent occasions, and its own variance, i.e. the inter-individual variability around these changes. After being modelled, LCS variables can be predicted through various factors, such as earlier levels of the investigated construct and other external variables (Matusik et al., 2021). Accordingly, we further examined through a conditional LCS model whether detrimental sleep hygiene practices measured at baseline could explain the inter-individual variability around the latent changes in sleep problems, after controlling for the previous state level of sleep problems (e.g. the influence of T1 sleep problems when examining the latent change occurred between T1 and T2).

According to a multifaceted conception of model fit (Tanaka, 1993), we relied on several goodness-of-fit indices to assess the fit of the models to the observed data, including the CFI, TLI, RMSEA, and standardized root mean square residual (SRMR), with cut-offs of CFI and TLI ≥ 0.90, RMSEA ≤ 0.08 and SRMR ≤ 0.08, indicating acceptable model fit (Browne & Cudeck, 1993; Wang & Wang, 2019). The chi-square test was not employed due to its oversensitivity to trivial misspecifications in large samples (Kline, 2011). Lastly, due to slight deviations from the univariate normal distribution of the observed parcels (skewness and kurtosis < |2|), the model parameters were estimated using robust maximum likelihood estimation (MLR; Muthén & Muthén, 1998–2017), which provides corrected chi-square statistics and standard errors to deal with non-normality.

3 | RESULTS

3.1 | Descriptive statistics

Table 2 reports observed means, standard deviations and zero-order correlations for the main constructs under investigation. Bivariate correlations of sleep problems across time were large in size (*r* range from 0.574 to 0.691, $p < 0.001$), highlighting a substantial rank-order stability. Moreover, we found significant correlations between sleep hygiene, measured at Time 1, and sleep problems, measured at all three time-points. Specifically, sleep hygiene at baseline (T1) was associated with sleep problems at Time 1 ($r = 0.445$, $p < 0.001$), Time 2 ($r = 0.428$, $p < 0.001$) and Time 3 ($r = 0.371$, $p < 0.001$). Similarly, baseline DASS-21 scores (T1) significantly correlated with sleep problems at Time 1 ($r = 0.642$, $p < 0.001$), Time 2 ($r = 0.517$, $p < 0.001$) and Time 3 ($r = 0.500$, $p < 0.001$).

3.2 | Longitudinal invariance

Longitudinal invariance was assessed through a confirmatory factor analysis, employing MLR as the parameter estimation method

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(Muthén & Muthén, 1998–2017). The analyses were conducted on item parcels serving as manifest indicators, and the residual variances of the same parcels measured at different time-points were a priori allowed to correlate over time (Little, 2013).

Firstly, we specified a configural invariance model with a one-factor structure for the MOS-SS sleep problem index at each time-point, which yielded a satisfactory fit to the data: χ^2 (39) = 78.868, $p < 0.001$; CFI = 0.979; TLI = 0.964; RMSEA = 0.054 (90% confidence interval [CI] 0.037–0.071); SRMR = 0.039. All standardized factor loadings were statistically significant ($p < 0.001$), ranging from 0.597 to 0.892. Additionally, the composite reliability coefficients demonstrated good levels of internal consistency, with values of 0.811, 0.835 and 0.838 at Time 1, Time 2 and Time 3, respectively. We employed this unconstrained model as a baseline point to test increasingly stringent levels of invariance. Specifically, the weak invariance model, which imposed equality constraints on the factor loadings across time, did not result in a significant deterioration in fit compared with the configural model. This is supported by the negligible changes in CFI (0.002), the TLI that improved by 0.002, and the RMSEA that improved by 0.001. Contrarily, the strong invariance model, which introduced additional equality constraints on parcel intercepts across time, ended in a significantly poorer fit than the weak invariance model. To explore this issue, we examined model modification indices (MI), and found that constraining the intercepts of one parcel to be invariant across time was not tenable. Following Byrne et al. (1989), we relaxed this constraint and tested for partial strong invariance. The fit of this partially invariant model was not significantly worse than the weak invariance model, as indicated by meaningless changes in CFI (0.003), TLI (0.001) and RMSEA (0.001). Results are summarized in Table 3. These findings guaranteed construct continuity, allowing for the investigation of latent changes in sleep problems across the three measurement occasions (Little, 2013; Meredith & Horn, 2001).

3.3 | LCS model

A multiple-indicator LCS model was implemented to assess changes in sleep problems that occurred during the three measurement occasions. MLR (Muthén & Muthén, 1998–2017) was employed as the parameter estimation method.

