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How did trends in sleep duration in 2020 compare to previous years and how did they vary by sex, race/ethnicity, and educational attainment?

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ABSTRACT

Recent evidence utilizing online samples indicates that sleep patterns were significantly altered during the initial months of the SARS-CoV-2 (COVID-19) pandemic/lockdown. However, it remains less clear how sleep duration changed in population-based samples, in the later months of 2020, and across subpopulations. Here we used a population-based sample to document sleep duration trends for the entire year of 2020, compared these trends to the previous years of 2013, 2014, 2016, and 2018, and systematically analyzed whether self-reported sleep duration patterns in 2020 varied by sex, race/ethnicity, and educational attainment. Data were from the Behavioral Risk Factor Surveillance System (n = 2,203,861) and focused on Americans aged 18 years and older. Respondents self-reported the hours of sleep they got in a 24-h period. We fit multinomial and linear regression models to predict the category of sleep duration (six or fewer hours, seven to eight h (base), and nine or more hours) and the raw reports of sleep duration, net of demographic, socioeconomic, and behavioral health covariates. Results revealed significant increases in sleep duration during the months directly after the COVID-19 lockdown (March and April in particular). However, these increases were short lived; reports of sleep duration reverted to historical levels by the Fall of 2020. We also found that the changes in sleep duration trends in 2020 were similar by sex, race/ethnicity, and educational attainment, cumulatively leading to little impact to disparities in sleep duration. In a dramatic, but brief, alteration of population-level sleep duration patterns, disparities in self-reported sleep duration remained intractable.

1. Introduction

Humans need sleep to function [1]. Sleep durations that constitute short sleep durations (i.e., six or fewer hours per 24-h period) are not only associated with decreased immune [2] and psychological functioning [3], but also are associated with increased risk of cardiometabolic conditions [4] and premature death [5]. Sleep durations that constitute long sleep duration (i.e., nine or more hours per 24-h period) may indicate an underlying health condition [6], but also are associated with increased risk of frailty [7] and death [8].

Salubrious sleep durations at the population-level are not only distributed in a manner that reflects social inequality [9,10] but can also be dramatically, and potentially unevenly, influenced by exogenous events. An increasingly robust body of research indicates that the initial lockdown in response to the SARS-CoV-2 (hereafter COVID-19) pandemic may have altered population-level sleep duration patterns, at least initially (discussed further below). Here we contribute to this research by utilizing a large population-based survey of more than two million American respondents to systematically analyze how self-reported sleep duration changed throughout the entire year of 2020 compared to previous years going back to 2013 and also examine whether shifting patterns during 2020 varied by sex, race/ethnicity, and educational attainment. Understanding secular trends in sleep duration has important implications for intervention and policy, as documenting trends can help to elucidate exposures that impede or

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improve population-level sleep.

Due to the lockdown that coincided with the emergence of the COVID-19 pandemic, researchers have been resourceful and nimble to gain access to high-quality sleep duration data, however this generally resulted in using data based on online sampling or via apps. These sampling designs have known biases relative to population-based research designs such as sampling participants mostly from urban areas in major global cities or those were more affluent and thus able to afford wearable sensors to capture their sleep data. In comparison to one to two years prior to the pandemic, these studies found that generally between March 2020 and May 2020, sleep duration abruptly increased (from 13.7 to 18.6 min), particularly on weekdays, bedtime shifted later, and variance of sleep duration within weeks decreased [11–13]. In contrast to the app-based studies, sleep duration data from the nationally representative National Health Interview Study collected before the pandemic were compared to a representative online survey collected during the pandemic. Minimal differences in average sleep duration were found but short and long sleep durations both increased in 2020 compared to 2018 [14].

The shifts in sleep duration patterns during the initial stages of the pandemic may have been unevenly experienced across the population. In the U.S., sleep duration remains stratified by social characteristics [9,10,15–17], yet the pandemic's economic and social impacts on society culminated in countervailing currents that make the influence of the pandemic and accompanying lockdowns on inequality in sleep duration based on gender, race/ethnicity, and educational attainment less clear. For instance, working aged women tended to sleep less than men prior to the pandemic, which likely results from their disproportionate share of household labor (e.g., child care), increased stressors, and gender discrimination broadly and in earnings in particular [15,18]. The pandemic may have exacerbated these trends as childcare burdens increased dramatically after daycares closed and schools transitioned online [19]. Alternatively, more American men were suddenly working from home or without work and could have more time to help with caregiving and household labor.

Sleep duration also varies by race/ethnicity. Black adults and Hispanic adults report significantly shorter sleep durations than non-Hispanic White adults [20]. In 2020, the pandemic disproportionately influenced non-Hispanic Black Americans and Hispanic Americans [21], including their insomnia [22]. Black Americans and Hispanic Americans who were more likely to work “frontline”, on-site jobs, and in service sectors that were economically decimated early in the pandemic [23]. The former may have contributed to less sleep opportunity, whereas the latter may have contributed to more sleep opportunity. Similarly, sleep is stratified by educational attainment, with Americans with more education sleeping significantly more [10,24]. Americans with more education were more likely to work from home and thus suddenly had more time to sleep [25]. In contrast, less educated Americans were more likely to work in subsectors of the economy that were devastated by the pandemic [26] and thus were more inclined to lose their job.

