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Racial Disparities in Adolescent Sleep Duration: Physical Activity as a Protective Factor

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Abstract

Objectives: Short sleep duration compromises adolescents' functioning across many domains, yet risk for short sleep is not evenly distributed among youth in the United States. Significant Black–White disparities in sleep duration have been observed, with Black/African American youth on average sleeping fewer minutes per night than their White/European American peers. However, not all Black adolescents have short sleep, and identification of moderators of effects, including protective and vulnerability factors in the association between race/ethnicity and sleep duration, is warranted. We examined whether engagement in physical activity attenuates the gap in sleep duration between Black and White teenagers.

Method: A sample of 246 adolescents (M_{age} = 15.79 years; 32.9% Black, 67.1% White) reported on their physical activity and participated in 1 week of at-home actigraphic sleep assessment, which was used to derive sleep duration (minutes scored as asleep from sleep onset to wake time).

Results: At higher levels of physical activity, relatively long sleep duration was observed for all youth regardless of their race/ethnicity. However, at lower levels of physical activity, an association emerged between race and sleep minutes, illustrating that youth most at risk for shorter sleep were Black adolescents with lower physical activity.

Conclusions: Findings suggest that for Black adolescents, physical activity is a protective factor against short sleep duration and, conversely, low physical activity is a vulnerability factor.

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Brian T. Gillis served as lead for conceptualization and formal analysis. Mina Shimizu served as lead for validation and served in a supporting role for conceptualization and formal analysis. Mona El-Sheikh served as lead for data curation, funding acquisition, investigation, methodology, project administration, resources, supervision, and writing – review & editing, contributed equally to validation, and served in a supporting role for conceptualization, formal analysis, and writing – original draft. Brian T. Gillis and Mina Shimizu contributed to methodology equally. Brian T. Gillis, Mina Shimizu, and Lauren E. Philbrook contributed to writing – original draft equally. Brian T. Gillis, Mina Shimizu, and Lauren E. Philbrook contributed to writing – review & editing equally.

Keywords

race; sleep; physical activity; health; adolescents

Black–White disparities in sleep duration among adolescents in the United States are well-documented (Basch, Basch, Ruggles, & Rajan, 2014; Guglielmo, Gazmararian, Chung, Rogers, & Hale, 2018; Mitchell et al., 2020), with estimates ranging from 12 to 36 fewer minutes per night for Black than White youth (Guglielmo et al., 2018). Consequences of short sleep during this important developmental time period are broad, including increased likelihood of depressive symptoms (Short, Gradisar, Lack, & Wright, 2013), higher rates of involvement in risk-taking behaviors such as alcohol use (Owens, Adolescent Sleep Working Group, & Committee on Adolescence, 2014), impairment of academic functioning (Short et al., 2013), and early markers of cardiovascular and metabolic diseases (Martinez-Gomez et al., 2011).

In adolescence, age-related changes in circadian rhythm and social demands threaten the length of teens' nightly sleep opportunity and duration (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). Although risk for short sleep is greater for Black youth compared to White adolescents (Petrov & Lichstein, 2016; Yip et al., 2019), it is important to note that not all Black youth experience short sleep (Philbrook, Buckhalt, & El-Sheikh, 2020). Assessment of moderation models is needed to identify protective and vulnerability factors for short sleep. Physical activity is one potential moderator given its association with longer sleep duration in adolescence (Gerber et al., 2014). Although the literature linking physical activity to sleep is mixed, there is evidence that greater physical activity promotes better sleep-wake regulation via changes in sleep physiology, such as decreased sleep onset latency and increased slow-wave sleep (Kalak et al., 2012), which may be associated with longer sleep duration.

