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## Original Article

# The mediation role of sleep quality in the association between the incidence of unhealthy movement behaviors during the COVID-19 quarantine and mental health



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## ABSTRACT

**Background:** Our aim was to investigate the mediating role of worsening sleep quality in the association of the incidence of physical inactivity, high TV-viewing, and high computer/tablet use with loneliness, sadness, and anxiety.

**Methods:** Data of 45,161 Brazilian adults from a nationwide behavior survey, conducted between April 24th and May 24th (2020), were used. Participants reported physical inactivity (PI; <150 min/week), high TV-viewing (TV; ≥4 h/day), and high computer/tablet use (PC; ≥4 h/day) before and during COVID-19 quarantine (exposures). For incidence indicators, we only considered participants without the risk behavior before quarantine. Changes in sleep quality during the quarantine period (maintained/got better or worsened) were treated as a mediator. Elevated frequencies of feelings of loneliness, sadness (feel sad, crestfallen, or depressed), and anxiety (feel worried, anxious, or nervous) during the pandemic period were the study outcomes. Analyses were adjusted for sex, age group, highest academic achievement, working status during quarantine, skin color, previous diagnosis of depression, and adherence to quarantine. Mediation models were created using the Karlson Holm Breen method.

**Results:** The incidence of PI, high TV, and high PC use were associated with loneliness, sadness, and anxiety feelings. Worsening sleep quality partly mediated the association of the incidence of PI, high TV, and high PC use with loneliness (PI:30.9%; TV:19.6%; PC: 30.5%), sadness (PI:29.8%; TV:29.3%; PC: 39.1%), and anxiety (PI:21.9%; TV:30.0%; PC:38.5%).

**Conclusion:** The association of the incidence of physical inactivity and sedentary behaviors with mental health indicators is partly mediated by worsening sleep quality during the COVID-19 pandemic quarantine.

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## 1. Introduction

The new coronavirus (COVID-19) spread quickly worldwide and reached Brazil in February (2020). To contain the COVID-19, social isolation measures such as quarantine are recommended [1].

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Although beneficial for containing COVID-19, quarantine measures frequently affect other health risk factors, leading to an increase in the adoption of unhealthy behaviors, especially those related to human movement behaviors (physical activity and sedentary behaviors), as well as affecting sleep and mental health indicators [2–4]. Previous studies in China and Italy reported that the pandemic affected different indicators of mental health, including well-being and psychological distress as well as increasing symptoms of depression and anxiety [2–7]. Similarly, sleep quality was highly affected by the COVID-19 pandemic [2,5], especially in the areas most affected by COVID-19 [5].

Before the COVID-19 pandemic, physical inactivity and sedentary behaviors were associated with both lower sleep quality and lower mental health indicators [8–12]. Therefore, considering the COVID-19 pandemic quarantine scenario, beyond the negative effects of quarantine itself on sleep quality and mental health [2,3,13], the reductions in physical activity and increased sedentary behaviors could be associated with a greater degree of negative effects. For example, previous findings from Austria and the UK showed that lower physical activity practice during the COVID-19 quarantine was associated with lower well-being, symptoms of depression, anxiety, and insomnia [14,15]. However, the association between the incidence of unhealthy movement behaviors with mental health, as well as the role of worsening sleep quality in this association, remain unknown.

In this sense, cross-sectional and prospective studies found that sleep quality can mediate the association between movement behaviors (especially sedentary behavior) and mental health indicators [16–18]. Therefore, the reductions in physical activity practice and increased sedentary behavior during COVID-19 quarantine can affect sleep quality, which, in turn, can be associated with poorer mental health. Thus, we investigate the mediating role of worsening sleep quality in the association of the incidence of physical inactivity, high TV-viewing, and high computer/tablet use with loneliness, sadness, and anxiety.

