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Trends in sleep duration in the U.S. from 2004 to 2018: A decomposition analysis

Jiahui Xu [a], Liying Luo [a,*], Alyssa Gamaldo [b], Ashton Verdery [a], Melissa Hardy [a], Orfeu M. Buxton [a], Qian Xiao [c]

[a] The Pennsylvania State University, University Park, PA, USA
[b] Clemson University, Clemson, SC, USA
[c] The University of Texas Health Science Center at Houston, Houston, TX, USA

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ABSTRACT

Average sleep duration in the United States declined in recent years, and the decline may be linked with many biopsychosocial factors. We examine how a set of biopsychosocial factors have differentially contributed to the temporal trends in self-reported sleep duration across racial groups between 2004-2005 and 2017–2018. Using repeated nationally representative cross-sections from the National Health Interview Survey, we decompose the influence of biopsychosocial factors on sleep duration trends into two components. One component corresponds to coefficient changes (i.e., changes in the associations between behaviors or exposures and sleep duration) of key biopsychosocial factors, and the other part accounts for the compositional changes (i.e., changes in the distributions of exposures) in these biopsychosocial factors during the study period. We reveal that changes in the coefficients of some biopsychosocial factors are more important than compositional changes in explaining the decline in sleep duration within each racial/ethnic group. Our findings highlight racial differences manifest across multiple biopsychosocial domains that are shifting in terms of association and composition. Methodologically, we note that the standard regression approach for analyzing temporal trends neglects the role of coefficient changes over time and is thus insufficient for fully capturing how biopsychosocial factors may have influenced the temporal patterns in sleep duration and related health outcomes.

Introduction

Sleep duration has declined in the past several decades in many modern industrialized societies (Bixler, 2009; Ferrie et al., 2011; Ford et al., 2015; Youngstedt et al., 2016; Sheehan et al., 2019). Epidemiological studies have raised alarms about the declining trends in sleep durations, arguing that they are a public health concern threatening population-level longevity and health (Kronholm et al., 2008; Cappucio et al., 2011; Wu et al., 2014). A particular concern is the issue of short sleep, defined as less than 7 hours per day on a regular basis for adults aged 18 to 60 years old (Watson et al., 2015). Short sleep is linked to declines in cognitive abilities (e.g., concentration and memory; Rice and Schroeder, 2019), mental health problems (e.g., alertness, anxiety, and depression; Kronholm et al., 2008; Sheehan et al., 2019), and physical health conditions (e.g., obesity, stroke, and cardiovascular disease; Cappucio et al., 2011; Wu et al., 2014).

At the population level, trends in self-reported sleep duration reflect changes in either or both coefficients and distributions of biopsychosocial factors over time. Coefficient changes refer to changes in the relationship between biopsychosocial factors and sleep duration over time, whereas distributional changes refer to changes in the composition of biopsychosocial factors within a population over time. Assessing the contributions to sleep trends of changes from both perspectives is important because it leads to a better understanding and more precise monitoring of temporal trends of sleep duration and related health outcomes in the population, inspiring further investigations and targeted policies.

Prior studies have identified several biopsychosocial factors related to sleep duration at both individual and environmental levels. The distributions of these biopsychosocial factors are changing over time and their relationships with sleep duration exhibit temporal variations. For example, at the individual level, obesity, work hours, income, drinking, smoking, and stress have been shown to negatively impact sleep duration (Basner et al., 2007; Gohil & Hannon, 2018; Masood et al., 2015;

* Corresponding author.
E-mail address: liyingluo@psu.edu (L. Luo).

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Palmer et al., 1980; Van Reeth et al., 2000; Riumallo-Herl et al., 2014; Sa et al., 2020; Stamatakis et al., 2007; Vgontzas et al., 2008). Individuals who are obese, employed, having lower household income, drinking heavily (5 or more drinks a day), and smoking are, on average, sleeping less. At the same time, the past decades have witnessed increases in the prevalence of several biopsychosocial risk factors at the population level. For example, there is well-established evidence showing that extended working hours and associated increased levels of stress across different sociodemographic groups are parallel to the shortened sleep duration (Pew Research Center, 2016). Similarly, over the past two decades, the prevalence rate of obesity has risen from 30% to above 40% in U.S. (Stierman et al., 2021).

Besides changes in the distributions of sleep-related biopsychosocial factors in the U.S. population, the associations between such biopsychosocial factors and sleep duration may have also changed. Past studies have suggested the time-varying association between exposures to health risk factors (e.g., stress) and outcomes (e.g., mental health and chronic diseases; Wagner et al., 2021; Wu et al., 2021). However, little prior research has explored time-varying associations between biopsychosocial factors and sleep duration despite the emerging evidence supporting these temporal trends.

Importantly, average sleep duration and its temporal trends largely differ by race in the US. Studies observed racial differences in extreme sleep durations, such as short sleep (<7 hours; Luo et al., 2021; Petrov & Lichstein, 2016; Nyarko, Luo, Schlundt, & Xiao, 2023) and long sleep (≥9 hours; Petrov & Lichstein, 2016; Nyarko et al., 2023). For example, Black adults have been shown to experience a shorter sleep duration and a steeper decreasing trend than white adults since 2004 (Ford et al., 2015). Moreover, the association between sleep duration and performance on cognitive tasks is particularly salient in Black adults (Gamaldo et al., 2010), who tend to perform worse on cognitive assessments, potentially reflecting a greater risk of Alzheimer's Disease and related dementias (ADRDs; Sabia et al., 2021). In this study, we focus on non-Hispanic white and Black adults while excluding Hispanic/Latinx respondents for two reasons. First, the majority of Hispanics/Lanix adults in our sample were foreign-born with different patterns of health behaviors and outcomes (see, e.g., Acevedo-Garcia et al., 2005; Angel et al., 2001; Collins & Shay, 1994; Danso, 2016; Kimbro et al., 2008). Second, although Hispanic/Lanix adults report poorer sleep duration than non-Hispanic/Latino white adults, the magnitude of disadvantages in health behaviors and sleep patterns varies greatly across Hispanic/Latino subgroups (see, e.g., Borella et al., 2011; García et al., 2020).