The LCS model and its corresponding strong invariance model were equivalent models that exhibited an identical fit to the data: χ^2 (49) = 98.788, $p < 0.001$; CFI = 0.974; TLI = 0.965; RMSEA = 0.054 (90% CI 0.038–0.069); SRMR = 0.043. The LCS model revealed a significant average increase in sleep problems between T1 and T2 (0.133, $p = 0.001$), but not between T2 and T3 (−0.027, $p = 0.471$). These estimates represent the average change in *z*-scores metric across neighbourhood occasions assessed at the latent level. Importantly, there was a significant inter-individual variability around these changes (0.376 and 0.315 for T2–T1 and T3–T2, respectively; $p < 0.001$). Additionally, we observed a negative correlation between baseline sleep problems (T1) and latent changes occurring between T1 and T2 ($r = -0.390$, $p < 0.001$), as well as between the two LCS variables (T2–T1 with T3–T2; $r = -0.312$, $p < 0.001$). Table 4 summarizes the main results of the LCS model.

TABLE 2 Descriptive statistics and zero-order correlations for the main constructs under investigation

Variable	Mean (SD)	1	2	3	4	5
1. Sleep hygiene (T1)	13.76 (6.93)					
2. Psychological distress (T1)	17.53 (11.71)	0.514*				
3. Sleep problems (T1)	19.98 (6.76)	0.445*	0.642*			
4. Sleep problems (T2)	20.55 (6.58)	0.428*	0.517*	0.673*		
5. Sleep problems (T3)	20.11 (6.43)	0.371*	0.500*	0.574*	0.691*	

Note: Comparisons of observed scores through paired *t*-tests showed significant differences in sleep problems between T1 and T2 ($t = -2.143$, $df = 354$, $p = 0.033$), but non-significant differences between T2 and T3 ($t = 1.593$, $df = 354$, $p = 0.112$).
Abbreviation: SD, standard deviation.
*$p < 0.001$.

TABLE 3 Longitudinal factorial invariance tests across the three measurement occasions

Model	MLR χ^2 (df)	CFI	TLI	RMSEA	SRMR	Model comparison	ΔCFI	ΔTLI	ΔRMSEA
1. Configural invariance	78.868 (39)	0.979	0.964	0.054	0.039				
2. Weak invariance	89.415 (45)	0.977	0.966	0.053	0.042	2 versus 1	−0.002	0.002	−0.001
3. Partial strong invariance	98.788 (49)	0.974	0.965	0.054	0.043	3 versus 2	−0.003	−0.001	0.001

Abbreviation: CFI, comparative fit index; MLR, maximum likelihood estimation; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; TLI, Tucker–Lewis index.

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TABLE 4 Results of the LCS model

Correlation between τ1 and τ2 – τ1	Correlation between τ1 and τ3 – τ2	Mean τ2 – τ1	Variance τ2 – τ1	Mean τ3 – τ2	Variance τ3 – τ2	Correlation between τ3 – τ2 and τ2 – τ1
−0.390**	−0.123	0.133*	0.376**	−0.027	0.315**	−0.312**

Note: τ2 – τ1 refers to the LCS variable for Time 2 minus Time 1. τ3 – τ2 refers to the LCS variable for Time 3 minus Time 2. Correlation between τ1 and τ2 – τ1 and between τ1 and τ3 – τ2 represent latent correlations among baseline sleep problems and LCS variables; Mean τ2 – τ1 and Mean τ3 – τ2 represent the means of the LCS variables across neighbourhood occasions (observed scores were linearly transformed into *z*-scores using the means and the standard deviations observed at Wave 1). Var τ2 – τ1 and Var τ3 – τ2 represent the inter-individual variability around latent changes. Correlation between τ3 – τ2 and τ2 – τ1 represents the correlation between the two LCS variables.
*$p < 0.05$.**$p < 0.01$.

3.4 | Conditional LCS model

A conditional LCS model was employed to evaluate whether sleep hygiene measured at baseline could predict the inter-individual variability around latent changes in sleep problems experienced during the pandemic, after accounting for immediately preceding levels of sleep problems. To mitigate the influence of possible confounding variables, we controlled for covariates measured at baseline, such as age, gender (i.e. 0 = female, 1 = male), overall psychological distress (i.e. anxiety, depression and stress), having tested positive for COVID-19 (i.e. 0 = no, 1 = yes), having close contacts who tested positive for COVID-19 (i.e. 0 = no, 1 = yes) and having lost someone close due to COVID-19 (i.e. 0 = no, 1 = yes). As previously, MLR (Muthén & Muthén, 1998–2017) was employed as the parameter estimation method. A simple graphical representation of the structural part of the LCS model is depicted in Figure 1.