In sum, previous research has generally indicated that sleep duration increased in the U.S. and other developed countries soon after the global lockdown (i.e., March and April of 2020). We build on this important work in a few important ways. First, rather than comparing trends to the immediate year or years before, we go back to 2013, providing a multi-year foundation that can rule out idiosyncratic baseline comparisons, broader secular trends, random data fluctuations, and potential seasonal (e.g., daylight savings) differences in measurement of sleep [27–29]. Second, we use a large population-based survey in the U.S. that used generally consistent data collection procedures for each of the time periods of analysis (telephone calls) to document month-by-month differences for the entire 2020 rather than the period just after the lockdown. Third, we document if the trends within 2020 varied across sex, race/ethnicity, and educational attainment. Overall, we aim to provide a comprehensive documentation regarding trends in sleep duration within the whole 2020, how they compare to multiple previous years, and whether specific segments of the population were differentially influenced by the shifting secular sleep patterns.

2. Materials and methods

2.1. Data

The data for this investigation came from the Behavioral Risk Factor Surveillance System (BRFSS) (Center of Disease Control 2020). The BRFSS is a large population-based survey that utilizes telephone-based sampling of cellphones and landlines of non-institutionalized American adults aged 18+ in all 50 states, Washington DC, Guam, and Puerto Rico. Recent estimates from the American Community Survey suggest that 99% of American households have a telephone number, and thus telephone-based sampling has strong external validity [30]. Telephone numbers within a state are randomly dialed, in a manner that each household in that State has a similar probability of being sampled. All responses are self-reports and there are no proxy respondents. Data are then weighted to adjust for non-response, selection, and demographic characteristics.

While the BRFSS is designed to be representative of States, estimates of health outcomes correspond quite well with national level estimates from nationally representative data [31]. The BRFSS is conducted throughout the year and has large sample sizes within each month (see Supplemental Table 1), allowing researchers to utilize a population-based survey and track temporal trends with large samples. Notably, the BRFSS operated continually throughout the pandemic, including in the height of the lockdown of March ($n = 43{,}046$) and April of 2020 ($n = 34{,}680$). The data are publicly available and thus the project is exempt from IRB review.

We combined the 2013, 2014, 2016, 2018, and 2020 BRFSS files, utilizing these years as sleep duration was not collected among the entire sample in other years. Our sampling frame consisted of adults aged 18+ ($n = 2{,}279{,}828$). We also removed those who did not report sleep duration ($n = 40{,}053$), or those not interviewed in the specified years (35,914, e.g., those in the 2014 file who were interviewed early in 2015). This sampling protocol provided an analytical sample of 2,203,861 respondents or nearly 97% of the total respondents interviewed in the 2013, 2014, 2018, and 2020 files. We found that women, racial/ethnic minorities, and those with low levels of education were less likely to report their sleep duration. Reassuringly, just over 1% of respondents in any given month in 2020 had missing sleep duration, reducing the likelihood that these missing reports of sleep duration affected the substantive conclusions.

2.2. Measures

Respondents were asked how much sleep they get in a 24-h period, and they could respond between 1 and 24 h. Consistent with previous research and guidelines [20], we coded those who reported six or fewer hours as “short-sleep,” those who reported seven to eight h as “normal-sleep,” and those who reported nine or more hours as “long-sleep.” To gauge the sensitivity of our results, we additionally analyzed the continuous specification. Previous research has validated the sleep duration measure utilized in the BRFSS by comparing it to actigraphy and other measures of sleep, and found that the duration measure is a valid measure [32].

BRFSS interview year (2013 as reference) and month (January as reference) were categorical, but given the relative comparison to the reference year and month we also calculated absolute levels of short-sleep and the sleep duration (discussed further below). There were no missing data for the year or month of survey. We coded the sex of the respondent as a dichotomous variable with females coded as "0" and males coded as "1." In terms of race/ethnicity, we used the respondent reports that were coded as: non-Hispanic White (reference; hereafter White), non-Hispanic Black (hereafter Black), Hispanic, and non-Hispanic Other/multiracial (hereafter Other/multiracial). Educational attainment was coded as: "less than high school" (reference), "high school," "some college," and "college or more." Detailed information regarding the coding of all the covariates is provided in the supplemental materials.

2.3. Data analytic plan

We began by calculating weighted descriptive statistics of the percentage reporting short sleep and the reported sleep duration (transformed into HH:MM) for each month from the 2013, 2014, 2016, 2018, and 2020 surveys. We documented short sleep, as it is particularly deleterious in terms of health [5], to be consistent with previous trend research [20], and because we found generally little differences in long sleep throughout the study period. We also calculated the weighted descriptive statistics for all covariates and present them in Supplemental Table 1.

Given the polytomous nature and implications of sleep duration we fit a multinomial model [33] with normal (seven-eight hours) sleep duration as the base category compared to short (six or fewer hours) and long sleep (nine or more hours). These models included an interaction term between year of interview and month of interview to examine if the reports of sleep duration each month significantly varied across years. These interactions are important as they allow the examination of trends irrespective of seasonality or year to year fluctuations in sleep *per se*. In addition to the interaction term, this model accounted for demographic, socio-economic, and behavioral health covariates. We next implemented an identical procedure with a multiple regression model predicting the raw reports of sleep duration with an interaction term between month and year accounting for the covariates. We also calculated the absolute levels of short sleep duration and reported sleep duration. We present these changes visually, by implementing the margins command to calculate the predicted probability of reporting short sleep and the predicted value of sleep duration (transformed into HH:MM) with all covariates held at their mean value [34].