Besides these documented disparities in sleep levels, trends, and their potential cognitive sequelae, studies have also shown that sleep-related factors may function differently across racial groups. Specifically, both the coefficients of biopsychosocial factors and their distributions differ for non-Hispanic white and Black adults due to historical and socioeconomic reasons. For example, Luo et al. (2021) identified the opposite educational gradient in sleep duration in US from 2004 to 2018 for white and Black adults, where greater education implies a protective effect for white adults but a counter-productive effect for Black adults. This and other factors could owe to historic and structural considerations that produce race-moderated associations between outcomes of interest and individual attributes, such as the tendency for education to have lower returns for Black than white adults (Gaddis, 2015; Hout, 2012) or differential access to healthcare (Chen et al., 2016). Beyond individual-level factors, there is well-established evidence showing that social, economic, and technological temporal changes are different for white and Black adults in scales and directions (Myers & Hwang, 2004; Boen, 2016; Sheehan et al., 2019). For example, Black adults experienced a higher level of stress not only at any given time point but cumulatively over time due to steeper pathways over the life course (Myers & Hwang, 2004; National Research Council (US) Panel on Race, 2004). Informed by this important literature of racial heterogeneity, we focus on within-race analysis to assess how distributions of biopsychosocial factors and their associations with sleep may have different implications for health outcomes. Our within-race decomposition analysis is useful for identifying the unique biopsychosocial factors related to sleep duration and the dynamic ways in which they influence temporal patterns for each racial group and respecting the historical and structural factors that yield race disparities (Iceland, 2019; Williams, 2019). Such dynamic heterogeneity between racial groups may likely be masked in conventional approaches that focus on between-group differences in sleep duration at one point of time.

In summary, our study addresses the knowledge gap in how the time-varying associations between sleep and biopsychosocial factors may have contributed to the observed trend in sleep duration and their implications for non-Hispanic white and non-Hispanic Black adults in the US. We *descriptively* decomposed the observed trends in self-reported sleep duration into compositional and coefficient changes in a known set of biopsychosocial factors identified in prior literature, including demographic characteristics, socioeconomic resources, health behaviors, and health covariates (Palmer et al., 1980; Van Reeth et al., 2000; Basner et al., 2007; Vgontzas et al., 2008; Riumallo-Herl et al., 2014; Masood et al., 2015; Gohil & Hannon, 2018; Sheehan et al., 2020; Sa et al., 2020). We conducted separate analyses for white and Black adults to investigate how these factors may differently contribute to the decline in sleep duration within each racial group. Compared to the standard regression models used in prior research on sleep duration that neglects the time-varying associations between biopsychosocial factors and sleep, our decomposition results provide new insight by clarifying and quantifying the relative contributions of compositional and coefficient changes in sleep-related biopsychosocial factors for different racial groups. We also discuss the public health implications of our study.

Methods

Data and measures

We used data from the National Health Interview Survey (NHIS), a nationally representative cross-sectional study of the U.S. civilian noninstitutionalized population on a range of health behaviors, health outcomes, and sociodemographic factors. In every year between 2004 and 2018, the NHIS asked respondents to report their sleep duration in a 24-hour period and recorded the response to the nearest hour. In this study, we limited our sample to non-Hispanic white and non-Hispanic Black adults between 25 and 69 years old who reported their average sleep duration in a 24-hour period (~1.02% missingness on sleep duration). We include adult respondents age 65 to 69 to account for the increasing retirement age and the growing employment rates among older workers in the US (U.S. Bureau of Labor Statistics, 2023; Congressional Research Service, "*The Social Security Retirement Age: An Overview*", 2023). As a sensitivity test, we included the results for traditional working-age respondents age 25 to 64 in Table S1 in the Supplemental Materials. Our main findings are robust to different age samples, although not surprisingly, the changes in age and labor force participation status play a different role in the 25–64 sample than the 25–69 age sample.

We restricted our sample to US-born noninstitutional non-Hispanic Black and white adults and excluded Hispanic/Latinx respondents for two reasons. First, the majority of the Hispanic sample (63.72%) in the NHIS were born outside of the United States. It has been shown that the foreign-born differ from the native-born in many health behaviors and outcomes (see, e.g., Acevedo-Garcia et al., 2005; Angel et al., 2001; Collins & Shay, 1994; Danso, 2016; Kimbro et al., 2008). Second, there is much heterogeneity among Hispanic people in their health behaviors and outcomes that require further analyses. Although certainly meriting future research, such heterogeneities are beyond the scope of the current study (see, e.g., Borella et al., 2011; Cho et al., 2004; García et al., 2020; Oza-Frank & Venkat Narayan, 2008; Salant & Lauderdale, 2003; Zsembik & Fennell, 2005).