## 2. Methods

### 2.1. Sample

This was a national cross-sectional health survey, with retrospective information. Data collection was conducted between April 24th and May 24th, 2020. Participants were invited through a chain sampling procedure. In the first stage, the 15 researchers involved in the study chose a total of 200 other researchers from different states in Brazil. Next, each one of the 200 researchers chose 20 people from their social network, making a total of 4000 people chosen. The people chosen in the first stage were called the seeds of the chain recruitment. These seeds sent the survey link to at least 12 people from their social networks, obeying a stratification by sex, age range (18–39; 40–59; 60+), and educational level (incomplete high school or less; complete high school or more). In addition, information about the survey was circulated through press releases, social communications from participating research institutions, state health departments, and social media. All procedures were approved by the National Research Ethics Commission (CONEP) (process: 30598320.1.0000.5241). The total sample was composed of 45,161 participants. The sample was weighted according to characteristics from the National Household Sample Survey (2019), considering the population of each state, education, age, sex, and prevalence of chronic diseases, aiming to recruit a nationally representative sample.

### 2.2. Physical activity and sedentary behavior

For physical activity, participants were asked “Before the COVID-19 pandemic, how many days a week did you practice any type of physical exercise or sport? (do not consider physical therapy)” and “During the COVID-19 pandemic how many days a week do you practice any type of physical exercise or sport? (do not consider physical therapy)”. Possible answers were: 1) less than 1 day/week; 2) 1–2 days/week; 3) 3–4 days/week; or 4) 5 or more days/week. For those reporting physical activity practice, we also asked: “How long does this activity last?”. Possible answers were: 1) less than 30 min; 2) 30–45 min; 3) 46–60 min; or 4) more than 1 h. We defined “before the pandemic” as before the initial restraint

measures adopted in Brazil, in the middle of March and “during the pandemic”, as the period in which the participants were completing the questionnaire. We classified physical inactivity using the recommendation of 150 min/week [19]. For our analysis purpose, we created an incidence indicator of physical inactivity, only considering participants who were active before quarantine (those that remained physically active vs. those that became physically inactive during quarantine).

For TV-viewing, participants were asked: “Usually, before the pandemic, how many hours a day did you use to spend watching television?” and “During the pandemic, how many hours a day have you been watching television?”. Possible answers for both were 1) none; 2) less than 1 h/day; 3) between 1 and less than 2 h/day; 4) between 2 and less than 3 h/day; 5) between 3 and less than 4 h/day; 6) between 4 and less than 5 h/day; 7) between 5 and less than 6 h/day; 8) 6 h/day or more. In addition, computer/tablet use was assessed using two questions “Usually, before the pandemic, how many hours a day did you use to spend using a computer or tablet?” and “During the pandemic, how many hours a day do you usually spend using a computer or tablet?” with open answers. TV-viewing and computer/tablet use were classified using the cut-off point of 4 h/day at both moments (before and during quarantine). For our analysis purposes, we considered only TV-viewing and computer/tablet incidence, calculated as: those without high TV-viewing or high computer/tablet use before quarantine (those who maintained low TV-viewing/computer use vs. those who changed to present high TV-viewing/computer use during quarantine).

### 2.3. Worsening sleep quality

Worsening sleep quality was assessed through the question “Has the pandemic affected the quality of your sleep?”, with the possible answers: 1) “It has not affected anything, I still sleep well”, 2) “With the pandemic, I have started having sleep problems”, 3) “I already had sleep problems and they have persisted during the pandemic”, 4) “I already had sleep problems and they have got worse”, or 5) “I already had sleep problems, but they have decreased”. We considered as worsening sleep quality those who reported starting to present sleep problems during the pandemic and those reporting worsening in sleep problems.

### 2.4. Mental health

As mental health indicators, we adopted three questions regarding feelings of loneliness, sadness, and anxiety only during the pandemic. The difference from the behavioral dimensions assessed is explained by the fact that physiological variables are less stable and more difficult to recall [20,21]. For loneliness, participants were asked: “During the pandemic period, how often have you felt isolated or alone?”, for sadness: “During the pandemic period, how often have you felt sad, crestfallen, or depressed?” and for anxiety, participants were asked “In the period of the pandemic, how often have you felt worried, anxious, or nervous?”. Possible answers for each question were: 1) “Never”, 2) “a few times”, 3) “Often”, or 4) “Always”. We classified as positive for loneliness, sadness, and anxiety those participants who answered “often” or “always”.