To examine if the trends varied by sex, race/ethnicity, and educational attainment we fit separate models with three-way interaction terms (see Supplemental Tables 2–4) including all covariates (e.g., sex was controlled for in the race/ethnicity interaction model). We present the results from 2020 from these models in the form of the predicted probability of reporting short sleep duration, from a model that included no other covariates (the substantive results with controls were similar, see Supplemental Tables 2-4). Missing data on covariates were handled with Stata's multiple imputation suite as 10 imputed datasets were created and then estimates across datasets were combined using Rubin's rule [35]. Unimputed results were similar to the imputed results.

3. Results

Table 1 provides the proportion of Americans who report short sleep duration each month as well as the calculated raw values of sleep duration reported by American adults by month and year. In the first month of the lockdown: March 2020, the proportion reporting short sleep decreased below 30.0% for the first time to 29.3% (95% CI [28.9%, 29.7%]), before decreasing to 28.7% (95% CI [28.3%, 29.2%]) in April of 2020. These decreases represent a 2.7% and 3.7% decrease compared to the respective month in 2018. A 3.7% decrease corresponds to approximately nearly eight to nine million fewer American adults reporting short sleep duration in April of 2020 compared to April of 2018 and represents a relatively similar amount relative to 2013. The raw reports of sleep duration were largely consistent. Beginning in March 2020 (7:07, 95% CI [7:06, 7:08]) reported sleep durations began to increase abruptly, further increasing in April (7:09, 95% CI [7:08, 7:10]) and May (7:08, 95% CI [7:07, 7:09]) and then reverting to traditionally observed levels in the Fall.

Table 2 provides the coefficients from multinomial and multiple regression models with an interaction term between month and year of interview predicting reported sleep duration. Before 2020 there were generally few significant interaction terms, about as many as would be expected by chance with an alpha level of 0.05. However, starting in March of 2020 significant month by year interaction terms were observed as there were significantly lower levels of reported short sleep in March, April, May, June, July, August, September, October, and November (given the comparison to January 2013, we present this graphically below). Consistently, the regression model predicting the raw reports of sleep duration indicated few differences in the interaction term before 2020. However, once again starting in March of 2020 respondents began reporting significantly higher levels of sleep duration and this pattern was similar in April, May, June, July, August, and September.

Fig. 1 provides the estimated predicted probability of reporting short sleep duration among Americans by month and year with the covariates held at their mean values. Starting in March of 2020 the percentage of Americans reporting short sleep duration decreased significantly, and stayed significantly lower through September of 2020, where after it reverted to levels consistent with previous years. Similarly, Fig. 2 provides the marginal predicted values of sleep duration (converted to HH:MM) by month and year with the covariates held at their mean values. While most of the years preceding 2020 were relatively similar in terms of reported sleep duration, starting in March and April of 2020 reported sleep duration increased significantly and remained elevated relative to the other years through September of 2020.

3.1. Sex, racial/ethnic, and educational differences

We next fit three-way interaction terms between year of interview, month of interview, and separate models for: sex, race/ethnicity, and educational attainment. The full results are presented in Supplemental Table 2 (sex), Supplemental Table 3 (race/ethnicity), and Supplemental Table 4 (educational attainment). We found little systematic evidence of sex differences in trends across years in general and within 2020 in particular. These results are also presented in Fig. 3A, where men's and women's sleep seemingly changed in concert with one another. Additionally, we found little evidence in racial/ethnic differences in trends within 2020. Fig. 3B consistently shows that the documented racial/ethnic disparities remained large and significant in 2020 and did not seem to change throughout 2020. Fig. 3C similarly indicates little changes in sleep disparities within 2020 by level of educational attainment. Taken together these results suggest that the significant shifts in reported sleep duration in 2020 were generally similar across sex, race/ethnicity, and educational attainment, resulting in little changes to sleep duration disparities.

Table 1
Self-Reported Short Sleep Duration and Mean Self-Reported Sleep Duration (HH:MM), Adults aged 18+, Behavioral Risk Factor Surveillance System, 2013, 2014, 2016, 2018, and 2020.