In the descriptive analysis of temporal trends in self-reported sleep

duration, we included 209,929 white and 42,960 Black respondents. In the decomposition analysis, time period 1 included 22,411 white respondents and 4,495 Black respondents from the 2004–2005 NHIS, and time period 2 included 19,406 white respondents and 2,833 Black respondents from the 2017–2018 NHIS. We used the first (2004 and 2005) and last two years (2017 and 2018) of the NHIS data in which sleep duration was measured. We focused on these two time periods primarily for parsimonious reasons: as Fig. 1 in Section Results will show, the decline in sleep duration between 2004 and 2018 appeared to be linear for both racial groups. We combined observations in two adjacent years to reduce yearly fluctuations. We conducted sensitivity analyses using different data aggregation strategies (e.g., aggregating the first and last three years' data, the first and last four years' data, and the first and last six years' data). The additional results reported in Table S2 in Supplementary Materials are qualitatively consistent with our main results. The numeric values naturally differ by aggregation strategies because the amounts of sleep duration decline being decomposed differ. However, the overall conclusions (i.e., the coefficient changes in some biopsychosocial factors are the main drivers of the decrease in sleep duration) are similar across data aggregation intervals.

The outcome variable is self-reported sleep duration, which was asked by NHIS between 2004 and 2018. We converted sleep duration recorded in average hours in a 24-hour period, which has been rounded to the nearest hour by NHIS, to sleep minutes for ease of interpretation. In the decomposition analysis, our predictors include a set of biopsychosocial factors that have been shown to be associated with sleep duration, inclusion of age (a continuous variable ranging from 25 to 69; e.g., Akerstedt et al., 2017), marital status (a binary variable with 0 indicating not currently married and 1 married; e.g., Sheehan et al., 2020), educational attainment (a 3-level categorical variable indicating education levels of less than high school, high school, and college or more; e.g., Luo et al., 2021), labor force status (a binary variable with 0 indicating not in the labor force and 1 in the labor force; e.g., Biddle and Hamermesh, 1990), self-reported household income (a 3-level categorical variable defined as $0-$34,999, $35k-$75k, and $75k or above; e.g., Stamatakis et al., 2007), self-reported homeownership (a binary variable with 0 indicating not owning a home and 1 homeownership), health insurance coverage (a binary variable with 0 as no health insurance covered and 1 as with health insurance; e.g., Sheehan et al., 2020), body weight categories based on body mass index (BMI, categorized as underweight (BMI <18.5), normal (18.5 ≤ BMI ≤ 24.9), overweight (25 ≤ BMI ≤ 29.9), and obese (BMI ≥ 30); e.g., Marshall et al., 2008; see Table S3 for using BMI as a continuous variable ranging from 14.3 to 55.3), drinking behavior (a continuous variable indicating number of days having 5 or more drinks last year, ranging from 0 to 100; e.g., Palmer et al., 1980), smoking (a binary variable with 0 as never smoked and 1 as current or former smoker; e.g., Sheehan et al., 2019), psychological distress (a binary variable with 0 indicating a Kessler score [K6] of 5 or lower and 1 indicating a K6 score 6 or higher; see, e.g., Kessler et al., 2010, Vgontzas et al., 2008), pain level (a continuous variable ranging from 0 [no pain] to 4 [had pain in jaw/front of ear, lower back, neck, and joints in the past 30 days or three months]; Kelly et al., 2011), and self-reported health (a binary variable with 0 as excellent, very good or good self-reported health and 1 as poor or fair; e.g., Sheehan et al., 2020). In the decomposition analysis, we removed persons with missing information on any of these biopsychosocial variables, which reduced the sample size by around 19.9% in the white sample and 24.7% in the Black sample, respectively. The NHIS has a complex survey design and we used the recommended weight "SAMWEIGHT" in all analyses to assess the population-level temporal trends of sleep duration.

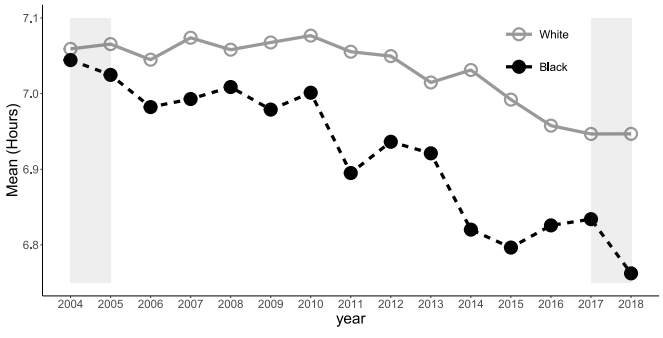

Fig. 1. Overall trends in sleep duration (in hours) for white and Black adults age 25–69, weighted by "SAMWEIGHT", the NHIS 2004–2018.

Decomposition analysis

For each racial group, we used the two-fold Kitagawa-Blinder-Oaxaca (KBO) method (Kitagawa, 1955;Blinder, 1973; Oaxaca, 1973) to decompose the total change in sleep duration from 2004 to 2005 and 2017–2018 into two components: one that can be attributed to compositional differences in the biopsychosocial factors, and the other to coefficient changes of the same set factors.

We conducted separate KBO analysis for white and Black respondents. Our descriptive KBO decomposition consisted of two steps. First, we fitted a multivariate linear regression model separately for the 2004–2005 and the 2017–2018 sample within a racial group:

$$y_{i,t} = b_{0,t} + \sum_{j=1}^{p} b_{j,t} X_{ij,t} + \varepsilon_{i,t}, \quad (1)$$

where t indicates the time period 2004–2005 or 2017–2018; $y_{i,t}$ represents the average sleep duration for respondent i in year 2004–2005 or 2017–2018; $b_{0,t}$ is the intercept in year t; and X is a vector of sleep related predictors including age, BMI, binge drinking, labor force participation status, education, psychological distress, and pain level.