### 2.5. Covariates

We used sex, age group, highest academic achievement, working status during quarantine, skin color and adherence to quarantine as covariates. The highest academic achievement was classified as incomplete high school, complete high school, and college education or more. Working status during quarantine was classified as currently not working, working in a normal routine, and home

office. Skin color was classified as white or other. Adherence to quarantine was classified as positive for those only going to grocery stores and pharmacies or staying strictly at home, leaving only for health care needs; and negative for those reporting that they continued a normal life or tried to stay away from people, reducing contact a little, not visiting the elderly, but carrying on working and leaving home as usual.

### 2.6. Statistical procedures

We used values of weighted frequencies and 95% confidence intervals for descriptive statistics and non-crossed 95% confidence intervals as an indicative of differences between groups [22]. Mediation analysis was conducted to assess the influence of worsening sleep quality on the associations of the incidence of physical inactivity, high TV-viewing, and high computer/tablet use (those that began to present the risk behavior during quarantine) with mental health indicators. The association between exposures and the mediator was assessed using crude and adjusted logistic regression models. The Karlson Holm Breen method was used for the mediation [23]. This method was applied using logistic regression models and decomposes the total effect (without the mediator effect) of a variable into direct (the direct association of the incidence of physical inactivity, high TV-viewing, and high computer/tablet use with mental health indicators, accounting for a potential mediator effect - worsening sleep quality) and indirect effects (the mediation effect). This estimation also provides the percentage of explanation by the mediator (mediated percentage). We previously tested for potential exposure × mediator interactions, which were not significant [24]. The theoretical mediation model for analysis is presented in Fig. 1. All analyses were conducted in STATA 15.1.

### 3. Results

Due to missing data and after excluding participants with unhealthy behaviors for the incidence indicators before COVID-19 pandemic quarantine, 16,059 individuals composed the sample for the incidence of physical inactivity, 40,903 composed the sample for the incidence of high TV-viewing, and 20,752 for the

incidence of high computer/tablet use. Characteristics of the sample are presented in Table 1. Participants who reported worsened sleep quality, and felt loneliness, sadness, and anxiety were more frequent within the incidence of physical inactivity, TV-viewing, and computer/tablet use groups.

Table 2 shows the association between the exposures (incidence of unhealthy movement behaviors) and the mediator (worsening sleep quality). In the adjusted models, the incidences of physical inactivity (OR: 1.51; 95%CI: 1.18–1.94), high TV-viewing (OR: 1.63; 95%CI: 1.42–1.87), and high computer/tablet use (OR: 1.91; 95%CI: 1.61–2.27) were associated with higher odds of worsening sleep quality.

The mediation models of the influence of worsening sleep quality in the association between the incidence of unhealthy movement behaviors and mental health indicators are presented in Table 3. The incidences of physical inactivity, high TV-viewing, and high computer/tablet use were associated with loneliness, sadness, and anxiety feelings. In addition, worsening sleep quality mediated part of the association of the incidence of physical inactivity, high TV-viewing, and high computer/tablet use with loneliness, sadness, and anxiety, with a higher mediation effect for the incidence of high computer/tablet use.

### 4. Discussion

We aimed to investigate whether changes in sleep quality mediate the associations between the incidence of unhealthy movement behaviors and mental health during COVID-19 quarantine. Our main finding was that worsening sleep quality mediated part of the associations of the incidences of physical inactivity, high TV-viewing, and high computer/tablet use and mental health. In addition, the mediation effect was higher for the association of the incidence of high computer/tablet use with sadness and anxiety.

The COVID-19 pandemic quarantine measures have promoted several changes in movement behaviors in different countries, reducing physical activity levels and increasing sedentary behavior [25]. In addition, quarantine measures were associated with higher psychological distress, lower mental health indicators, and sleep disturbances [2,13]. Considering the times before the COVID-19

