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Sleep problems predict cortisol reactivity to stress in urban adolescents

Sylvie Mrug [a,*], Anna Tyson [a], Bulent Turan [a], Douglas A. Granger [b,c]

[a] Department of Psychology, University of Alabama at Birmingham, 1720 2nd Ave South, Birmingham, AL 35294, United States
[b] Institute for Interdisciplinary Salivary Bioscience Research, Arizona State University, Tempe, AZ 85287, United States
[c] Johns Hopkins University School of Nursing, Johns Hopkins University Bloomberg School of Public Health, Johns Hopkins University School of Medicine, Baltimore, MD 21287, United States

HIGHLIGHTS

- Sleep problems predicted greater cortisol reactivity to stress in urban adolescents.
- Longer sleep duration predicted post-stress cortisol over sleep problems.
- Self-reports of sleep were more consistently related to cortisol than parent reports.
- Effects of sleep problems on cortisol levels were stronger in girls than boys.

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ABSTRACT

This study examined the role of sleep problems and sleep duration on stress-related HPA axis reactivity among urban, low income adolescents. A total of 84 adolescents (M age 13.36 years; 50% male; 95% African American) and their parents provided information on adolescents' sleep problems and sleep quantity. Adolescents completed a standardized social stress test in the laboratory (the Trier Social Stress Test; TSST). Saliva samples collected before and after the TSST yielded measures of cortisol pre-test, 15 min post-test, and 55 min post-test, as well as overall cortisol secretion and its increase (AUC_G and AUC_I). More sleep problems and longer sleep duration predicted higher cortisol reactivity to the TSST, particularly among females. Self-reports of sleep were more consistently related to stress-related cortisol reactivity than parent reports. Sleep problems and longer sleep duration may place adolescents at risk for HPA axis hyper-reactivity to stress, contributing to academic, behavioral and health problems.

1. Introduction

Almost 70% of US adolescents do not receive sufficient sleep (8 or more hours per night) and only 8% report optimal sleep duration of 9 or more hours [12]. Both insufficient sleep and sleep problems contribute to cognitive problems and poor mental and physical health over time [35]. Since adequate sleep is necessary for optimal functioning of the HPA axis [42] and dysregulation of the HPA axis contributes to cognitive, emotional, and health problems [24], alteration of HPA axis activity has been proposed as a key mechanism through which sleep problems lead to negative outcomes [27]. The relationship between sleep and HPA axis activity has been studied in children and adults, but little is known about this link during adolescence when both sleep and the HPA axis undergo significant developmental changes related to puberty [10,35].

Among prepubertal children and adults, insufficient sleep and sleep problems consistently predict elevated cortisol levels throughout the day [13,19,22,27,32,38]. The only study conducted with adolescents found no effect of sleep restriction on morning and evening cortisol levels [43], but the study was limited by small sample sizes in each experimental condition (n = 12 to 17). Children with sleep problems and sleep deprived adults also had greater cortisol reactivity to stress [19,27,38], but lower stress reactivity was observed in adult women with lower objectively measured sleep quality [46] and in 10–12 year olds with more self-reported sleep–wake problems [8]. In the latter study, there was no link between sleep–wake problems and cortisol reactivity among adolescents (13–17 years old); however, the conclusions are limited by a small sample size (N = 31 across both age groups) and the use of parent reports of sleep problems. Parent reports of sleep problems have been validated for pre-adolescent children [3], but they tend to underestimate older children's sleep problems [33] and may be particularly inaccurate for adolescents who receive less parental supervision [1].

Given the paucity of research on sleep and HPA axis in adolescence, this study sought to examine the effects of sleep on HPA axis activity in this age group. Specifically, we examined two dimensions of sleep — sleep duration and sleep problems, from the perspectives of adolescents and their parents, as well as cortisol levels before and after social stress.

* Corresponding author at: Department of Psychology, University of Alabama at Birmingham, 1720 2nd Ave S, CH 415, Birmingham, AL 35294-1170, United States.
E-mail address: smrug@uab.edu (S. Mrug).