Second, the difference in sleep duration between the two time points can be expressed as follows:

$$\Delta_{2018,2004} = (\mathrm{X}_{2018} - \mathrm{X}_{2004})\beta_{2004} + (\beta_{2018} - \beta_{2004})\mathrm{X}_{2018}, \quad (2)$$

where X_{2004} and X_{2018} are vectors of means of each variable in the 2004–2005 and the 2017–2018 sample, respectively. β_{2004} and β_{2018} are vectors of estimated multivariate linear regression coefficients from equation (2). Setting the year 2004–2005 as the reference, (X_{2018}-X_{2004}) β_{2004} represents the compositional component underlying the observed change. This term quantifies the decrease in sleep duration between 2004-2005 and 2017–2018 attributed to the distributional changes in the predictors. (β_{2018}-β_{2004})X_{2018} is the coefficient component, indicating the decrease in sleep duration that is attributed to changes in coefficients of the predictors on sleep between 2004-2005 and 2017–2018.

Prior research often used the standard regression model to analyze temporal trends in sleep duration (see, e.g., Ford et al., 2015; Sheehan et al., 2019). Although the standard regression approach can account for compositional or distributional changes over time, it assumes that the coefficients of the predictors are time invariant (i.e., their relationships with sleep duration do not change over time) unless complex interaction terms among all explanatory variables are included. The KBO decomposition relaxes this statistical assumption by considering the contributions of both compositional differences and coefficient changes to the total difference. Despite the mathematical equivalence between the KBO decomposition and a single, fully interacted model, the KBO decomposition avoids adding those interaction terms manually and provides a straightforward interpretation that remains consistent with what is attainable from the interaction approach. For our study, the KBO method provides new insights into sleep duration trends by clarifying and quantifying the extent to which compositional and coefficient differences in biopsychosocial factors may have contributed to the observed decline in sleep duration.

We focused on within-group changes in sleep duration by conducting separate KBO analyses for white and Black adults between 2004-05 and 2017–18. Our within-group analysis is informed by recent discussions among race scholars. This literature suggests when analyzing trends in racial inequality, within-race analysis should be preferred over between-race comparison because biopsychosocial factors may have different and dynamic implications for health and economic outcomes over time (Iceland, 2019; Williams, 2019). Although it is certainly interesting to decompose group differences over multiple time points, suitable methods for this purpose are unfortunately underdeveloped and tend to mask the historic and structural legacies that contribute to race disparities. Future methodological development will facilitate the assessment of what biopsychosocial factors have contributed to the heterogenous health conditions observed within racial groups, which could assist in understanding racial health disparities over time (Whitfield & Baker-Thomas, 1999; Whitfield et al., 2008, pp. P301–P308).

Results

Fig. 1 depicts the observed overall trends in sleep duration from 2004 to 2018 for white and Black adults in the NHIS sample, weighted by the "SAMWEIGHT" variable recommended by the NHIS. Both white and Black adults slept significantly less in recent years ($p < .001$) than in the 2000s. However, the decline was larger among Black adults (14.57 min) than white adults (6.34 min) respondents from 2004 to 2005 to 2017–2018.

Table 1 presents the weighted means (or proportions for categorical variables) and standard errors (in parentheses) for all analytical variables. We used the Wilcoxon rank sum test adjusted for the NHIS's complex survey design to examine whether the means of the key variables in the 2004–2005 sample differ from the 2017–2018 sample. The results suggest that the distributions of all variables, except for labor force participation, self-reported health, and Black adults' age, have significantly changed between 2004-2005 and 2017–2018 for both racial groups (all $p < .05$). For example, among white adults, obesity prevalence increased from 25.26% in 2004–2005 to 32.07% in 2017–2018. The percentage of respondents experiencing psychological distress increased by 4.12%. Among Black adults, obesity prevalence increased from 35.94% in 2004–2005 to 44.27% in 2017–2018. Black adults who experienced psychological distress increased by 2.3%. The average age among white adults increased from 45.94 years in 2004–2005 to 47.47 years in 2017–2018. The average age among Black adults, however, did not show a significant change (i.e., from 44.04 years to 44.76 years). This reflects that the white population was aging more quickly than Black population owing to a later fertility decline for Black people during this period of time. The racial difference in aging may also reflect the challenges in studying older Black populations with survey data since they tend to be underrepresented and with more missing values in demographics (Griffin, 2002; Mohamed et al., 2021). We describe below why and how a decomposition analysis for each racial group is useful for quantifying the extent to which such distributional changes in these sleep-related biopsychosocial factors contribute to the observed sleep duration decline relative to a different source of changes.

Table 2 presents the KBO decomposition results separately for white and Black adults. Values in columns "X_{2004}" and "X_{2018}" are weighted means or proportions of each biopsychosocial factor in 2004–2005 and 2017–2018 separately (see Table 1 for statistical significance of the difference between the two time periods). Consistent with Table 1, the compositional changes shown in columns "X_{2004}" and "X_{2018}" suggest that the distributions of many sleep-related biopsychosocial factors changed significantly between 2004-2005 and 2017–2018. For example, both white and Black adults showed higher obesity prevalence and a higher proportion of them experienced moderate or severe psychological distress. The directions and magnitudes of such changes are largely comparable for white and Black adults.

