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Relationship between sleep duration and quality and mental health before and during COVID-19 pandemic: Results of population-based studies in Brazil

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ABSTRACT

Objective: This study aimed to evaluate the association between sleep duration and quality and mental health before and amid the COVID-19 pandemic.
Methods: Data from two population-based cross-sectional studies conducted in 2019 and 2020 with adults in Criciúma, Southern Brazil. The Patient Health Questionnaire-9 (PHQ-9) was used to screen major depressive episodes, while the perceived stress scale was used to assess perceived stress. Sleep was evaluated through self-reported duration and quality. Crude and adjusted Poisson regression models were used to assess the association between sleep and mental health disorders.
Results: A total of 820 (in 2019) and 863 subjects (in 2020) were assessed. Sleep quality presented significant associations with depression and stress in both years, and the magnitude of the association with depression increased amid COVID-19 pandemic. In individuals with poor/very poor sleep quality, the risk of depression in 2019 was 2.14 (95%IC 1.48;3.09) higher when compared to those with good/very good sleep quality. This risk increased to 2.26 (95%IC 1.49;3.40) in 2020. The risk of stress was 1.90 (95%IC 1.42;2.55) in 2019 and 1.66 (95%IC1.34;2.07) in 2020. The sleep duration was not associated with mental health disorders in the adjusted analyses.
Conclusion: The results provide important evidence that sleep quality can influence mental health of adults. The COVID-19 pandemic seems to have had a considerable impact on this association.

1. Introduction

The COVID-19 pandemic is bringing countless consequences for the population's health, and changes to daily life caused by this pandemic, such as social isolation and financial problems, may increase mental health disorders in the short and long-terms [1]. Recent investigations have shown an increase in prevalence of certain disorders, such as depression and mental distress, during the COVID-19 pandemic in different settings, e.g., Czech Republic, Italy, United Kingdom, Italy and the United States [2–6].

Brazil has one of the worst pandemic scenarios worldwide. The country has implemented weak mitigation measures, contradicting scientific recommendations and the Federal Government has, so far, minimized the importance of COVID-19 and its impact on people's health [7,8]. As a result, until the end of April 2021, Brazil had more than 14 million cases of COVID-19 and more than 390 thousand deaths [9]. Because of this situation, we can presume that the impact of the pandemic on the Brazilian population's mental health may be even greater, given that in countries where the pandemic has been properly addressed, such impact has been found.

Inadequate sleep duration and quality are among the main determinants of mental health disorders [10–12]. The association between

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sleep patterns and mental health disorders can be explained by the circadian cycle, which is responsible for regulating the production of melatonin and cortisol and the sleep-wake cycle. Disruption in the circadian cycle can cause alterations in cortisol levels, which may contribute to stress-related dysregulation linked to physical and mental disorders [13–15]. The circadian cycle has been significantly affected during the COVID-19 pandemic, owing to changes in people's routine and social life [16].

Studies conducted in Israel, United States, Australia and Canada have shown an association between negative changes in sleep during the pandemic and depression [17–19], and stress [18,19]. Stanton et al. [19] comparing data before and during the pandemic showed that negative changes (in duration and/or quality) in sleep were associated with higher risk of depression (OR = 1.19, 95%CI 1.15 to 1.23) and stress (OR = 1.30, 95%CI 1.26 to 1.35) [19]. Another study from Osiogo et al. showed that individuals with stress were more likely to have sleep disturbances amid the COVID-19 outbreak (trouble falling asleep, keep sleeping, or oversleeping) when compared to the non-stressed ones (OR = 2.42, 95%CI 1.99 to 2.94) [18]. It is noteworthy that all the above-mentioned studies have been conducted in high-income countries, and evidence from middle- and low-income countries, such as Brazil, are important to better understand the effects of sleep patterns on mental health amid the COVID-19 pandemic.

Therefore, considering the current scenario and the need of population-based studies to investigate the effects of the COVID-19 pandemic on mental health, in order to mitigate the present situation and prevent future health problems [1], we aimed to assess the association between sleep duration and quality and mental health before and amid the COVID-19 pandemic using data from two population based-studies conducted in Southern Brazil. We hypothesized that this association has been intensified during the COVID-19 pandemic, due to mental health and sleep impairments in the overall population occasioned by this public health issue. We also investigated if there were differences in sleep duration and quality as well as in mental health before and during COVID-19 outbreak, according to the sociodemographic characteristic of the participants.