A 2018 workshop convened by the National Institute on Minority Health and Health Disparities, the National Heart, Lung, and Blood Institute, and the National Institutes of Health Office of Behavioral and Social Sciences Research called for the identification of factors that may reduce racial and ethnic differences in sleep (Jackson, Walker, Brown, Das, & Jones, 2020). The present study is consistent with this recommendation and examines physical activity as a moderator of risk that could mitigate disparities in sleep duration across Black and White adolescents. Such a moderation model has not been tested and may explicate the role of a modifiable variable that attenuates or amplifies risk for short sleep duration. Using actigraphy, we examined actual sleep duration (indexed by sleep minutes and also referred to as total sleep time in the literature), which reduces potential systematic biases associated with self-reported sleep (Guglielmo et al., 2018). We expected that a higher level of physical activity would function as a protective factor and lessen differences in sleep duration commonly found between Black and White youth.

Method

Participants

Participants were recruited by letters sent home through schools in semirural and small towns in the Southeastern United States. The sample ($N = 246$; 52.85% female; M_{age} = 15.79 years, $SD = 9.58$ months) was representative of its community with regard to race/ethnicity (reported by mothers)—32.93% Black/African American ($n = 81$; 56.79% female) and 67.07% White/European American ($n = 165$; 50.91% female)—and socioeconomic status (SES). SES also was based on mothers' reports and was operationalized as relative poverty using income-to-needs ratio, the quotient of family income divided by the federal poverty threshold for a family's household size (U.S. Department of Commerce, 2012). Nearly 14.29% of participants' families were classified as poor (ratio ≤1), 29.41% were low-income (ratio 1–2), 47.06% had adequate income (ratio 2–4), and 9.24% were affluent (ratio >4; Diemer, Mistry, Wadsworth, López, & Reimers, 2013).

Procedure

The university Institutional Review Board approved study procedures; consent was obtained from parents, and assent was obtained from adolescents. Youth wore actigraphs at home for seven consecutive nights during the school year and visited a campus laboratory, where they reported on frequency of physical activity, an average of 3.96 days ($SD = 12.25$) after actigraphic data collection. Adolescents' height and weight were obtained during the laboratory visit using a wall-mounted stadiometer and Tanita digital scale; these were used to derive standardized body mass index (zBMI).

Measures

Physical activity.—Youth completed the well-established Physical Activity Questionnaire for Adolescents (Kowalski, Crocker, & Kowalski, 1997). This survey measures frequency of involvement in physical activity over the previous seven days through a variety of questions assessing participation in particular sports and common exercises, engagement in activities at various times such as after school, during physical education, and on weekends, as well as use of leisure time for physical activity. Items ask participants to report on physical activity in any setting, including home, school, work, organized sports, or elsewhere; however, participants do not specify the setting in which physical activity occurred. Responses on each item range from 1 (*less-frequent activity*) to 5 (*more-frequent activity*), and the mean of all items represents the total score, which was used in analyses (eight items; $\alpha = .82$ in the study sample). This instrument has strong psychometric properties and corresponds well with objective measurement of physical activity by accelerometry (Saint-Maurice, Welk, Bartee, & Heelan, 2017).

Sleep duration.—Adolescents wore actigraphs (Ambulatory Monitoring, Ardsley, NY) on their nondominant wrists and, per established procedures, completed sleep diaries to facilitate actigraphy scoring. Sleep data were collected in 1-min epochs using zero-crossing mode and were scored in ActionW2 (Ambulatory Monitoring). Sleep duration was indexed by *sleep minutes*, comprised of the total minutes scored as asleep from sleep onset to wake time, exclusive of night awakenings.[1] Based on the software and the Sadeh algorithm