Values in columns "β_{2004}" and "β_{2018}" are estimated coefficients from separately regressing sleep duration on the aforementioned set of biopsychosocial factors in 2004–2005 and 2017–2018 within each racial group. The coefficients for the biopsychosocial factors in 2017–2018 differ from those estimated in 2004–2005 for both Black and white adults. The associations between some sleep-related biopsychosocial factors and sleep duration became stronger (e.g., the coefficient of psychological distress on sleep duration among Black adults changed from −6.57 ($p = .077$) to −34.36 ($p < .001$)), whereas the others have decreased (e.g., the coefficient of obesity on sleep duration among white

Table 1
Descriptive statistics for key analytical variables by race, weighted by SAMWEIGHT provided by NHIS.

Variables	Non-Hispanic White Sample			Non-Hispanic Black Sample		
	2004–2005 N = 22,411[a]	2017–2018 N = 19,406[a]	p-value[b]	2004–2005 N = 4,495[a]	2017–2018 N = 2,833[a]	p-value[b]
Sleep duration (minutes)	423.51 (71.38)	417.17 (73.75)	<0.001	421.77 (88.46)	407.20 (91.10)	<0.001
Age	45.94 (11.94)	47.47 (13.02)	<0.001	44.04 (11.84)	44.76 (13.22)	0.17
Not married	24.82%	27.78%	<0.001	51.20%	56.95%	<0.001
Education			<0.001			<0.001
Less than high school	38.15%	27.56%		52.15%	40.21%	
High school	49.30%	55.91%		42.11%	50.02%	
College	12.55%	16.53%		5.73%	9.77%	
Not in labor force	22.63%	23.88%	0.008	24.57%	26.19%	0.19
Household Income			<0.001			0.012
<35k	21.91%	16.30%		45.50%	41.07%	
35k ~ 75k	32.37%	27.03%		28.06%	30.52%	
>75k	45.71%	56.67%		26.43%	28.41%	
No homeownership	17.97%	24.85%	<0.001	43.10%	56.14%	<0.001
No health insurance	11.34%	7.61%	<0.001	19.02%	12.01%	<0.001
BMI			<0.001			<0.001
Underweight	1.08%	0.90%		0.57%	1.02%	
Normal	35.72%	30.87%		26.39%	22.08%	
Overweight	37.93%	36.16%		37.09%	32.63%	
Obese	25.26%	32.07%		35.94%	44.27%	
# Days with 5 + drinking	5.35 (18.17)	7.02 (19.74)	<0.001	4.04 (16.86)	4.72 (17.32)	<0.001
Smoking	48.98%	42.90%	<0.001	39.06%	32.06%	<0.001
Psychological distress	14.29%	18.41%	<0.001	17.52%	19.82%	0.039
Pain	0.88 (1.04)	0.94 (1.06)	<0.001	0.71 (1.00)	0.79 (1.01)	0.001
Health: poor or fair	9.40%	10.12%	0.028	17.27%	17.08%	0.85

[a] Mean (SD); %.
[b] Wilcoxon rank-sum test for complex survey samples.

Table 2
Sleep duration decline in hypothetical scenarios by race, the NHIS[b].