2. Materials and methods

2.1. Setting, study sample and data collection

This investigation used data from two different population-based studies conducted in 2019 and 2020 in Criciúma, Santa Catarina state, Brazil. Criciúma is a city located in southern Brazil with approximately 215,000 inhabitants [20], with a Human Development Index of 0.788, and a population density of around 815.87 inhabitants per km^2. In 2018, the city had a Gross Domestic Product per capita of 36,073.31 Brazilian *Reais* (BRL) and an average monthly wage of 2.6 Brazilian minimum wages. Criciúma has a territorial area of 234,865 km^2 and, in addition to being considered a regional capital, it is located near the capital of Santa Catarina state, Florianópolis [20].

Two population-based studies were performed before and amid the COVID-19 pandemic in Criciúma. The first study, called "Health of the Criciúma population", was conducted between March and December 2019, while the second one, called "Covid Mental", was conducted between October 2020 and January 2021. In both population-based studies, individuals aged 18 years or older who were living in the urban area of the city were included. Those physically or cognitively unable to complete the survey were excluded from both studies.

The sampling process of each research study was conducted in two stages, based on data from the 2010 Brazilian Demographic Census [21]: the first stage, which focused on the random selection of the primary units (the census tracts), and the second stage, when the secondary units (households) were randomly selected. In the "Health of the Criciúma population" study, 77 out of 306 census sectors of Criciúma were randomly selected. The number of households was sampled proportionally to sector size and visits were made to 618 households systematically selected within the census sectors. All individuals aged 18 years old or older, living in the selected households, were invited to take part in the study, in a total of 820 individuals interviewed in this study.

The sampling process of "Mental Covid" was quite similar to the one used in the "Health of the Criciúma population": a total of 60 census tracts were randomly selected, resulting in 15,765 households. The number of households was sampled proportionally to sector size, in a total of 607 households systematically selected within the census sectors. All adults living in the selected households were invited to participate, resulting in 863 individuals included in this study.

In both studies, the interviews were conducted by previously trained personnel, and in the "Mental Covid", all interviewers worn personal protective equipment during the fieldwork to avoid SARS-CoV-2 infection. The questionnaires used in both studies were applied face to face in home interviews to those who had consented to participate in the study and had signed the informed consent. It was a single, precoded, and standardized questionnaire that collected information on mental health symptoms, behaviors amid the pandemic, quality of life, nutrition, physical activity, and chronic diseases. Application of the questionnaire lasted 30 min, on average.

2.2. Mental health symptoms

The mental health symptoms used in this study were major depressive episode (MDE) and perceived stress. The Patient Health Questionnaire (PHQ-9) was applied for assessing MDE, which is used for screening MDE and has been validated for the Brazilian population [22]. The PHQ-9 consists of nine questions that assess the presence of the symptoms of MDE. The nine symptoms are depressed mood, anhedonia (loss of interest or pleasure in doing things), problems with sleep, tiredness or lack of energy, change in appetite or weight, feelings of guilt or worthlessness, concentration problems, feeling slow or restless, and suicidal thoughts. The frequency of each symptom in the two weeks before the interview was evaluated on a Likert-type scale from 0 to 3 corresponding to "never", "less than once a week", "once a week or more" and "almost every day", respectively. When the answers provided were "once a week or more (2 points)" or "almost every day (3 points)", the item/question was considered to have a positive response, except for symptom 9 (suicidal thoughts), for which any value other than zero was coded as positive.

To define positive screening for MDE, the cut-off point of $\geq$9 proposed by Santos et al. [22] was used. This cut-off presented high sensitivity and specificity and have already been used in previous population-based studies in Brazil [22–25].

Perceived stress was evaluated through the perceived stress scale (PSS), previously validated for the Brazilian population [23]. The PSS is a self-reported measure designed to deal with the degree to which situations in an individual's life are appraised as stressful. It was originally developed as a 14-item scale that assessed the perception of stressful experiences over the previous month using a Likert-type scale from 0 to 4, corresponding to the answers "never", "almost never", "sometimes", "fairly often", and "very often". The total score consisted of the sum of points, ranging from 0 (lower stress) to 56 points (higher stress). As there are no defined cut-offs to classify stress using the PSS questionnaire, we categorized the total score into quintiles and those individuals in the highest quintile (who presented the highest scores) were classified as having perceived stress.