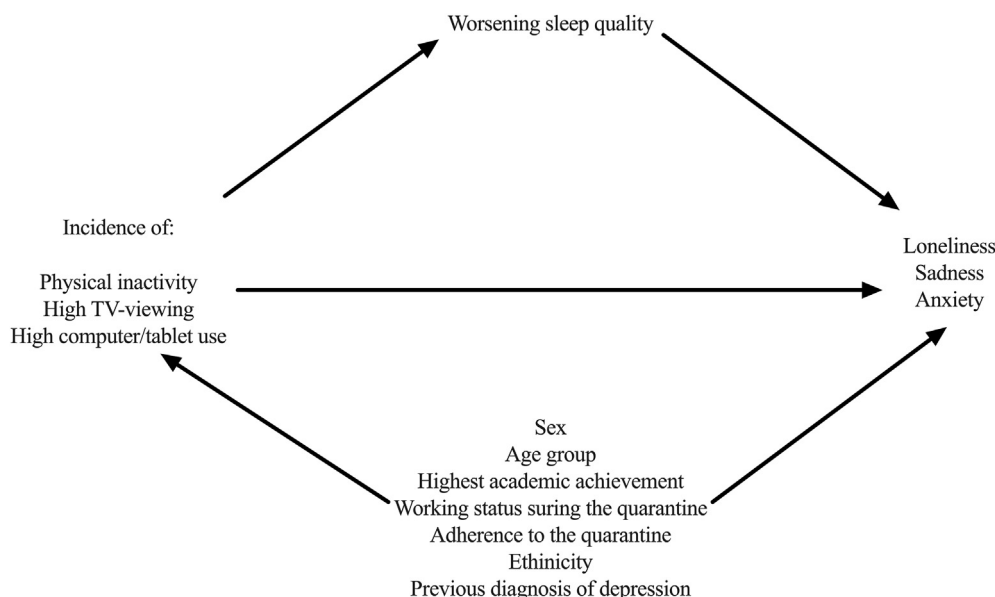


Fig. 1. Theoretical model.

**Table 1**  
Characteristics of the sample.

	Physical inactivity incidence (n = 16,059)		TV-viewing incidence (n = 40,903)		Computer/tablet use incidence (n = 20,752)	
	No (n = 4803)	Yes (n = 11,256)*	No (n = 28,575)	Yes (n = 12,328)	No (n = 11,365)	Yes (n = 9387)
Sex (male)	57.4 (52.8–61.8)	48.3 (45.2–51.4)*	48.3 (46.4–50.2)	42.6 (40.0–45.4)*	40.3 (37.7–43.0)	43.3 (39.9–46.7)
Age group						
18–39	39.0 (34.5–43.8)	52.7 (49.6–55.7)*	49.5 (47.6–51.3)	46.9 (44.3–49.6)	33.9 (31.4–36.3)	51.3 (48.1–54.5)*
40–59	36.7 (32.3–41.4)	29.4 (26.9–32.0)*	32.3 (30.6–34.0)	36.1 (33.7–38.6)	38.1 (35.7–40.6)	32.7 (29.9–35.7)
60 +	24.2 (19.9–29.1)	17.9 (15.4–20.8)*	18.2 (16.8–19.8)	17.0 (15.0–19.1)	28.0 (25.7–30.5)	16.0 (13.9–18.3)*
<i>Highest academic achievement</i>						
No academic achievement or elementary school	9.7 (7.0–13.4)	6.8 (5.2–8.9)	9.7 (8.5–11.0)	10.1 (8.6–12.0)	17.4 (15.3–19.6)	8.5 (6.8–10.5)*
High school	69.1 (65.3–72.6)	71.0 (68.7–73.1)	72.0 (70.6–73.3)	73.9 (72.0–75.7)	72.6 (70.4–74.7)	75.7 (73.5–77.7)
More than high school	21.2 (19.1–23.4)	22.2 (20.8–23.7)	18.3 (17.6–19.1)	16.0 (15.1–16.9)	10.0 (9.5–10.6)	15.8 (14.8–17.0)*
<i>Working status during quarantine</i>						
No	53.4 (48.6–58.1)	55.8 (52.8–58.7)	49.4 (47.5–51.3)	62.5 (59.9–65.0)*	62.5 (59.9–64.9)	62.4 (59.1–65.6)
Normal routine	21.2 (17.5–25.6)	18.8 (16.6–21.3)	23.2 (21.7–24.8)	15.7 (13.5–18.1)*	25.6 (23.4–28.0)	16.8 (14.2–19.7)*
Home office	25.4 (21.8–29.4)	25.4 (23.1–27.8)	27.4 (25.8–29.0)	21.9 (20.0–23.9)*	11.9 (10.4–13.6)	20.9 (18.3–23.7)*
Ethnicity (non-white)	50.6 (45.8–55.4)	52.9 (49.9–55.8)	52.9 (51.0–54.7)	56.1 (53.6–58.5)	59.3 (56.9–61.6)	53.6 (50.6–56.7)*
Adherence to quarantine (yes)	71.1 (66.2–75.5)	75.9 (73.1–78.6)	71.5 (69.8–73.2)	79.4 (77.1–81.6)*	69.0 (66.6–71.4)	80.3 (77.7–82.7)*
Depression	9.6 (7.4–12.3)	12.7 (11.0–14.6)	14.5 (13.3–15.8)	15.8 (14.2–17.6)	13.0 (11.5–14.6)	14.6 (12.9–16.3)
Worsened sleep quality	33.6 (29.2–38.3)	47.0 (43.9–50.0)*	42.3 (40.5–44.1)	55.2 (52.5–57.8)*	38.2 (35.8–40.7)	55.1 (51.9–58.3)*
Loneliness	49.3 (44.5–54.1)	59.5 (56.5–62.4)*	53.5 (51.7–55.4)	65.5 (62.9–68.0)*	52.0 (49.5–54.6)	63.7 (60.6–66.7)*
Sadness	27.5 (23.6–31.8)	40.1 (37.2–43.1)*	37.0 (35.2–38.8)	49.6 (46.9–52.2)*	35.1 (32.8–37.6)	48.5 (45.3–51.7)*
Anxiety	37.4 (32.9–42.1)	55.8 (52.7–58.8)*	50.1 (48.2–51.9)	62.6 (60.0–65.1)*	44.5 (42.0–47.0)	61.0 (57.8–64.1)*