	Non-Hispanic White Adults									
	X_{2004}	X_{2018}	Hypothetical decline if $X_{2018} = X_{2004}$	Diff.	p	β_{2004}	β_{2018}	Hypothetical decline if $\beta_{2018} = \beta_{2004}$	Diff.	p
Observed Decline				417.17–423.51 = −6.34 min						
Age	45.94	47.47	−6.69	0.35	*	0.23	0.25	−7.49	1.15	
Not married	0.25	0.28	−6.22	−0.12	*	−4.01	−0.61	−7.28	0.95	
Education										
Less than HS	0.38	0.28	−6.37	0.03		−0.33	−1.47	−6.02	−0.32	
High school (ref)										
College	0.13	0.17	−6.40	0.06		1.55	0.78	−6.21	−0.13	
Not in labor force	0.23	0.24	−6.56	0.22	*	17.62	15.99	−5.95	−0.39	
Household income										
<35k	0.22	0.16	−6.34	0.00		−0.02	−0.15	−6.32	−0.02	
35k - 75k (ref)										
>75k	0.46	0.57	−6.12	−0.22		−2.02	2.24	−8.75	2.41	*
No homeownership	0.18	0.25	−6.11	−0.23	*	−3.32	−1.17	−6.87	0.53	
No health insurance	0.11	0.08	−6.23	−0.11		2.97	5.00	−6.49	0.15	
Body weight[a]										
Underweight	0.01	0.01	−6.32	−0.02		8.70	7.81	−6.33	−0.01	
Normal weight (ref)										
Overweight	0.38	0.36	−6.43	0.10	*	−5.36	−3.69	−6.95	0.61	
Obese	0.25	0.32	−5.68	−0.66	*	−9.74	−4.92	−7.89	1.55	*
# Days with 5 + drinks	5.35	7.02	−6.41	0.07		0.04	0.09	−6.65	0.31	
Smoking	0.49	0.43	−6.54	0.20	*	−3.25	−6.83	−4.81	−1.53	*
Psychological distress	0.14	0.18	−5.91	−0.43	*	−10.49	−18.59	−4.85	−1.49	*
Pain	0.88	0.94	−5.98	−0.36	*	−5.53	−8.20	−3.82	−2.52	*
Health										
excellent, very good, good (ref)										
fair or poor	0.09	0.10	−6.32	−0.02		−2.90	1.99	−6.83	0.49	
	Non-Hispanic Black Adults									
	X_{2004}	X_{2018}	Hypothetical decline if $X_{2018} = X_{2004}$	Diff.	p	β_{2004}	β_{2018}	Hypothetical decline if $\beta_{2018} = \beta_{2004}$	Diff.	p
Observed Decline				407.20–421.77 = −14.57 min						
Age	44.04	44.76	−14.54	−0.02		−0.03	0.18	−24.26	9.69	
Not married	0.51	0.57	−14.91	0.34	*	5.95	0.82	−11.64	−2.92	
Education										
Less than HS	0.52	0.40	−12.00	−2.57	*	21.47	9.37	−9.70	−4.86	*
High school (ref)										
College	0.06	0.10	−14.61	0.04		1.02	−3.01	−14.17	−0.39	
Not in labor force	0.25	0.26	−14.95	0.39		24.14	15.94	−12.42	−2.15	
Household income										
<35k	0.46	0.41	−14.43	−0.14		3.14	2.97	−14.50	−0.07	
35k - 75k (ref)										
>75k	0.26	0.28	−14.53	−0.04		−1.84	−7.29	−13.02	−1.55	
No homeownership	0.43	0.56	−13.62	−0.94	*	−7.23	−2.12	−17.44	2.87	
No health insurance	0.19	0.12	−14.06	−0.51	*	7.21	4.37	−14.22	−0.34	
Body weight[a]										
Underweight	0.01	0.01	−14.56	−0.01		−2.21	22.50	−14.82	0.25	
Normal weight (ref)										
Overweight	0.37	0.33	−14.94	0.37	*	−8.39	−8.38	−14.57	0.00	
Obese	0.36	0.44	−13.44	−1.13	*	−13.52	−7.96	−17.03	2.46	
# Days with 5 + drinks	4.04	4.72	−14.74	0.18		0.26	−0.02	−13.28	−1.29	*
Smoking	0.39	0.32	−14.69	0.12		−1.75	0.37	−15.24	0.68	
Psychological distress	0.18	0.20	−14.41	−0.15		−6.57	−34.36	−9.06	−5.51	*
Pain	0.71	0.79	−13.51	−1.06	*	−13.84	−9.04	−18.34	3.78	*
Health										
excellent, very good, good (ref)										
fair or poor	0.17	0.17	−14.60	0.03		−17.05	−10.90	−15.62	1.05	

[a] See Table S3 in Supplemental Materials for results using the BMI as a continuous variable ranging from 14.3 to 55.3.

[b] Values in columns "X_{2004}" and "X_{2018}" are weighted means or proportions of each biopsychosocial factor for each racial group in 2004-2005 and 2017-2018, respectively. Values in column "hypothetical decline if $X_{2018} = X_{2004}$" are estimated sleep duration decline had the distribution of a biopsychosocial factor in 2017-2018 been the same as in 2004-2005. Values in columns "β_{2004}" and "β_{2018}" are estimated coefficients from separate weighted multivariate linear regressions for each racial group using the 2004-2005 and 2017-2018 samples, respectively. Values in column "hypothetical decline if $\beta_{2018}=\beta_{2004}$" are estimated sleep duration decline we would have observed had the sleep-predictor association in 2017-2018 been the same as that in 2004-2005. The "Diff" column indicates the difference between the observed and hypothetical declines. A positive difference implies a greater sleep duration decline had the composition or the coefficient of a biopsychosocial factor had not changed. A negative difference implies a smaller decline had the composition or the coefficient of a biopsychosocial factor not changed. Asterisks indicate a statistically significant ($p<.05$, two-sided tests) contribution.

adults changed from −9.74 ($p < .001$) to −4.92 ($p < .001$)) or even disappearing (e.g., the coefficient of Not married among white adults).

Values in the "hypothetical decline if $X_{2018} = X_{2004}$" column are estimated sleep duration decline had the distribution or composition of a biopsychosocial factor in 2017–2018 been the same as in 2004–2005 (i.e., forcing $X_{2018} = X_{2004}$ in equation (2)). Values in the "hypothetical decline if $\beta_{2018} = \beta_{2004}$" column are estimated sleep duration decline we would have observed had the predictor-sleep association in 2017–2018 been the same as that in 2004–2005 (i.e., forcing $\beta_{2004} = \beta_{2018}$ in equation (2)). The "Diff" column indicates the difference between the hypothetical and observed declines: a positive value in this column means a greater sleep duration decline had the composition or the coefficient of a biopsychosocial factor not changed, and a negative value implies a smaller decline had the composition or the coefficient of a biopsychosocial factor not changed. Asterisks indicate if the estimated changes under the hypothetical scenario are statistically significant at .05 or a lower level (two-tailed tests within a racial group). For example, among white adults, the observed decline in self-reported sleep duration from 2004 to 2005 to 2017–2018 was 6.34 min. Had the coefficient of obesity been the same in 2017–2018 as that in 2004–2005, we would have observed a decline of 7.89 min ($p < .05$) in sleep duration. That is, the decline would have been 1.55 min (−6.34-(-7.89)) greater, assuming the negative association between obesity and sleep duration in 2017–2018 was as large as in 2004–2015.