2.3. Self-reported sleep duration and quality

Sleep was evaluated through self-reported sleep duration and quality. Sleep duration per day was determined through the following questions: "What time do you usually go to sleep during the week (Monday to Friday)?" and "What time do you usually wake up during

the week (Monday to Friday)?". Individuals with sleep duration between 7 and 8 h per day were classified with "adequate sleeping duration" and those whose sleep lasted less than 7 h or more than 9 h per day were classified with "inadequate sleeping duration" [11]. Sleep quality was self-reported through the question: "How do you consider the quality of your sleep to be like?" considering the following answers options: "very good", "good", "regular", "poor", and "very poor".

2.4. Sociodemographic, physical activity and nutritional characteristics

Socioeconomic, demographic, physical activity-related and nutritional characteristics were included in our analyses as covariables in order to control for potential confounders, as follows: sex (male/female), age (years), schooling (0–4/5–8/9–11/12 years or more), total monthly income in BRL (<500,00/500,00–1000,00/1001,00–2000,00/2001,00–4000,00/>4000,00), currently employed (yes/no), marital status (single/married/separated/widowed), physical activity (inactive (<150 min/week)/active (≥150 min/week)) [26], body mass index (in Kg/m^2), food intake (diet quality tertile) [27], and food insecurity (no/yes) [28,29].

2.5. Statistical analyses

Descriptive analysis was stratified for each study, presenting absolute and relative frequencies and its corresponding 95% confidence intervals (95% C.I.). Crude and adjusted analyses of the association between sleep (duration and quality) and mental health symptoms (MDE and stress) were performed using Poisson regression with robust variance, and they presented a *p*-value corresponding to the Wald test for heterogeneity, because analyses of cross-sectional studies with binary outcomes fit better when using Poisson than logistic regression [30]. Regression results were reported as prevalence ratio and its respective 95% C.I. Adjusted models were used to check whether significant associations were independent of possible confounders.

To define potential confounders, a hierarchical model of analysis was designed [31], and the variables were selected using the backward method, considering each hierarchical level. Those variables associated with both exposure and outcome at a 20% significance level (*p*-value <0.20) were considered confounders and remained in the final model. We used different adjusted models to analyze the association between sleep and mental health. In all analyses, the following variables were included as possible confounders: sex, age, schooling, income, working, marital status, physical activity, body mass index, food intake, and food insecurity. In the association between sleep quality and MDE, perceived stress and sleep duration were included as potential confounders because both stress and sleep duration can affect sleep quality and MDE. For the analysis of sleep quality and stress, sleep duration was included as a potential confounder as this variable is associated with sleep quality and stress. Finally, when we explored the associations while having sleep duration as exposure, the same logic was used - replacing sleep duration with sleep quality as confounder. All analyses were performed in STATA version 16.1.

2.6. Ethical aspects

All participants provided a written informed consent to participate in the study, and the projects were approved, respectively, by the Research Ethics Committee of the University of Southern Santa Catarina in December 2018 under CAAE 04033118.4.0000.0119, and by the National Research Ethics Committee in July 2020 under CAAE: 30955120.0.0000.5324.

3. Results

A total of 820 (response rate of 86.1%) and 863 (response rate of 75.0%) individuals participated in the Health of the Criciúma population and the Mental Covid studies, respectively. Before the COVID-19 pandemic, most participants were female (63.8%) and 60 years old or more (45.0%), and more than half had 8 years of schooling or less (53.6%). In addition, the majority of participants were overweight or obese (57.3%) and physically inactive (74.9%) (Table 1). During the COVID-19 pandemic, women (58.4%) and elderly people (29.7%) composed the majority of the sample. Less than a half had 8 years of schooling or less (46.4%). Moreover, most of the participants were overweight or obese (57.6%) and physically inactive (76.4%) (Table 2). Comparing both surveys, we observed a decrease in the proportion of women, elderly and lower educated individuals in the sample of the Mental Covid study, the one which was carried out amid COVID-19 pandemic. No differences were observed for behavioral characteristics like physical activity, nutritional status and diet quality between the two surveys (Supplementary Table 1).