(Sadeh, Sharkey, & Carskadon, 1994), sleep onset was defined as the first of at least 3 consecutive minutes scored as sleep, and wake time as the last of at least 5 consecutive sleep minutes before wake, with corroboration of sleep diaries. Data were excluded when diary-reported sleep onset and wake times differed by more than 30 min from sleep actigraphy; this was a rare occurrence because participants pressed a button on the actigraph when they attempted to fall asleep and when they woke in the morning, which produced event marks in the actigraphy files. Nights on which participants took medication for acute illnesses also were excluded. After exclusions, 33.74% of youth had seven nights of sleep data; 26.42% had six nights, and 18.29% had five nights. Sleep data were treated as missing for the remaining 21.55% of participants who had fewer than five nights of actigraphy (Meltzer, Montgomery-Downs, Insana, & Walsh, 2012). The 53 participants whose sleep data were excluded (n = 27 Black adolescents; n = 26 White adolescents) did not differ from the rest of the sample in their physical activity levels or sleep minutes. Participants whose data were treated as missing were not excluded from analyses, and missing data was handled statistically (detailed in the Analysis Plan section). Sleep minutes had high stability over the week (α = .75), and the average across nights was used in analyses.

Covariates variables.—Covariates included sex (0 = female, 1 = male), family income-to-needs ratio, and zBMI.

Analysis Plan

To examine the moderation effects of physical activity on relations between race and sleep duration, an interaction term (Race × Physical Activity) was created and included in multiple regression models, along with predictors (race and physical activity) and covariates. Covariates were entered in the first step, main effects of race and physical activity in the second step, and the interaction of race and physical activity in the third step. Analyses were conducted in Amos 24. Study variables were not skewed, and all continuous exogenous variables were mean-centered. Correlated exogenous variables were covaried with one another, and missing data were handled with full information maximum likelihood (FIML). Missingness for study variables ranged from 0% to 21.55%, which is well within the range acceptable for use of FIML (Enders, 2001). Further, FIML has been shown to have the least-biased estimates and the lowest Type-I error rates compared to other methods such as listwise or pairwise deletion (Enders, 2001; Raykov, 2005). For significant interactions, simple slope analyses were conducted using an online utility (Preacher, Curran, & Bauer, 2006) and plotted at ± 1 *SD* from the mean of the moderator (physical activity).

Results

Table 1 presents descriptive statistics and Pearson correlations. Independent-samples t tests examined potential Black–White differences in study variables (see Table 2). Compared to White participants, Black adolescents came from families with lower SES, had higher BMI, and slept an average of 25.55 fewer minutes per night. Sex differences in study variables also were examined. Compared to males, females reported lower physical activity, $t(230)$ =

[1]Analyses also were conducted using actigraphic measures of sleep quality, including sleep efficiency, sleep onset latency, number of long-wake episodes, and sleep activity as outcomes. No results were significant (ps = 0.37–0.91).

−3.65, $p < .001$; females: $M(SD) = 2.20$ (0.81); males: $M(SD) = 2.62$ (0.92), and had longer sleep duration, $t(191) = 3.49$, $p = .001$; females: $M(SD) = 418.78$ min (53.36); males: $M(SD) = 391.88$ min (53.24). There was no relation between race and sex in the sample, $\chi^2(1, N = 246) = 0.75$, $p = .39$.

Physical activity moderated relations between race and sleep minutes (Table 3; Figure 1). Overall, the model explained 18.4% of the variance in sleep minutes (medium effect size, $f^2 = .22$), of which the moderation effect of physical activity accounted for 2.6% of unique variance. Simple slope analyses revealed no association between race and sleep minutes at higher levels of physical activity, demonstrating that predicted means for sleep minutes are relatively high and do not vary among more active Black and White adolescents. However, an association between race and sleep minutes emerged for more sedentary adolescents, with Black youth obtaining 42.28 fewer minutes per night on average than their White peers—a difference of 0.75 *SD*. Thus, higher levels of physical activity served as a protective factor and lessened Black–White disparities in sleep duration, whereas lower physical activity operated as a vulnerability factor for Black adolescents.