	Proportion Reporting Short Sleep (≤6 h per 24-h period) Duration														
	2013			2014			2016			2018			2020		
	%	95% CI		%	95% CI		%	95% CI		%	95% CI		%	95% CI	
January	32.0%	31.4%	32.5%	30.8%	30.3%	31.3%	30.9%	30.3%	31.6%	31.7%	31.0%	32.4%	31.3%	30.6%	32.0%
February	32.6%	32.1%	33.0%	30.7%	30.2%	31.2%	31.5%	31.0%	32.0%	31.2%	30.7%	31.7%	32.4%	31.9%	32.9%
March	33.1%	32.7%	33.6%	31.0%	30.5%	31.4%	31.4%	31.0%	31.9%	32.0%	31.5%	32.4%	29.3%	28.9%	29.7%
April	32.8%	32.4%	33.3%	31.0%	30.5%	31.4%	31.5%	31.1%	32.0%	32.4%	31.9%	32.8%	28.7%	28.3%	29.2%
May	33.1%	32.7%	33.6%	31.7%	31.2%	32.2%	31.5%	31.0%	31.9%	33.0%	32.5%	33.5%	29.3%	28.8%	29.7%
June	33.1%	32.6%	33.6%	32.0%	31.6%	32.5%	31.8%	31.4%	32.3%	32.9%	32.5%	33.4%	30.3%	29.8%	30.8%
July	33.1%	32.7%	33.6%	31.7%	31.2%	32.1%	32.3%	31.9%	32.8%	33.0%	32.5%	33.5%	30.4%	29.9%	30.9%
August	33.3%	32.8%	33.7%	31.4%	31.0%	31.9%	32.7%	32.2%	33.1%	32.8%	32.4%	33.3%	30.9%	30.4%	31.5%
September	33.4%	33.0%	33.9%	32.5%	32.0%	33.0%	32.7%	32.3%	33.2%	33.8%	33.3%	34.3%	31.7%	31.2%	32.3%
October	32.8%	32.4%	33.3%	31.7%	31.2%	32.1%	31.9%	31.4%	32.4%	34.0%	33.5%	34.4%	31.7%	31.1%	32.2%
November	32.0%	31.5%	32.4%	31.1%	30.7%	31.6%	32.1%	31.7%	32.5%	33.2%	32.7%	33.6%	30.8%	30.3%	31.2%
December	31.8%	31.3%	32.2%	32.4%	31.9%	32.9%	32.4%	31.9%	32.8%	33.5%	33.0%	34.0%	31.6%	31.1%	32.1%
	Mean Reported Sleep Duration (in HH:MM)														
	2013			2014			2016			2018			2020		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
January	7:04	7:03	7:05	7:05	7:04	7:06	7:04	7:03	7:06	7:04	7:03	7:06	7:06	7:04	7:07
February	7:02	7:02	7:03	7:05	7:04	7:06	7:04	7:03	7:05	7:03	7:03	7:04	7:03	7:02	7:04
March	7:01	7:01	7:02	7:04	7:04	7:05	7:03	7:02	7:04	7:03	7:02	7:04	7:07	7:06	7:08
April	7:02	7:02	7:03	7:04	7:03	7:05	7:03	7:02	7:04	7:03	7:02	7:04	7:09	7:08	7:10
May	7:02	7:01	7:03	7:03	7:02	7:04	7:03	7:02	7:04	7:01	7:00	7:02	7:08	7:07	7:09
June	7:03	7:02	7:04	7:03	7:02	7:04	7:03	7:02	7:03	7:02	7:01	7:03	7:05	7:04	7:06
July	7:02	7:01	7:03	7:03	7:02	7:04	7:02	7:01	7:03	7:01	7:00	7:01	7:05	7:04	7:06
August	7:02	7:01	7:03	7:03	7:02	7:03	7:02	7:01	7:03	7:02	7:01	7:03	7:04	7:03	7:05
September	7:01	7:00	7:02	7:01	7:01	7:02	7:02	7:01	7:02	7:00	6:59	7:01	7:03	7:02	7:04
October	7:02	7:02	7:03	7:03	7:02	7:04	7:03	7:02	7:04	6:59	6:59	7:00	7:04	7:03	7:05
November	7:03	7:03	7:04	7:04	7:03	7:05	7:03	7:03	7:04	7:01	7:00	7:02	7:05	7:04	7:06
December	7:05	7:04	7:05	7:02	7:01	7:03	7:02	7:01	7:03	7:01	7:00	7:02	7:04	7:04	7:05
N =	478,811			458,992			466,777			413,998			385,283		

Notes: CI = confidence interval. Behavioral Risk Factor Surveillance System. Data are weighted.

4. Discussion

In this study, we analyzed the BRFSS years of 2013, 2014, 2016, 2018, and 2020 collectively leading to a sample of more than 2 million Americans, to document secular sleep duration trends within and between years. In doing so, we paid close attention to how reported sleep duration shifted during the emergence of the COVID-19 pandemic and corresponding lockdown, while documenting sex, racial/ethnic, and educational differences in these trends. We contribute to previous research in three ways.

First, our results, at least substantively, replicated past findings using app data and online samples [11–13] with a population-based sample. In March and April of 2020, we found that reports of short sleep duration (six or fewer hours per 24-h period), decreased by about 4% compared to previous years. Based on our weighted sample size, this estimate corresponds to roughly eight to nine million fewer Americans reporting short sleep duration in April of 2020 than in April of 2018, and similar amounts compared to the other years where sleep patterns were generally consistent (e.g., about a 4% decrease in short sleep compared to 2013). This means that for the months immediately after lockdown, at least eight million fewer Americans than in previous years were sleeping short sleep durations associated with deleterious health outcomes [4] and risk of death [5]. Correspondingly, we observed significant *increases* in the raw reports of sleep duration through the Fall of 2020.

While our results substantively replicated past findings, the estimates did differ slightly as reported sleep duration increased by 3–7 min in March and April of 2020 (depending on the year of comparison), which is less than previous studies using smartphone data one of which estimating an 13.7 min increase in sleep duration in Western cities [13] and another estimating 11.3–18.6 min increases in Europe [11]. The discrepancy in the exact amount could be due to less accurate measurements (i.e., self-reports), the inclusion of rural Americans, Americans who do not use smart phones/track their sleep, or Americans who live in urban areas that did not as stringently enforce or adhere to the lockdown. That is, our sample is likely to include those whose lives may not have been as dramatically influenced by the lockdown as those who live in highly connected global cities. Accordingly, the population-based results we estimated were more conservative than previous studies. The varying influence of the lockdown on sleep patterns based on adherence to the lockdown remains an important area for subsequent research.