Regarding sleeping characteristics of the sample, before the COVID-19 pandemic, 52.4% (95%CI 49.0 to 55.8) of the individuals referred inadequate sleep duration and almost 20% considered their sleep quality to be poor or very poor (19.9%; 95%CI 17.1 to 22.6). In the Mental Covid study (during the pandemic), the prevalence of self-reported inadequate sleep duration decreased to 43.2% (95% CI 39.9 to 46.5), and there was a decrease in the prevalence of sleep quality classified as poor or very poor: 10.7% (95%CI 8.8 to 12.9) (Tables 1 and 2, and Supplementary Table 1).

The prevalence of MDE decreased from 29.2% (95%CI 26.02 to 32.3) in 2019 to 13.9% (95%CI 11.7 to 16.3) in 2020. Before the COVID-19 pandemic, prevalence of MDE was almost as twice as higher in women than in men (35.0% vs 18.8%; *p-value* < 0.001), more frequent in younger individuals (18–29 years old), singles, and in those who earned less than 500,00 BRL per month. Moreover, individuals who were physically inactive, had poor diet quality, and experienced household food insecurity also presented higher prevalence of MDE (Table 1). During the pandemic, MDE was about three times more frequent in females than males (18.5% vs 7.3%; *p-value* < 0.001). Individuals aged 40–49 years old, who earned less than 500,00 BRL per month, had poor diet quality, and who experienced household food insecurity also had a higher frequency of MDE (Table 2).

The prevalence of stress remained stable from 2019 to 2020 (35.8%; 95%CI 32.5 to 39.1 in 2019 and 37.5%; 95%CI 34.3; 40.8 in 2020). Before the pandemic, stress was more prevalent among the participants who were physically inactive, and who experienced household food insecurity. On the other hand, during the COVID-19 pandemic, women, individuals with less than 5 years of schooling, who earned 500,00 to 1000,00 BRL per month, and who had poor diet quality presented higher prevalence of stress (Tables 1 and 2).

Table 3 shows the association between sleep quality and mental health symptoms. In the crude model, sleep quality was associated with both depression and stress at both time-points, with the measures of association being a little higher in 2020. After adjustment for confounders, nevertheless, sleep quality remained associated with MDE in both studies: individuals with poor or very poor sleep quality presented higher risk of MDE when compared to those with good or very good sleep quality. Comparing both periods, there was an increase in the risk amid COVID-19 pandemic (from 114% in 2019 to 126% in 2020). Similar results were observed for the association between sleep quality and stress. In both 2019 and 2020 surveys, individuals who have reported regular or poor/very poor sleep quality presented higher prevalence of stress than those individuals who perceived their sleep quality as good or very good. Interesting to notice that the prevalence of stress was almost two times higher in those classified with poor or very poor sleep quality (Table 3).

When we assessed the association between sleep duration and mental disorders, significant associations were found only in the crude models at both time-points. Inadequate sleep duration was associated with higher risk of depression and stress before the pandemicas well as with higher risk of stress amid the COVID-19 outbreak. However, all the

Table 1
Characteristics of individuals and prevalence of mental health disorders according sociodemographic and behavioral variables. Health of the Criciúma population study. Criciúma, Santa Catarina, Brazil, 2019 ($n = 820$).