Compared to studies that aggregate racial groups, separate within-group analyses reveal distinct patterns of compositional and coefficient changes for sleep duration for the two racial groups. Specifically, the results in Table 2 suggest that for white and Black adults, the decline in sleep duration may be attributed to different sets of predictors. For white adults, changes in the coefficients of pain, high income, obesity, and smoking on sleep duration are the most influential factors for the sleep duration decline ($p < .05$). For example, the coefficient of pain and smoking was −8.20 and −6.83, whereas they were −5.53 and −3.25 in 2004–2005. Had the negative coefficients of pain and smoking on sleep in 2017–2018 been as large as in 2004–2005, the decline in sleep duration from 2004 to 2005 to 2017–2018 would have been 4.05 (-(-2.52-1.53)) minutes smaller for white adults. Had the negative coefficients of obesity on sleep in 2017–2018 (−4.92) been the same as that in 2004–2005 (−9.74), the hypothetical sleep duration decline would have been 7.89 min (−6.34-1.55) among white adults. Other factors did not contribute much to the decline for white adults (all less than 1.5 min).

In contrast, for Black adults, changes in the coefficients of age, psychological distress, lower educational attainment, pain, Not married, not owning a home, and obesity on sleep duration all play important roles in driving the sleep duration decline between 2004-2005 and 2017–2018. Although the coefficient changes in age, Not married, no homeownership, and obesity are statistically nonsignificant, the effect size or magnitude of their influence is large and notable. For example, the negative coefficient of pain on sleep duration decreased from −13.84 in 2004–2005 to −9.04 in 2017–2018. Had the coefficients of being older, experiencing higher levels of pain, no homeownership, and obesity been the same in 2017–2018 as in 2004–2005, the decline in sleep duration from 2004 to 2005 to 2017–2018 would have been 2.46–9.69 min greater for Black adults. The coefficients of having less than high school education and higher psychological distress levels are 9.37 and −34.36 in 2017–2018, while they were 21.47 and −6.57 in 2004–2005. Had the coefficients of having less than high school education, higher psychological distress, and the proportion of being unmarried remained the same in 2017–2018 as in 2004–2005, the observed sleep duration decline would be 2.92–5.51 min smaller. Coefficient changes in labor force status, drinking, smoking, health insurance coverage, higher education, low household income, and self-reported health status contributed relatively little to the decline in sleep duration between the two time periods for both white and Black adults.

For both white and Black adults, compositional changes were not as influential as coefficient changes on changes in sleep duration during the study period. Among the limited explanations attributed to compositional changes, a higher level of educational attainment stands out in explaining the largest proportion of sleep duration change for Black adults. If the proportion of Black adults who did not graduate from high school in 2017–2018 were the same as that in 2004–2005, the observed decline in sleep duration would have been 2.57 min smaller.

Discussion

In this study, we used the Kitagawa-Blinder-Oaxaca (KBO) decomposition to assess how compositional and coefficient changes in a set of biopsychosocial factors may have contributed to the decline in self-reported sleep duration between 2004-2005 and 2017–2018, separately for non-Hispanic white and non-Hispanic Black adults. Our analysis showed that for both racial groups, the declining temporal trends in sleep duration in the recent two decades were largely driven by changed coefficients of biopsychosocial factors on sleep duration rather than their distributional differences. Specifically, for both non-Hispanic white and non-Hispanic Black respondents, the coefficient changes in pain, psychological distress, and obesity are the most notable drivers underlying the temporal decline in sleep duration.

Our within-group decomposition analysis has important implications for understanding diversified sleep duration declining trends by race. Specifically, we showed that sleep-related biopsychosocial factors may play different roles in explaining sleep duration decline for Black and white adults. For example, the compositional and/or distributional changes in labor force participation and household income appeared to be related to the temporal decline in sleep duration for white adults, but not for Black adults. At the same time, the compositional and distributional changes in education seemed to influence the temporal decline in sleep duration only for Black adults. Consistent with an emerging literature (Caraballo et al., 2022; Jackson et al., 2013; Luo et al., 2021; Sheehan et al., 2020), we found that educational attainment is functioning in opposite directions for sleep duration for white and Black adults. Specifically, a college degree was associated with longer sleep among white adults but *shorter* sleep among Black adults in 2017–2018, suggesting that greater education may not reduce short sleep in Black population but rather exacerbate the problem in recent years. According to the stress process model, it is possible that Black adults with greater educational attainments are more susceptible than those with relatively less educational levels to experiencing mundane, extreme environmental stress, and chronic exposure to racial micro-aggregations, which lead to poor sleep quality and declined sleep duration (Pieterse & Carter, 2007; Grandner et al., 2010; Sellers, Neighbors, & Bonham, 2011; Mouzon et al., 2020; Luo et al., 2021).

We also found a weakened association of pain and sleep duration among Black adults from 2004 to 2005 to 2017–2018 with unclear mechanisms, whereas for white adults, pain levels and psychological distress are consistently increasing. These findings may suggest that for Black adults, opportunities for exposure to various systematic forms of stress (e.g., microaggressions; mundane, extreme, environmental stress; Robinson-Wood et al., 2020) may be greater for individuals as they advance their education and, subsequently, their professional careers (Smith et al., 2011). Additional research, therefore, is warranted to further explore whether these socially relevant underlying mechanisms may contribute to the understanding of the current study's observations. However, our results suggest that the burden of shorter sleep is high and likely increasing in Black adults with a college degree, which calls for attention from both public health research and practice.