Note. Values are presented in frequencies and 95% confidence intervals. No or yes refers to the incidence or not of the risk behavior.

\*represents  $p < 0.05$ .

pandemic, movement behaviors were associated with mental health [8] as well as sleep quality [10,12] and sleep quality was prospectively associated with mental health [26]. In this sense, sleep quality could act as a mediator of the association between

**Table 2**  
Association of incidence of unhealthy movement behaviors with worsening sleep quality during the COVID-19 quarantine.

Incidence of unhealthy movement behaviors	OR (95%CI)
<b>Crude models</b>	
Physical inactivity	1.73 (1.36–2.20)
High TV-viewing	1.67 (1.46–1.91)
High computer/tablet use	1.95 (1.64–2.31)
<b>Adjusted models<sup>a</sup></b>	
Physical inactivity	1.51 (1.18–1.94)
High TV-viewing	1.63 (1.42–1.87)
High computer/tablet use	1.91 (1.61–2.27)

Note. Reference groups: Maintained physically active for physical inactivity analysis, maintained with low TV-viewing for TV-viewing analysis and maintained with low computer/tablet use for computer/tablet use analysis.

<sup>a</sup> Models are adjusted for sex, age group, highest academic achievement, working status during quarantine, ethnicity, previous diagnosis of depression, and adherence to quarantine.

**Table 3**  
Mediation of sleep quality changes in the association of incidence of unhealthy movement behaviors and mental health.

	Total effect OR (95%CI)	Direct effect OR (95%CI)	Indirect Effect OR (95%CI)	% mediated
<b>Loneliness</b>				
Incidence of physical inactivity	1.39 (1.11–1.75)	1.26 (1.01–1.58)	1.11 (1.04–1.18)	30.9
Incidence of high TV-viewing	1.62 (1.40–1.87)	1.47 (1.27–1.71)	1.10 (1.07–1.13)	19.6
Incidence of high computer/tablet use	1.48 (1.24–1.77)	1.31 (1.10–1.57)	1.13 (1.08–1.18)	30.5
<b>Sadness</b>				
Incidence of physical inactivity	1.56 (1.21–2.03)	1.37 (1.05–1.78)	1.14 (1.05–1.24)	29.8
Incidence of high TV-viewing	1.73 (1.49–2.00)	1.47 (1.27–1.71)	1.17 (1.12–1.23)	29.3
Incidence of high computer/tablet use	1.70 (1.39–2.06)	1.38 (1.14–1.67)	1.23 (1.16–1.31)	39.1
<b>Anxiety</b>				
Incidence of physical inactivity	1.94 (1.52–2.48)	1.68 (1.31–2.15)	1.16 (1.06–1.26)	21.9
Incidence of high TV-viewing	1.82 (1.56–2.13)	1.52 (1.30–1.78)	1.20 (1.14–1.26)	30.0
Incidence of high computer/tablet use	1.86 (1.52–2.27)	1.46 (1.20–1.79)	1.27 (1.18–1.36)	38.5