Discussion

As hypothesized, physical activity moderated relations between race and sleep duration. Black adolescents with lower levels of physical activity were at greatest risk for shorter sleep duration, while all other youth had similar and relatively long sleep duration. Findings demonstrate that Black–White disparities in sleep duration (Guglielmo et al., 2018) are eliminated at higher levels of physical activity. The size of our moderation effect, 2.6% of 18.4% of total explained variance, is satisfactory in social science (Cohen, Cohen, West, & Aiken, 2003) and similar to that of prior work (El-Sheikh, Kelly, Sadeh, & Buckhalt, 2014). These findings are noteworthy and highlight the importance of examining interactions between race and other individual-difference variables that can operate as protective factors for key health outcomes including sleep.

Although we did not address mechanisms of effects and cannot discern from the study why the protective function of exercise was particularly evident for Black adolescents, there are some tentative possibilities. For example, although factors such as morning circadian preference (Malone, Patterson, Lozano, & Hanlon, 2017), socioeconomic adversity and its correlates (Petrov & Lichstein, 2016), or genetic difference (Halder et al., 2015) may increase risk for shorter sleep duration among Black adolescents relative to Whites, they may function primarily in the presence of additional risk factors such as low physical activity. This phenomenon would be consistent with a literature showing that low physical activity is associated with poorer sleep-wake regulation (Brand et al., 2010; Kalak et al., 2012) and specifically exacerbates risk for negative outcomes in the context of environmental stressors (Norris, Car roll, & Cochrane, 1992; Sigfusdottir, Asgeirsdottir, Sigurdsson, & Gudjonsson, 2011).

For Black adolescents, higher levels of physical activity protected against short sleep. Race-related factors may act on similar sleep processes promoted by exercise. For example, both a higher genetic percentage of African ancestry (Halder et al., 2015) and greater experiences of racial discrimination (Tomfohr, Pung, Edwards, & Dimsdale, 2012) have been found to predict less slow-wave sleep among Black adults. Thirty minutes of daily moderate-intensity exercise over a 3-week period, on the other hand, has been linked to an increase in slow-wave sleep relative to baseline among adolescents (Kalak et al., 2012). Although we examined sleep duration and not sleep architecture, it is possible that physical activity is protective because of its associations with various sleep/wake parameters. These plausibilities merit further investigation, and if these potential pathways are tested and supported empirically, then physical activity may be considered as a prevention and intervention strategy to promote longer sleep for some youth.

The feasibility of a prevention or intervention program likely is dependent in part on an adolescent's neighborhood context (Spence & Lee, 2003). Prior work has shown that Black adolescents, regardless of SES, are more likely than their White counterparts to live in neighborhoods with higher levels of violence (Zimmerman & Messner, 2013), which may limit the number of safe places and times of day to exercise, thereby reducing physical activity and increasing risk for short sleep (Philbrook & El-Sheikh, 2016). Of note, however, in the present study there were no differences in overall levels of physical activity between Black and White adolescents.

Though the questionnaire used to examine physical activity has been validated against accelerometry (Saint-Maurice et al., 2017), limitations of this study include its reliance on self-reported data. In addition, our measure of physical activity did not allow for assessment of the specific setting of such activity (e.g., school, neighborhood), which prohibits the differentiation between effects of energy expenditure versus increased time in structured activities, for example. Future investigations of pertinent research questions could benefit from an objective assessment of physical activity and a diary that records the setting of activity. Further, generalizability of results cannot be ascertained beyond the demographics of the community sample including age, geographic locale, and SES levels. Nevertheless, the study provides novel evidence that physical activity is a protective factor against short sleep otherwise observed for Black youth. Given the connection of sleep to myriad aspects of adolescents' functioning, including physical and mental health (Martinez-Gomez et al., 2011; Short et al., 2013), increasing physical activity, and extending sleep duration may help to promote healthy outcomes across multiple domains of development.

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Public Significance Statement

On average, Black/African American teenagers sleep less at night than White/European American teens. In our study, physical activity eliminated this difference: Black youth who were more physically active slept as long as White adolescents, using an objective measurement of sleep. Further, Black youth with lower levels of physical activity tended to have the shortest sleep. Thus, increasing physical activity may be one avenue for promoting longer sleep, especially among Black adolescents.