Our study revealed the significant role of obesity in contributing to the observed sleep duration declines among both white and Black adults. However, the way in which obesity contributed to the trends differs from what one might have anticipated. On the one hand, consistent with prior literature (Vgontzas et al., 2008; Beccuti and Pannain, 2011), we found that increasing obesity prevalence was associated with sleep duration

decline in the population. We also updated the empirical evidence by showing that among white adults, the increased obesity prevalence explained a 1.55-min decline (24.45% of the total decline) from 2004 to 2005 to 2017–2018. For Black adults, the increased obesity prevalence accounts for a 2.46-min decline (16.88% of the total decline) in the same period.

On the other hand, and more importantly, our analysis provided new empirical evidence that the association between obesity and sleep duration has become smaller in recent years. Had the association between obesity and sleep duration remained the same in 2017–2018 as that in 2004–2005, both Black and white would sleep even less in recent years. We are the first to provide empirical evidence about a decreasing obesity coefficient, which may indicate other underlying changes. Suggestively, it may point to the rising importance of other biopsychosocial factors, such as psychological factors and education, in recent years or a result of effective public health intervention on the association between obesity and sleep.

Our KBO decomposition also has important methodological implications for studying temporal patterns in sleep by race. In analyzing trends in sleep duration, prior research often used the standard regression approach to account for distributional changes while paying relatively little attention to the coefficient or associational changes of related factors over time (see, e.g., Sheehan et al., 2019). Our findings indicate that the standard approach may be inadequate because the associations between sleep and related biopsychosocial factors are dynamic rather than static. For example, for Black adults, heavy drinking was positively associated with sleep duration (.26, $p < .001$) in 2004–2005, whereas this association was not observed in 2017–2018 (-0.02, $p = .88$). Using the standard regression would miss this important source of changes and lead to inconclusive evidence that binge drinking is not related to changes in sleep duration. Although this limitation may be addressed by adding multiple interactions and manipulating the regression coefficients, it is difficult to interpret high-order interaction terms among time, biopsychosocial, and demographic factors. The KBO decomposition method provides more straightforward and interpretable results for identifying and assessing the dynamic relationships between biopsychosocial factors and the related sociodemographic disparities.

As mentioned earlier, our within-race decomposition analysis may provide insights about the unique and dynamic ways in which biopsychosocial factors influences trends in sleep duration for each race group (Iceland, 2019; Williams, 2019). However, the KBO decomposition method can be modified and extended to study how racial disparity in sleep may have changed over time. Such work would, however, benefit from additional attention to structural factors that may create differential associations within race groups (Williams, 2019).

There are limitations in our current study. First, we used pooled cross-sectional data from the NHIS, which blocks us from investigating the changes within individuals to account for the declining sleep duration trends. Second, the NHIS did not routinely collect sleep duration information earlier than 2004 or later than 2018, not allowing an investigation of earlier or later temporal changes in sleep duration. Third, we focused on US-born noninstitutional non-Hispanic Black and white adults. How changes in sleep-related biopsychosocial factors have influenced sleep duration trends for Hispanic/Latinx respondents or other racial/ethnic groups are merited in future research. Fourth, our KBO analysis *descriptive* in nature, which does not permit a causal interpretation of the results. Although it is out of the current study, future research may use causal decomposition (Jackson & VanderWeele, 2018) to identify interventions for improving sleep duration and health. In addition, we used a two-fold KBO decomposition, which ignores the nonlinear correlation structures of biopsychosocial factors. For the purpose of sensitivity test, we conducted a three-fold decomposition, and the results were largely the same (see Table S4 in Supplementary Materials). Lastly, we only assessed a limited number of biopsychosocial factors based on prior literature. We did not include gender in our main results. Although prior literature documented gender differences in sleep duration, our additional results (see Table S5 in Supplementary Materials) suggest little compositional or coefficient contribution associated with gender. This evidence is consistent with prior empirical findings about the relatively small role of gender on sleep duration within racial groups (e.g., Luo et al., 2021; Voderholzer et al., 2003). Future studies may include different sets of biopsychosocial factors.

Despite these limitations, our study is the first to assess different implications of biopsychosocial factors for temporal declines in sleep duration for non-Hispanic white and non-Hispanic Black adults in the United States using nationally representative data. By decomposing the overall temporal trends into the coefficient and distributional changes of biopsychosocial factors for each racial group, we show that the influences of biopsychosocial factors on sleep duration are dynamic rather than static. Our study encourages a refined understanding of group-specific mechanisms by which downstream health behavior patterns may change at the population level over time. For policymakers, understanding both sides helps monitor population health trends and design targeted interventions on public health as well as racial inequality before they reach alarming levels. For example, our results suggest the important implications of psychological distress, education, and pain on Black adults' sleep deprivation, especially among the older. We encourage policymakers to invest more in equalizing opportunities across races to reduce the pain and psychological distress level encountered by Black adults for a healthier society.

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Ethical Statement

Hereby, Liying Luo consciously assure that for the manuscript titled "Trends in Sleep Duration in the U.S. from 2004 to 2018: A Decomposition Analysis" the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.
2) The paper is not currently being considered for publication elsewhere.
3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
5) The results are appropriately placed in the context of prior and existing research.
6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

The violation of the Ethical Statement rules may result in severe consequences.

CRediT authorship contribution statement

Jiahui Xu: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft. **Liying Luo:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Visualization,

Writing – review & editing. **Alyssa Gamaldo:** Writing – review & editing. **Ashton Verdery:** Writing – review & editing. **Melissa Hardy:** Writing – review & editing. **Orfeu M. Buxton:** Writing – review & editing. **Qian Xiao:** Writing – review & editing.

Declaration of competing interest

The authors declare no competing interests.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101562.

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