Note. Models are adjusted for sex, age group, highest academic achievement, working status during quarantine, ethnicity, previous diagnosis of depression, and adherence to quarantine. OR, odds ratio. CI, confidence interval.

movement behaviors and mental health [16–18]. Therefore, our findings agree with previous studies from before quarantine [16–18]. However, these results suggest that the association between the incidence of unhealthy movement behaviors and mental health can be mediated by worsening sleep quality even in relatively short periods of movement deprivation and quarantine.

Even though the specific mechanisms of the effect of sleep problems in the association between unhealthy movement behaviors and mental health were not specifically studied, there are several shared mechanisms. The associations of movement behaviors with sleep quality can occur through different mechanisms such as regulation of circadian rhythm, increased body temperature, improved physical fitness, changing melatonin release, and increasing the time spent outdoors in light exposure [27–29]. Furthermore, physical inactivity can be associated with disorders such as sleep apnea, which is associated with lower sleep quality [30]. Similarly, higher sedentary behavior, especially screen time can be associated with higher exposure to blue light, which can affect mechanisms related to melatonin release, which is detrimental to sleep quality [31]. In this sense, poorer sleep quality due to the incidence of unhealthy movement behaviors could explain part of the association of the incidence of



unhealthy movement behavior and mental health. In addition, the mediation can be explained by sharing some mechanisms, as poorer sleep quality can be associated with higher inflammation, which is associated with poorer mental health indicators [32–34].

We highlight that, to our knowledge, this is the first study to explore the mediation role of worsening sleep quality in the association of the incidence of physical inactivity, high TV-viewing, and high computer/tablet use with mental health during COVID-19 pandemic quarantine. Therefore, the promotion of physical activity practice and reduction in sedentary behavior, as recommended by the World Health Organization [35] could be an important strategy to mitigate part of the negative effect of COVID-19 quarantine on mental health. Furthermore, interventions aiming to improve mental health during COVID-19 quarantine should focus on movement behaviors and sleep quality in an integrated manner, as worsening sleep quality mediated part of the effect of the incidence of unhealthy movement behaviors on mental health indicators.

Some limitations should be considered for the interpretation of our findings. Firstly, the present study used a retrospective design for questions related to behaviors before quarantine, which could contain recall bias. Second, as this was a web-based survey, our sample contains a low representativity of people with low socioeconomic conditions as well as those without access to the internet, which may represent a bias even with a weighted sample. Third, the questionnaire only included questions about the leisure-time domain of physical activity, which is the most associated with mental health [36], but it is possible that reductions in other domains such as transport may also be negative for mental health. Fourth, the lack of standardized questionnaires for the exposures sleep quality and mental health indicators could limit the extrapolation of our findings. However, we present data from more than 40,000 Brazilian adults, weighted for a national representation of population distribution during the COVID-19 pandemic and we consider this as a strength.

Thus, the association of the incidence of high sedentary behaviors and physical inactivity with mental health indicators is partly mediated by worsening sleep quality during COVID-19 pandemic quarantine. Policies addressing the increase in unhealthy behaviors as well as sleep quality and mental health are important during quarantine, with physical activity representing an effective and affordable non-pharmacological option to improve sleep and mental health.

#### CRediT authorship contribution statement

**André O. Werneck:** Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Danilo R. Silva:** Conceptualization, Writing - original draft, Writing - review & editing, Visualization. **Deborah Carvalho Malta:** Methodology, Project administration, Writing - review & editing, Validation. **Margareth G. Lima:** Writing - review & editing, Validation. **Paulo R.B. Souza-Júnior:** Project administration, Investigation, Writing - review & editing, Validation. **Luiz O. Azevedo:** Project administration, Investigation, Writing - review & editing, Validation. **Marilisa B.A. Barros:** Methodology, Project administration, Writing - review & editing, Validation. **Célia L. Szwarcwald:** Supervision, Methodology, Project administration, Writing - review & editing, Validation.

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#### Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: <https://doi.org/10.1016/j.sleep.2020.09.021>.

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