Variables	Total	Depression		Stress	
	n (%)	% (95CI)	*p* value*	% (95CI)	p value*
Sex			<0.001		0.004
Male	297 (36.2)	18.8 (14.2; 23.3)		32.2 (27.1; 37.8)	
Female	523 (63.8)	35.0 (30.1; 39.2)		42.6 (38.4; 47.0)	
Age group			0.001		<0.001[b]
18–29	101 (12.3)	41.6 (31.8; 51.4)		54.5 (44.5; 64.2)	
30–39	93 (11.3)	30.8 (21.1; 40.4)		51.6 (41.4; 61.7)	
40–49	85 (10.4)	34.9 (24.5; 45.4)		48.8 (38.0; 59.6)	
50–59	172 (21.0)	33.5 (26.4; 40.7)		39.3 (32.1; 46.9)	
≥60	369 (45.0)	21.8 (17.5; 26.2)		28.4 (23.9; 33.4)	
Schooling (years)			0.218		0.762
0–4	219 (26.7)	28.2 (22.1; 34.3)		38.2 (31.9; 45.0)	
5–8	220 (26.9)	34.6 (28.2; 41.0)		41.8 (35.3; 48.7)	
9–11	266 (32.5)	27.5 (22.0; 32.9)		37.1 (31.4; 43.1)	
≥12	114 (13.9)	25.0 (16.9; 33.1)		38.6 (30.0; 47.9)	
Income (BRL per month)			<0.001		<0.001[b]
<500,00	151 (19.0)	41.9 (33.8; 49.9)		52.7 (44.6; 60.7)	
500,00-1000,00	166 (20.9)	35.0 (27.6; 42.4)		41.4 (33.9; 49.3)	
1001,00-2000,00	248 (31.2)	29.8 (24.0; 35.6)		38.8 (32.8; 45.1)	
2001,00-4000,00	164 (20.6)	15.6 (9.9; 21.3)		29.4 (22.8; 36.9)	
>4000,00	66 (8.3)	18.5 (8.8; 28.2)		22.7 (14.1; 34.6)	
Marital status			0.009		0.132
Single	147 (17.9)	39.6 (31.5; 47.7)		45.6 (37.6; 53.7)	
Married	495 (60.4)	26.1 (22.2; 30.1)		38.4 (34.1; 42.8)	
Separated	77 (9.4)	34.2 (23.3; 45.1)		38.7 (28.2; 50.3)	
Widowed	101 (12.3)	25.0 (16.4; 33.6)		30.5 (22.0; 40.6)	
Overweight			0.087		0.095
No	333 (42.7)	25.2 (20.5; 30.0)		35.0 (30.0; 40.3)	
Yes	446 (57.3)	30.9 (26.5; 35.2)		40.9 (36.4; 45.7)	
Physical activity			<0.001		<0.001
Inactive	611 (74.9)	33.8 (30.0; 37.6)		44.3 (40.3; 48.3)	
Active	205 (25.1)	15.8 (10.8; 20.9)		22.8 (17.5; 29.3)	
Diet quality (tertile)			0.003[b]		<0.001[b]
1 (best)	287 (35.3)	24.3 (19.2; 29.3)		28.6 (23.6; 34.2)	
2	259 (31.8)	27.0 (21.5; 32.5)		41.1 (35.0; 47.3)	
3 (worst)	268 (32.9)	36.2 (30.4; 42.1)		47.5 (41.5; 53.6)	
Food security[a]			<0.001		<0.001
No	417 (74.2)	20.9 (17.0; 24.9)		31.1 (26.8; 35.8)	
Yes	145 (25.8)	41.4 (31.5; 51.3)		47.0 (37.3; 56.9)	
Sleep duration			<0.001		0.001
Adequate	389 (47.6)	22.3 (18.1; 26.4)		33.0 (28.4; 37.9)	
Inadequate	428 (52.4)	35.5 (30.9; 40.1)		44.2 (39.4; 49.0)	
Sleep quality			<0.001[b]		<0.001[b]
Very good/ good	425 (51.8)	18.7 (14.9; 22.4)		26.9 (22.8; 31.4)	
Regular	232 (28.3)	30.2 (24.2; 36.3)		47.3 (40.8; 53.9)	
Poor/very poor	163 (19.9)	55.3 (47.5; 63.2)		57.9 (50.0; 65.3)	
Total		**29.2 (26.02; 32.3)**		**38.8 (35.5; 42.1)**	

CI: confidence interval.
[a] Variable with highest number of missing data points.
[*] Chi square test.
[b] Chi square test for linear trend.

significant effects disappeared after adjustment for confounders included in the analyses (Table 4).

4. Discussion

Our study, which aimed to assess the association between sleep duration and quality and mental health symptoms before and amid the COVID-19 pandemic, using data from two population-based studies, indicated that only sleep quality presented significant associations with depression and stress. Our study also indicated that although there were no increases in the prevalence of mental health symptoms from 2019 to 2020, the magnitude of the association between sleep quality and mental health symptoms increased, since effect measures were a little higher in the second study, indicating that this association became stronger amid the COVID-19 pandemic.

In consonance with our results, the study from Osiogo et al. [18] found higher frequency of sleep disturbances during the COVID-19

Table 2
Characteristics of individuals and prevalence of mental health disorders according sociodemographic and behavioral variables. Mental Covid study. Criciúma, Santa Catarina, Brazil, 2020–2021. ($n = 863$).