Even after accounting for demographic, socioeconomic, and behavioral health covariates, we were statistically unable to explain the increase in trends of sleep duration; however, we offer the following three potential explanations. First, many Americans had more time flexibility than ever as millions of Americans worked from home for the first time, had their schooling moved online, lost their jobs, or underwent some combination of these experiences. While losing a job can be incredibly stressful and past work has shown this has undermined sleep in 2020 [19], work too can be stressful and undermine sleep [36]. For many Americans, the lockdown represented the first real respite from the quotidian stressors of work. The millions of Americans who were suddenly not working for the first time in their adult lives had more time for sleep. In addition, the financial and unemployment stressors in 2020 were also at least somewhat buffered by the CARES act which provided enhanced jobless benefits and additional stimuli. Those

Table 2
Coefficients from Multinomial and Regression Models predicting Self-Reported Sleep Duration, American Adults aged 18+, Behavioral Risk Factor Surveillance System 2013, 2014, 2016, 2018, and 2020.

	Multinomial Models Predicting Categorical Sleep Duration						Regression Model Predicting Raw Sleep Duration		
	≤6 h. vs. 7–8 h (base)			≥9 h. vs. 7–8 h (base)					
	RRR	95% CI		RRR	95% CI		b	95% CI	
Year									
2013 (Reference)									
2014	**0.950**	**0.915**	**0.985**	0.969	0.913	1.028	0.019	−0.005	0.043
2016	0.967	0.928	1.009	0.942	0.881	1.007	−0.010	−0.036	0.017
2018	1.016	0.972	1.062	0.965	0.899	1.036	−0.015	−0.043	0.014
2020	1.032	0.989	1.077	1.040	0.972	1.112	−0.005	−0.033	0.022
Month									
January (Reference)									
February	1.012	0.978	1.046	0.974	0.922	1.028	**−0.024**	**−0.046**	**−0.002**
March	**1.035**	**1.001**	**1.070**	0.951	0.901	1.004	**−0.039**	**−0.061**	**−0.018**
April	**1.038**	**1.004**	**1.074**	0.996	0.944	1.052	**−0.024**	**−0.046**	**−0.003**
May	**1.058**	**1.023**	**1.095**	0.999	0.945	1.055	**−0.036**	**−0.058**	**−0.014**
June	**1.076**	**1.040**	**1.114**	1.021	0.966	1.079	**−0.026**	**−0.048**	**−0.004**
July	**1.072**	**1.036**	**1.108**	0.983	0.931	1.038	**−0.040**	**−0.062**	**−0.019**
August	**1.083**	**1.047**	**1.120**	1.010	0.957	1.067	**−0.034**	**−0.056**	**−0.012**
September	**1.078**	**1.041**	**1.115**	0.935	0.884	0.988	**−0.061**	**−0.083**	**−0.039**
October	**1.054**	**1.020**	**1.091**	0.956	0.905	1.009	**−0.037**	**−0.059**	**−0.016**
November	0.999	0.966	1.033	**0.937**	**0.888**	**0.990**	−0.017	−0.039	0.005
December	0.991	0.958	1.026	0.966	0.915	1.020	−0.002	−0.024	0.020
Year X Month									
2014 X February	0.997	0.949	1.046	1.007	0.932	1.090	0.006	−0.025	0.037
2014 X March	0.979	0.934	1.026	1.034	0.957	1.116	0.027	−0.003	0.058
2014 X April	0.991	0.944	1.040	0.977	0.903	1.056	−0.004	−0.035	0.027
2014 X May	1.007	0.959	1.057	0.966	0.893	1.046	−0.010	−0.041	0.021
2014 X June	1.013	0.965	1.064	0.968	0.894	1.047	−0.019	−0.051	0.012
2014 X July	1.007	0.959	1.056	0.992	0.918	1.073	−0.013	−0.044	0.018
2014 X August	0.988	0.942	1.037	**0.916**	**0.847**	**0.991**	−0.029	−0.060	0.002
2014 X September	1.044	0.994	1.096	1.024	0.945	1.109	−0.021	−0.053	0.010
2014 X October	1.021	0.972	1.071	1.007	0.931	1.089	−0.020	−0.051	0.011
2014 X November	1.048	0.998	1.099	1.041	0.963	1.126	−0.026	−0.057	0.005
2014 X December	**1.110**	**1.056**	**1.166**	1.034	0.955	1.120	**−0.059**	**−0.091**	**−0.027**
2016 X February	0.999	0.948	1.053	1.034	0.950	1.126	0.027	−0.007	0.060
2016 X March	0.981	0.932	1.033	1.032	0.949	1.123	0.033	−0.001	0.066
2016 X April	1.002	0.951	1.056	1.008	0.926	1.097	0.008	−0.026	0.041
2016 X May	0.984	0.934	1.036	1.001	0.921	1.089	0.016	−0.018	0.049
2016 X June	0.973	0.923	1.025	0.966	0.888	1.051	0.001	−0.033	0.034
2016 X July	1.002	0.952	1.054	0.992	0.912	1.078	0.001	−0.032	0.034
2016 X August	1.006	0.956	1.059	0.983	0.905	1.068	−0.004	−0.037	0.029
2016 X September	1.011	0.960	1.065	1.058	0.972	1.152	0.018	−0.015	0.052
2016 X October	1.025	0.972	1.079	1.039	0.954	1.131	0.006	−0.028	0.039
2016 X November	**1.088**	**1.033**	**1.145**	1.068	0.982	1.161	−0.014	−0.047	0.019
2016 X December	**1.087**	**1.032**	**1.145**	0.976	0.898	1.062	**−0.050**	**−0.083**	**−0.016**
2018 X February	0.952	0.902	1.005	0.959	0.878	1.047	0.018	−0.017	0.053
2018 X March	0.963	0.913	1.016	1.022	0.937	1.116	0.034	0.000	0.069
2018 X April	0.975	0.923	1.029	1.006	0.921	1.099	0.024	−0.011	0.059
2018 X May	0.982	0.930	1.038	0.945	0.864	1.033	−0.009	−0.045	0.026
2018 X June	0.979	0.927	1.034	0.976	0.893	1.067	−0.004	−0.039	0.031
2018 X July	0.983	0.931	1.037	0.969	0.887	1.058	−0.011	−0.045	0.024
2018 X August	0.973	0.922	1.027	0.979	0.896	1.069	0.003	−0.032	0.038
2018 X September	1.015	0.961	1.072	0.991	0.906	1.084	−0.007	−0.043	0.028
2018 X October	1.045	0.991	1.103	1.016	0.931	1.109	−0.032	−0.067	0.002
2018 X November	**1.058**	**1.002**	**1.117**	1.026	0.939	1.121	−0.024	−0.059	0.011
2018 X December	**1.081**	**1.024**	**1.142**	1.011	0.926	1.105	**−0.046**	**−0.081**	**−0.010**
2020 X February	1.008	0.955	1.064	0.958	0.879	1.045	−0.012	−0.047	0.022
2020 X March	**0.863**	**0.819**	**0.910**	0.996	0.916	1.083	**0.078**	**0.044**	**0.111**
2020 X April	**0.834**	**0.790**	**0.879**	1.042	0.958	1.134	**0.112**	**0.078**	**0.146**
2020 X May	**0.833**	**0.789**	**0.879**	0.992	0.910	1.080	**0.102**	**0.067**	**0.136**
2020 X June	**0.869**	**0.823**	**0.917**	0.978	0.896	1.067	**0.051**	**0.016**	**0.086**
2020 X July	**0.879**	**0.832**	**0.927**	0.962	0.882	1.049	**0.057**	**0.023**	**0.092**
2020 X August	**0.884**	**0.837**	**0.933**	**0.916**	**0.840**	**0.999**	**0.035**	**0.001**	**0.070**
2020 X September	**0.915**	**0.867**	**0.967**	0.967	0.885	1.057	**0.041**	**0.005**	**0.076**
2020 X October	**0.942**	**0.893**	**0.994**	1.015	0.931	1.106	0.029	−0.006	0.063
2020 X November	**0.941**	**0.892**	**0.992**	0.998	0.917	1.086	0.026	−0.008	0.060
2020 X December	0.984	0.933	1.038	0.970	0.890	1.057	0.007	−0.027	0.042
Constant	**0.585**	**0.564**	**0.606**	**0.105**	**0.099**	**0.111**	**6.949**	**6.925**	**6.972**