The conditional LCS model yielded an excellent fit to the data: χ^2 (112) = 202.076, $p < 0.001$; CFI = 0.963; TLI = 0.950; RMSEA = 0.048 (90% CI 0.037–0.058); SRMR = 0.040. Findings revealed that participants with detrimental sleep hygiene practices showed a higher increase in sleep problems between T1 and T2 ($\beta = 0.191$, $p = 0.013$), but not between T2 and T3 ($\beta = -0.053$, $p = 0.589$). As before, individuals with lower levels of sleep disturbance at T1 experienced greater worsening between T1 and T2 ($\beta = -0.520$, $p < 0.001$). In addition, we found that female participants showed a greater increase in sleep problems between T1 and T2 compared with males (unstandardized $B = -0.171$, $p = 0.035$). No significant effects of the other covariates were observed ($p > 0.05$).

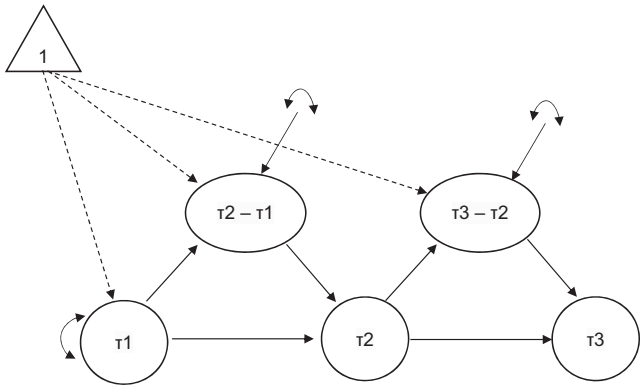

FIGURE 1 A simple graphical representation of the structural part of the latent change score (LCS) model (Geiser, 2021). LCS variables were regressed on sleep hygiene and external covariates measured at baseline (i.e. age, gender, psychological distress, having tested positive for COVID-19, having close contacts who tested positive for COVID-19, and having lost someone close due to COVID-19). External variables were not depicted to avoid clutter. Residual changes variables were allowed to correlate.

4 | DISCUSSION

To the best of our knowledge, this is the first study to examine changes in sleep problems over three waves of the COVID-19 pandemic, by employing an innovative LCS modelling approach. Moreover, we aimed to investigate the role of detrimental sleep hygiene practices in explaining the variability around the changes in sleep problems.

The LCS model highlighted a significant change in sleep problems between the first and second pandemic waves. Importantly, although the average extent of change was small, we identified significant inter-individual variability, indicating that the rate of change was not uniform among all individuals. In contrast, no average changes in sleep disturbances were observed between the second and the third waves. On the one hand, we confirmed that the COVID-19 pandemic had a significant impact on sleep problems. Our results are partly in line with Salfi et al. (2021), showing that Italian subjects had lower sleep duration, greater sleep medications use and higher daytime dysfunction during the second wave, although the sleep quality was improved, and sleep disturbances were reduced. On the other hand, the absence of significant average changes between the second and third waves may be related to a sort of "adaptation" to the pandemic situation, as already suggested by investigations on dreaming (Sommantico et al., 2021) and mental health (Ochnik et al., 2022).

In the second step, we focused on examining the role of detrimental sleep hygiene practices as potential predictors of the variability around changes in sleep problems, after taking into account the effects of previous levels of sleep problems, psychological distress, socio-demographic and COVID-19-related covariates. Findings showed that individuals with higher levels of sleep problems at T1 experienced less worsening between T1 and T2, while those with fewer sleep disturbances at baseline had a greater increase. Not

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surprisingly, female individuals tend to have a greater increase in sleep problems between T1 and T2 than males. Aligned with the current state of knowledge, females are more prone to developing sleep alterations such as insomnia (Alimoradi et al., 2022; Ohayon, 2011). Moreover, some findings reported that women were more susceptible to increase stress levels than men during quarantine (Kowal et al., 2020). Also, research suggests that males tend to have a naturally later sleep schedule than females, which may give them an advantage during the pandemic in adapting their sleep patterns (Adan & Natale, 2002; Randler & Engelke, 2019). On the other hand, women may face challenges related to caring for children or meeting family responsibilities, which could worsen their sleep quality during this time (Conversano et al., 2020). This seems to be reflected in their oneiric activity, as several results pointed out that women had more dreams and nightmares during the first wave of the pandemic (Kilius et al., 2021).

Importantly, our findings also provided empirical support for the main hypothesis regarding the role of detrimental sleep hygiene practices in explaining changes in sleep problems between T1 and T2. Specifically, the conditional LCS model indicated that individuals who reported poor sleep hygiene exhibited a greater increase in sleep problems. Consistent with previous research, our study strengthens the notion that sleep hygiene is strongly associated with sleep quality (Baranwal et al., 2023; Brown et al., 2002). These findings are further supported by a recent Italian study that investigated the impact of the pandemic on sleep and mental health in young adults, revealing a significant association between insomnia severity and poor sleep hygiene practices, as well as dysfunctional beliefs about sleep, self-reported mental disorders, anxiety and depression, among a large sample of 1989 participants (Bacaro et al., 2020).