Variables	Total	Depression		Stress	
	n (%)	% (95CI)	p value*	% (95CI)	p value*
Sex			<0.001		0.003
Male	359 (41.6)	7.3 (5.0; 10.5)		31.7 (27.1; 36.8)	
Female	504 (58.4)	18.5 (15.4; 22.2)		41.6 (37.3; 46.0)	
Age group			0.012		0.120
18–29	146 (16.9)	16.4 (11.2; 23.4)		43.8 (36.0; 52.0)	
30–39	138 (15.9)	13.0 (8.3; 19.8)		37.7 (29.9; 46.1)	
40–49	162 (18.8)	19.1 (13.8; 26.0)		40.7 (33.4; 48.5)	
50–59	161 (18.7)	16.1 (11.2; 22.7)		38.0 (30.7; 45.8)	
≥60	256 (29.7)	7.9 (5.2; 12.0)		31.3 (25.9; 37.4)	
Schooling (years)			0.970		0.006
0–4	186 (21.6)	16.7 (3.5; 52.4)		58.3 (27.8; 83.6)	
5–8	214 (24.8)	14.7 (10.1; 20.9)		39.1 (31.9; 46.7)	
9–11	265 (30.7)	13.6 (9.6; 18.9)		27.2 (21.6; 33.6)	
≥12	198 (22.9)	12.8 (9.3; 17.4)		41.1 (35.3; 47.2)	
Income (BRL per month)			0.011		0.019
<500,00	130 (20.9)	21.5 (15.3; 29.5)		48.5 (39.9; 57.1)	
500,00-1000,00	42 (6.8)	19.5 (9.9; 35.0)		58.5 (42.7; 72.8)	
1001,00-2000,00	241 (38.7)	13.7 (9.9; 18.7)		44.0 (37.8; 50.3)	
2001,00-4000,00	172 (27.7)	7.6 (4.4; 12.6)		37.4 (30.5; 45.0)	
>4000,00	37 (5.9)	13.5 (5.6; 29.3)		27.0 (14.9; 44.0)	
Marital status			0.103		0.153
Single	482 (55.8)	11.6 (9.0; 14.8)		36.8 (32.6; 41.2)	
Married	252 (29.2)	18.3 (13.9; 23.5)		42.2 (36.2; 48.5)	
Separated	48 (5.6)	12.5 (5.6; 25.6)		27.7 (16.6; 42.4)	
Widowed	81 (9.4)	14.3 (8.0; 24.2)		32.5 (22.8; 43.8)	
Overweight			0.406		0.341
No	339 (42.4)	12.7 (9.6; 16.7)		35.9 (30.9; 41.2)	
Yes	460 (57.6)	14.8 (11.8; 18.3)		39.2 (34.8; 43.8)	
Physical activity			0.055		0.562
Inactive	659 (76.4)	15.1 (12.6; 18.1)		38.0 (34.4; 41.8)	
Active	204 (23.6)	9.8 (6.4; 14.7)		35.8 (29.5; 42.6)	
Diet quality (tertile)			0.001		<0.001[b]
1 (best)	315 (36.5)	10.9 (7.9; 14.9)		30.9 (26.0; 36.2)	
2	297 (34.5)	10.8 (7.7; 14.9)		36.4 (31.1; 42.0)	
3 (worst)	250 (29.0)	20.9 (16.3; 26.4)		47.0 (40.8; 53.2)	
Food security[a]			0.044		0.335
No	677 (78.5)	12.6 (10.3; 15.3)		36.7 (33.1; 40.4)	
Yes	186 (21.5)	18.4 (13.4; 24.7)		40.5 (33.7; 47.8)	
Sleep duration			0.853		0.197
Adequate	488 (56.8)	14.0 (11.2; 17.4)		35.5 (31.3; 39.8)	
Inadequate	371 (43.2)	13.6 (10.4; 17.4)		39.8 (34.9; 44.9)	
Sleep quality			<0.001[b]		<0.001[b]
Very good/ Good	614 (71.1)	8.2 (6.3; 10.6)		31.5 (27.9; 35.3)	
Regular	157 (18.2)	15.4 (10.5; 22.0)		47.1 (39.3; 55.0)	
Poor/Very poor	92 (10.7)	48.9 (38.8; 59.2)		61.5 (51.0; 71.1)	
Total		**13.9 (11.7; 16.3)**		**37.5 (34.3; 40.8)**	

CI: confidence interval.
[a] Variable with highest number of missing data points.
[*] Chi square test.
[b] Chi square test for linear trend.

pandemic between individuals with stress, while Stanton et al. [19] found that negative changes in sleep quality and/or duration were associated with higher risk of depression and stress. Nevertheless, the effect measures observed in our study were higher than those effects observed by Stanton et al. [19], indicating that the risk for mental disorders in those with poor sleep quality was even greater in Brazil. Importantly, these above-mentioned studies were conducted in high-income countries, and our results showed that the association between sleep and mental disorders was also found in a middle-income country, namely Brazil.