Data Source: Behavioral Risk Factor Surveillance System, 2013, 2014, 2016, 2018, and 2020. N = 2,203,861.
Notes: RRR = relative risk ratio, CI = confidence interval. Normal (7–8 h) sleep duration is the base category in multinomial models. Significant coefficients ($p < 0.05$) **bolded.** Models account for age, sex, race/ethnicity, marital status, number of children, educational attainment, income, home ownership, employment status, smoking status, drinking status, BMI, and exercise status.

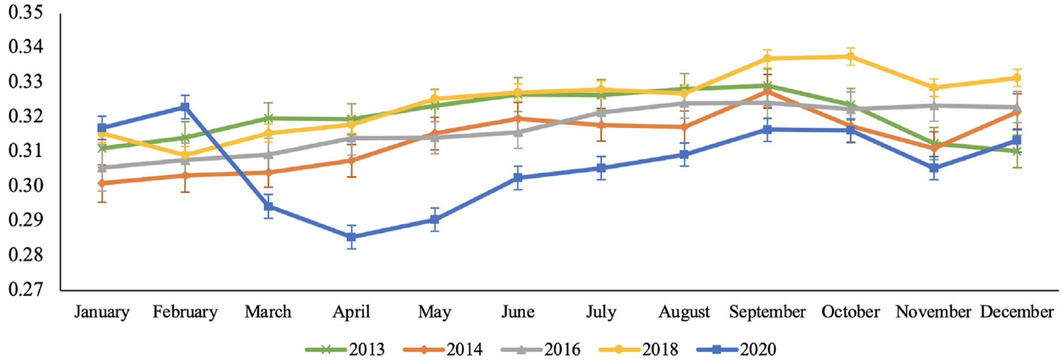

Fig. 1. Predicted Probability of Reporting Short Sleep Duration (Six or Fewer Hours), Adults aged 18+, Behavioral Risk Factor Surveillance System, 2013–2020
Note. Error bars represent 95% confidence interval. Model accounts for age, sex, race/ethnicity, marital status, number of children, educational attainment, income, home ownership, employment status, smoking status, drinking status, BMI, and exercise status.