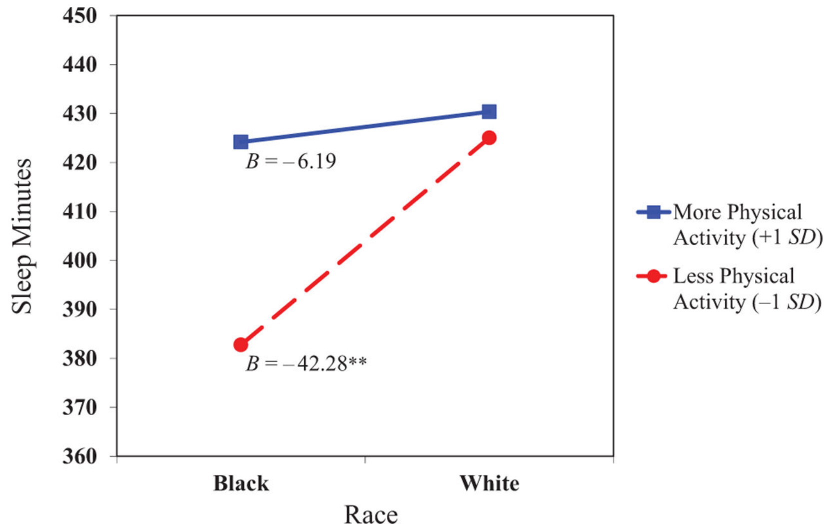

Figure 1.

Physical activity as a moderator of relations between race and adolescents' sleep duration. Sleep duration is indexed by sleep minutes. Analyses control for sex, socioeconomic status, and standardized body mass index. $^{**}p < .01$.

Table 1

Descriptive Statistics and Correlations Among Continuous Variables

Variable	*n*	*M*	*SD*	1	2	3	4
1. SES	238	2.39	1.31	1.00			
2. zBMI	225	.87	.98	−.09	1.00		
3. Physical activity	232	2.40	.89	.06	.00	1.00	
4. Sleep minutes	193	406.37	54.84	.16*	−.03	.06	1.00

Note. SES = socioeconomic status, operationalized as family income-to-needs ratio; zBMI = standardized body mass index. 406.37 min = 6.77 hr.

* $p < .05$.

Table 2

Race Differences in SES, zBMI, Physical Activity, and Sleep Duration

Variable	White *M*	White *SD*	Black *M*	Black *SD*	*t*-value
SES	2.64	1.28	1.87	1.22	4.40***
zBMI	0.77	1.00	1.07	0.94	−2.18*
Physical activity	2.39	0.91	2.40	0.86	−0.06
Sleep minutes	413.52	50.27	387.97	61.93	2.71**

Note. SES = socioeconomic status, operationalized as family income-to-needs ratio; zBMI = standardized body mass index. Race: 0 = White, 1 = Black.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 3

Moderation Effects of Physical Activity on Black–White Disparities in Sleep Duration

Variable	*B*	*SE*	β	R^2	ΔR^2	f^2
Step 1						
Sex (male)	−31.54***	7.45	−.28***			
SES	4.40	2.92	.10			
zBMI	−.69	3.87	−.01	.086		
Step 2						
Race (Black)	−24.23**	51.55	−.21**			
Physical activity	2.98	5.22	.05	.158	.072	
Step 3						
Race × Physical Activity	20.28*	8.98	.18*	.184	.026	.22

Note. SES = socioeconomic status, operationalized as family income-to-need ratio; zBMI = standardized body mass index. Variables were entered in steps, but coefficients are reported from the final model. Sex: 0 = female, 1 = male. Race: 0 = White, 1 = Black. ΔR^2 = change in R^2. f^2 = Cohen's effect size: $f^2 \geq .02$ (small), $f^2 \geq .15$ (medium), and $f^2 \geq .35$ (large).

* $p < .05$.

** $p < .01$.

*** $p < .001$.

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