We know that major depressive disorders involve several alterations, including decreased monoaminergic neurotransmitters (including serotonin), decreased neurotrophic factors (including brain-derived neurotrophic factor (BDNF)), increased inflammation, alteration in microbiota-gut-brain axis, and deregulation in the hypothalamic-pituitary-adrenal (HPA) axis [32–35]. The HPA axis is pivotal to understanding the neurobiology of stress response. The activation of the HPA axis is initiated by the hypothalamic release of corticotropin-releasing hormone (CRH), which stimulates the anterior pituitary to secrete the adrenocorticotropin hormone (ACTH), which in turn triggers the adrenal cortex to release cortisol into the bloodstream [36]. On the other hand, sleep has an inhibitory influence on the HPA axis. In line with this fact, decrements in sleep quality potentiate the stress reactivity of the HPA axis [37].

A systematic review and meta-analysis of cohort studies evidenced that sleep disturbance was associated with higher inflammatory markers [38]. Interestingly, inflammation is not only associated with depression and stress disorder, but it can also play an important role in their pathophysiology [39,40]. An increase in inflammation can increase kynurenine pathways and decrease serotonin, which are important factors associated with the pathophysiology of depression [41].

Moreover, sleep quality and duration can affect gut microbiota composition [42]. The microbiota-gut-brain axis is a bidirectional communication system that can influence several neurological diseases [35]. Notably, depressive individuals have significant changes in gut microbiota composition [43]. A growing body of evidence has also suggested that sleep disturbances can alter BDNF levels, and this alteration plays a key role in the pathophysiology of stress-related mood disorders [44]. Indeed, lower serum BDNF levels and the BDNF Val66-Met polymorphism is associated with sleep patterns [45], stress, and depression [46,47].

The association between sleep and mental health amid the COVID-19 outbreak, reported in this study and in other publications [17–19], has demonstrated how the impact of the pandemic is multiple for the public health [48]. During the pandemic, risk factors for mental disorders that

Table 3
Crude and adjusted analysis of the association between sleep quality and mental health disorders in adults aged 18 years or older. Criciúma, Santa Catarina, Brazil, 2019–2021.

Sleep quality	Before COVID-19 pandemic				During COVID-19 pandemic			
	Crude analyses		Adjusted analyses		Crude analyses		Adjusted analyses	
	PR (95%CI)	p value	PR (95%CI)	p value	PR (95%CI)	p value	PR (95%CI)	p value
Outcome: Depression[a]		<0.001[c]		<0.001[c]		<0.001[c]		<0.001[c]
Very good/Good	Reference		Reference		Reference		Reference	
Regular	1.62 (1.22; 2.15)		1.26 (0.84; 1.89)		1.88 (1.19; 2.96)		1.46 (0.95; 2.23)	
Poor/Very poor	2.97 (2.32; 3.79)		2.14 (1.48; 3.09)		5.98 (4.26; 8.38)		2.26 (1.49; 3.40)	
Outcome: Stress[b]		<0.001[c]		<0.001[c]		<0.001[c]		<0.001[c]
Very good/Good	Reference		Reference		Reference		Reference	
Regular	1.76 (1.42; 2.17)		1.69 (1.25; 2.27)		1.50 (1.22; 1.83)		1.41 (1.14; 1.74)	
Poor/Very poor	2.15 (1.75; 2.65)		1.90 (1.42; 2.55)		1.96 (1.60; 2.39)		1.66 (1.34; 2.07)	

[a] Adjusted for sex, age, schooling, income, working, marital status, perceived stress, physical activity, body mass index, food intake, food insecurity, and sleep duration.
[b] Adjusted for sex, age, schooling, income, working, marital status, physical activity, body mass index, food intake, food insecurity, and sleep duration.
[c] Wald test for linear trend.

Table 4
Crude and adjusted analysis of association between sleep duration and mental health disorders in adults aged 18 years or older in Criciúma, Santa Catarina, Brazil, 2019–2021.