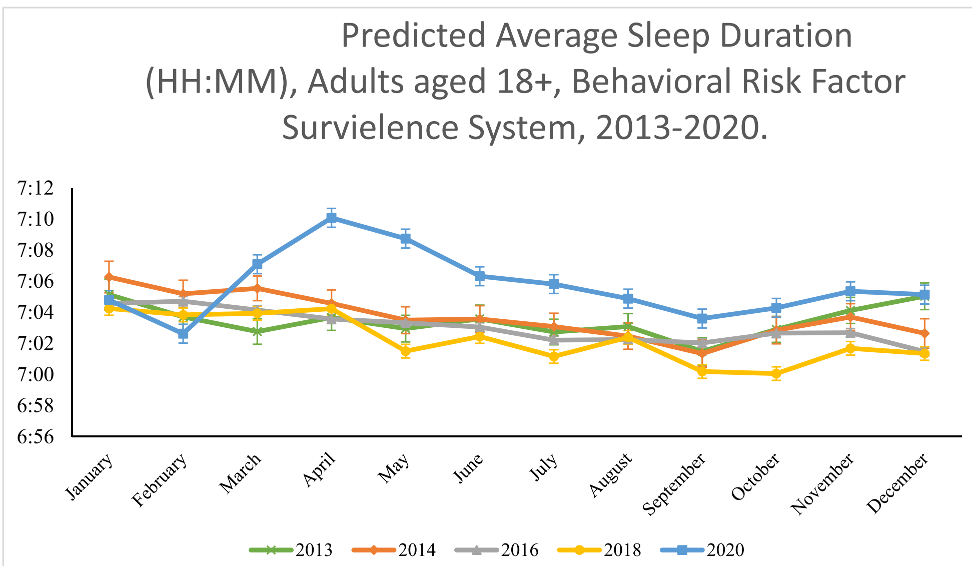

Fig. 2. Predicted Mean of Self-Reported Sleep Duration (HH:MM), Adults aged 18+, Behavioral Risk Factor Surveillance System, 2013–2020
Note. Error bars represent 95% confidence interval. Model accounts for age, sex, race/ethnicity, marital status, number of children, educational attainment, income, home ownership, employment status, smoking status, drinking status, BMI, and exercise status.

Americans working at home suddenly had no commutes or lighter work schedules, providing more time to sleep. Second, the pandemic and lockdown more broadly were extremely stressful [19], and thus sleep quality might have decreased and need to be made up for with increased duration. Indeed, the sleep duration question was asked regarding a typical 24-h period, thus people could be making up for poor quality sleep with naps, and recent research has illustrated that naps increased considerably in the pandemic [37,38]. Third, people had considerably more flexibility in their social schedules early in the pandemic and spent less time socializing but more time sleeping. Likely, the increases in sleep duration, are a mix of these three factors [13,39].

A second contribution is that we found that the increase in sleep duration among Americans was relatively short lived. By Fall of 2020 sleep patterns were largely similar to previous years. This is a novel contribution given that past research has tended to focus on the period immediately after lockdown or until the early summer [11,12,19]. Thus, we contribute to this work by showing that by Fall of 2020, sleep duration patterns were consistent with how they were before the pandemic. As Americans adjusted to living in the pandemic, and society began to reopen, sleep duration patterns reverted. The increasing reports of short sleep duration in the Fall of 2020 are concerning for population health, as over the course of a few months millions of Americans who were sleeping healthy durations in the months after lockdown began sleeping durations associated with higher attendant risk of negative health outcomes [4] as well as death [5].

The third major finding is that we found no significant differences in sleep duration trends within 2020 based on sex, race/ethnicity, and educational attainment. Sleep disparities were just as intractable during and after the pandemic as before. These findings coincide with previous research suggesting that the influence of COVID-19 specific stressors did not uniquely influence sleep quality by gender, race/ethnicity, or educational attainment [19]. The findings are troubling as during one of the most dramatic and abrupt *increases* in the reported sleep duration on record, sleep disparities across sex, race/ethnicity, and educational attainment remained [22,38]. That is, Americans seemingly consistently changed their sleep duration in the early stages of the pandemic resulting in stable levels of inequality in sleep as before the pandemic. Similarly, as more unhealthy sleep patterns remerged in the Fall of 2020, sleep disparities persisted. Overall our results