Along this vein, a recent meta-analysis demonstrated that sleep hygiene recommendations were effective in improving sleep in patients with insomnia, based on significant pre- to post-treatment changes, albeit this strategy was less effective than cognitive behavioural therapy for insomnia (CBT-I) and mindfulness-based therapy (Chung et al., 2018). Additionally, Lin and Chung (2022) showed that sleep hygiene may be considered an underlying mechanism that explained the difference in sleep quality between individuals varying in trait self-control and chronotype. Hence, increasing adaptive sleep hygiene behaviours could maximize the ability of individuals to implement functional routines for consistent and efficient sleep. Moreover, it should be considered that sleep hygiene education is currently the most common practice in the family of non-pharmacological treatments for sleep problems (Morin et al., 1992; Sivertsen et al., 2010), representing a promising protective factor to prevent sleep alterations, having low cost and easy availability.

More directly, a large study conducted in the Italian context showed that the SHI (Zagaria et al., 2021) represents a viable instrument to measure sleep hygiene practices, also demonstrating to have a predictive validity on sleep quality, as observed in follow-up assessments. Given these results, we argue that having a reliable tool to detect sleep hygiene behaviours and being able to predict future sleep problems could be beneficial for implementing clinical programmes focused on insomnia and other sleep alterations in the post-pandemic period (Baglioni et al., 2020).

The main strength of our study lies in the application of LCS models, a flexible framework for investigating change over time that offers several advantages over standard longitudinal correlations or cross-lagged regressions (see Alessandri et al., 2017 for a detailed discussion), including the ability to model longitudinal changes in mean levels of the focal constructs, account for measurement error by estimating true changes within a latent variable framework, and enable the examination of inter-individual differences in these latent changes. However, several limitations should be acknowledged. Firstly, it is important to highlight the considerable dropout rate across the three data collection periods. Similarly to other longitudinal studies carried out during the COVID-19 pandemic (Markovic et al., 2021; Martínez-de-Quel et al., 2021; Nyberg et al., 2023 Salfi et al., 2021, 2023), the low response rate during the third wave could be explained by: (a) the loss of interest in participating in scientific research on the COVID-19 pandemic over time; (b) the reduced availability of time in completing long surveys given the easing of restrictions and resumption of regular routines/work activities; (c) the absence of any monetary compensation. Nonetheless, the attrition bias may be considered marginal as the missing data were found to be completely at random (MCAR; Little & Rubin, 2002). Secondly, the majority of the sample consisted of females and young adults, which may limit the generalizability and external validity of our results to male and adult individuals. Thus, future studies should strive for more representative samples to strengthen the generalizability of findings. Thirdly, our investigation relied solely on self-report questionnaires prone to recall bias. Future research should consider using objective measures, such as actigraphy or polysomnography, to assess sleep-related parameters. Fourthly, we opted to use the composite index from the MOS-SS questionnaire for evaluating sleep problem changes over time. While this approach provides a better representation of a multifaceted construct like sleep disturbances enhancing its content validity, it also comes with the potential drawback of losing information about the relationship between specific sleep aspects and sleep hygiene. Lastly, other unconsidered factors may have accounted for changes in sleep disturbances during the pandemic (e.g. circadian typology, psychiatric comorbidity and pharmacological therapies). Future studies should investigate the role of these variables to gain a more comprehensive understanding of the factors contributing to changes in sleep problems in the aftermath of the COVID-19 pandemic.

5 | CONCLUSIONS

In summary, our study contributes to the understanding of inter-individual differences in mental health changes during the pandemic. Specifically, we found that sleep problems significantly increased between the first and second pandemic waves, and that the inter-individual variability around this increase could be explained by detrimental sleep hygiene practices. This research serves as an essential update

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and extension of prior studies on the impact of the pandemic on mental health, suggesting that interventions targeting sleep hygiene practices may prove useful in mitigating the worsening of sleep disturbances during such challenging times.

AUTHOR CONTRIBUTIONS

Andrea Zagaria: Writing – original draft; methodology; formal analysis; data curation; conceptualization. **Scarpelli Serena:** Writing – original draft; conceptualization; data curation. **Alessandro Musetti:** Writing – review and editing. **Giada Rapelli:** Writing – review and editing. **Luigi De Gennaro:** Writing – review and editing. **Giuseppe Plazzi:** Writing – review and editing. **Christian Franceschini:** Writing – review and editing; supervision; conceptualization; data curation.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare that may be affected by the publication of the paper. Other conflicts of interest are as follows: GP research is supported by Takeda, Jazz Pharmaceuticals, Bioproject, Idorsia.

DATA AVAILABILITY STATEMENT

Data are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

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