Sleep duration	Before COVID-19 pandemic				During COVID-19 pandemic			
	Crude analyses		Adjusted analyses		Crude analyses		Adjusted analyses	
	PR (95%CI)	p value	PR (95%CI)	p value	PR (95%CI)	p value	PR (95%CI)	p value
Outcome: Depression[a]		<0.001		0.286		0.853		0.949
Adequate	Reference		Reference		Reference		Reference	
Inadequate	1.60 (1.27; 2.00)		1.19 (0.87; 1.63)		0.97 (0.69; 1.36)		1.01 (0.71; 1.45)	
Outcome: Stress[b]		0.001		0.054		0.035		0.629
Adequate	Reference		Reference		Reference		Reference	
Inadequate	1.34 (1.12; 1.60)		1.28 (0.99; 1.64)		1.36 (1.02; 1.80)		1.04 (0.87; 1.25)	

[a] Adjusted for sex, age, schooling, working, income, marital status, perceived stress, physical activity, body mass index, food intake, food insecurity, and sleep quality.
[b] Adjusted for sex, age, schooling, working, income, marital status, physical activity, body mass index, food intake, food insecurity, and sleep quality.

already existed began to be accompanied by many pandemic stressors, such as social restriction, economic changes, domestic violence, and fear of contamination, among others [48]. Sleep is also normally influenced by multiple determinant factors, including environment; public policies; social, economic, racial, cultural, behaviors; and genetic characteristics, for example [49], many of which are also affected by the pandemic. Therefore our results, along with those of other published studies, claim a necessity of global health interventions to mitigate the impacts of this association [19,49].

The reduction in the prevalence of MDE and the increase in the prevalence of adequate sleep duration and very good or good sleep quality are other interesting results of our study. But although our results show alleged improvements in sleep and mental health amid the COVID-19 pandemic, the association between sleep and mental health became stronger. This intensification in the analyzed association is another critical situation at a vulnerable time for Brazil, since the country has been going through a series of weaknesses in public health [7]. Therefore, it is extremely important and urgent to support interventions that promote coping strategies and help improve the population's mental health during this moment.

Deterioration in mental health during this time is also associated with the level and form of measures adopted in public health to contain the dissemination of COVID-19. Higher restrictions, such as lockdown, social isolation, and big changes in daily life were negatively related to mental health, contributing to anxiety, depression, stress, and lower life satisfaction [50]. In Brazil, mitigation measures to contain the novel coronavirus have been weak so far [8], and this can explain our results for a decrease in the prevalence of MDE, since part of the population may have not felt the major changes in their lives occasioned by the novel coronavirus pandemic.

The cross-sectional design can be considered a limitation of our study, since it does not establish whether the observed associations are causal. The findings may be subject to reverse causality bias and should be interpreted with caution. Another limitation is the method used to assess MDE: the PHQ-9 is a scale for screening but cannot be used as a diagnostic tool. However, diagnostic interviews are not feasible in a population-based study, mainly amid the pandemic. In addition, the PHQ-9 is easy and quick to apply, and it has been widely used in previous epidemiological studies [22,25,51].

Sleep quality and duration were self-reported and not directly measured, which can be considered another limitation of our study. Nevertheless, self-reported sleep duration and quality have already been used in other epidemiological studies [11,17,19] and have demonstrated moderate correlations with objectively measured sleep information [52,53]. Besides, adequate sleep duration is an individual parameter and the existing cut-off points for its evaluation are based in sleep patterns found at population-level, not representing the individual's needs [54]. Sleep deprivation would be a more appropriate variable for this investigation, since is a more specific factor related to physical and mental health outcomes [55]. But, unfortunately, this variable was not included in the study questionnaire. A last limitation important to be pointed out is the existence of a selection bias in the samples analyzed, since the studied individuals were not the same in 2019 and 2020, not allowing us to exclusively attribute the results to the COVID-19 pandemic.

On the other hand, two population-based surveys that studied the same target population can be considered a strength of our study. In addition, data collection from both studies was carried out face to face, which can be considered a differential when compared to most studies performed amid COVID-19 pandemic that used online questionnaires.

In conclusion, our study showed that sleep quality was associated to MDE and stress. In addition, the COVID-19 pandemic seems to have had an influence on this association, since effect measures for the observed associations were a little higher amid the outbreak, mainly when MDE was used as the outcome. This finding shows how COVID-19 is affecting mental health in Brazil, and it also contributes to the construction of evidence for the creation of coping actions for this critical moment.

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Declaration of Competing Interest

The authors have no competing interests to report.

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