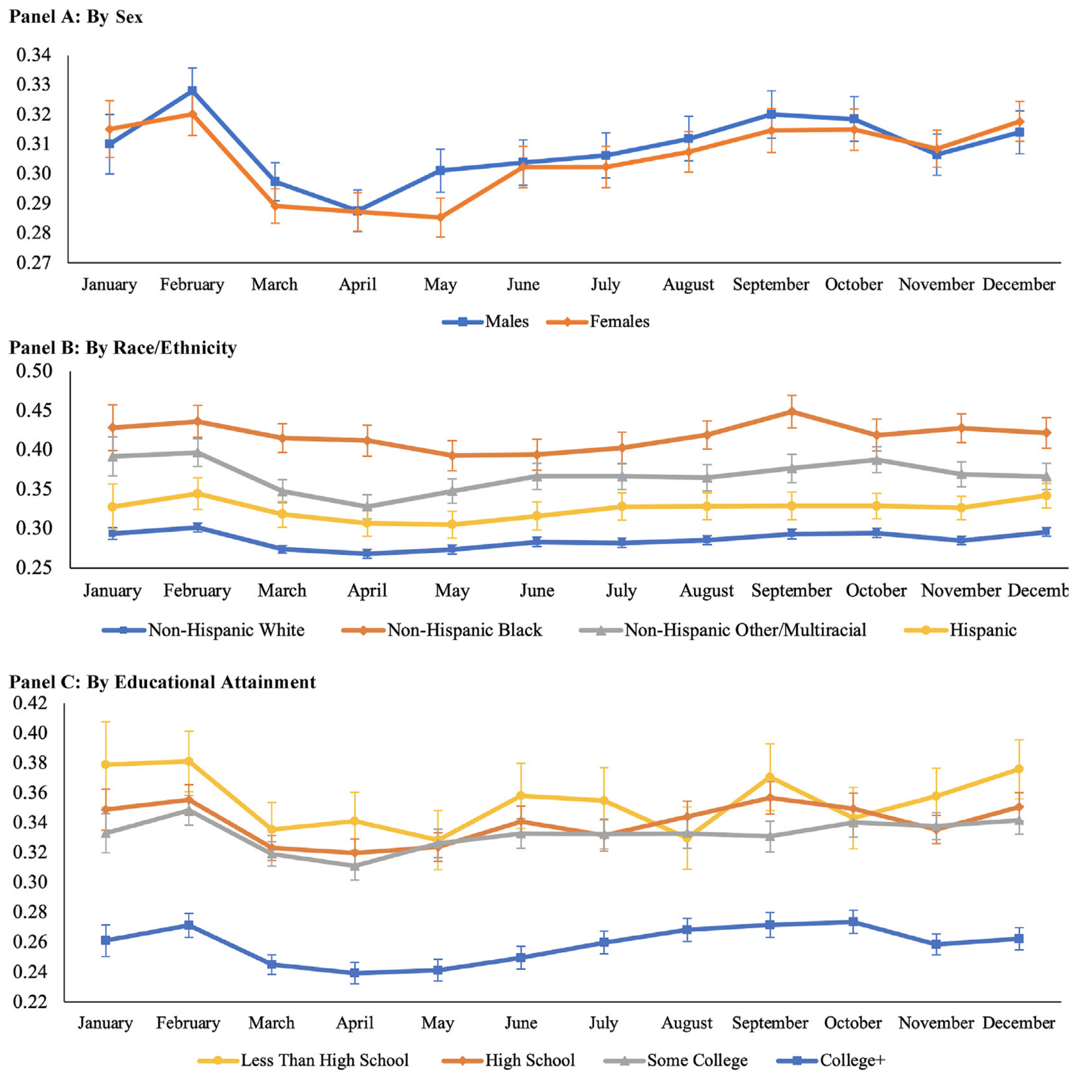

Fig. 3. Predicted Probability of Reporting Short Sleep Duration (Six or Fewer Hours), By Sex (Panel A), Race/Ethnicity (Panel B), and Educational Attainment (Panel C), Adults aged 18+, Behavioral Risk Factor Surveillance System, 2020
Note. Error bars represent 95% confidence interval. No covariates included in the model. See Supplemental Tables 2–4 for results with covariates.

indicate that health disparities that result from sleep inequalities [40] will likely endure going forward.

There are important limitations that must be considered. First, we relied on self-reported sleep duration, which has been shown to be biased relative to objective measures [41]. However, research that compared the questions utilized by the BRFSS, including sleep duration, to objective measures of sleep, including duration as measured by actigraphy [32], found that the BRFSS measure was "valid." We also have no reason to think that the bias would suddenly and dramatically shift in March of 2020, which would be necessary to explain our results, and are similarly reassured that our substantive results are consistent with online, app, and Fitbit data. Additionally, sleep health is also viewed as an increasingly multidimensional construct that should include self-reports in addition to objective measures [42]. Second, while the BRFSS is designed to be representative of States and has held up well in comparison to national level estimates of other health conditions [31], the extent to which it has external validity at the month level is not clear. Saying that, the large sample sizes during a period of lockdowns where other data collection procedures were untenable, makes its usage alluring for analyzing trends between years and especially within 2020. While, data collection was influenced by COVID-19 in the BRFSS, the cell sizes in March and April of 2020 were consistent with previous years. A third limitation is the lack of a 2019 comparison. As the BRFSS sleep questions are generally conducted bi-annually we lacked data to compare to 2019, and thus perhaps a new seasonal trend could have emerged in 2019. Reassuringly, past researchers who did have 2019 data did not document trends similar to those during the lockdown [12], and we found little other examples of idiosyncratic patterns within the other years we investigated. The data, while population-based are cross-sectional and longitudinal data would provide more internal validity, however we are unaware of any prospective population based monthly data of sleep in the U.S.

5. Conclusions

Sleep duration remains not only an important barometer of current population-health, it is likely also an important indicator of subsequent population health. Overall, we add to a collectively robust literature documenting substantial increases in sleep duration the early phases of the COVID-19 pandemic. While we can only speculate, the short-lived increases we documented might have been beneficial for the population-health of Americans by promoting immune system functioning [2] and the ability to cope with contextual stressors as well as adversities during the early phases of the pandemic. However, more research is needed to understand the short and long-term consequences of the short-lived increases in sleep duration. Regardless of the potential consequences, these brief increases did little to abate social inequality in sleep. Overall, our findings illustrate how ingrained sleep disparities are even in the face of an exogenous shock to population-level sleep duration patterns.

CRediT authorship contribution statement

Connor Sheehan: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Writing – review & editing. **Longfeng Li:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization. **Megan E. Petrov:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2022.12.008.

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