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Because urban African American adolescents are more likely to experience insufficient sleep [1,26] and their functioning is more negatively affected by lower sleep quality [5], we focused on the understudied population of urban and mostly African American adolescents. We hypothesized that shorter sleep duration and more sleep problems will predict higher cortisol levels and reactivity to stress (i.e., a social evaluative threat). Finally, because cortisol reactivity to stress in urban, African American adolescents and young adults varies by gender [2,11], we also examined gender differences in the effects of sleep on stress-related cortisol regulation and reactivity.

2. Material and methods

2.1. Participants and procedures

Participants were 84 adolescents (M age 13.36 years, SD = 0.95; 50% male; 95% African American, 4% Caucasian and 1% Hispanic) who took part in the Coping with Violence Study. The sample was socioeconomically heterogeneous, but comprised primarily low-income families; average annual family income was $20,000–$25,000 (range <$5000 to $70,000–$90,000) and average parental education was some college but no degree (see Table 1 for sample characteristics). The adolescents were recruited from four public middle schools (grades 6–8 or 9) serving low income, urban communities in Birmingham, AL. Across the four schools, 83% to 87% of students were eligible for free or reduced price lunch. Students received an envelope that contained a description of the study, contact information form, and informed consent and assent forms. Families interested in participating were instructed to return a completed contact information form to the school. These families were later contacted by study staff and scheduled for an interview at a university laboratory. From approximately 240 invited students, 129 (54%) provided their contact information and 84 of those (65%) completed the interview (recruitment was curtailed by limited resources). After providing parental informed consent and child assent, parents and adolescents were interviewed separately in private spaces by trained interviewers using computer assisted technology. The adolescent interview included anthropometric measurement of height and weight, as well as the Trier Social Stress Test-Children's version (TSST-C; [7]) with saliva samples collected before and after the TSST-C (see Fig. 1 for a timeline of interview procedures). Following recommendations by Granger et al. [16], all interviews were conducted in the afternoon (between 3 and 6 pm) to minimize the effects of diurnal variation in cortisol production on the likelihood of detecting an increase in cortisol levels in response to the TSST-C. None of the adolescents were diagnosed with any psychiatric disorders (per parent report) or were taking any medications [17] that would affect cortisol levels (per self-report). The interview session took two hours to complete, and adolescents and their caregivers were compensated for their time with $50 gift cards. All procedures were approved by the university Institutional Review Board.

Table 1
Descriptive statistics.

	Adolescent report		Parent report	
	M (SD)	Range	M (SD)	Range
Bedtime weeknight	22:00 (0:59)	19:00–24:00	21:32 (1:00)	19:50–1:00
Wake time weeknight	6:00 (0:32)	4:00–6:52	6:00 (0:32)	4:45–7:00
Bedtime weekend	23:50 (1:47)	20:00–6:00	23:23 (1:28)	20:00–3:00
Wake time weekend	9:32 (2:25)	5:00–15:00	9:13 (1:48)	6:00–13:00
Sleep quantity, hours	8.73 (1.12)	5.57–11.71	8.87 (1.15)	5.21–11.79
Sleep problems	1.90 (0.41)	1.23–3.20	1.57 (0.34)	1.00–2.81
Pubertal development	2.64 (0.65)	1.00–4.00	2.48 (0.63)	1.00–4.00
		Other measures		
Child age, years		13.36 (0.95)		11.82–16.56
Pubertal development		2.56 (0.57)		1.10–3.75
BMI%		74.15 (26.43)		0.60–99.80
Family income[a]		5.22 (3.30)		1–12
Parental education[b]		4.67 (2.05)		2–8
Pre-test cortisol, μg/dL		0.10 (0.10)		0.02–0.59
15 min post-test cortisol, μg/dL		0.11 (0.15)		0.02–0.94
55 min post-test cortisol, μg/dL		0.07 (0.09)		0.00–0.50
Area under the curve, ground (AUC_G)		6.77 (7.61)		1.34–51.75
Area under the curve, increase (AUC_I)		−0.65 (7.05)		−29.50–39.49

Note:
[a] A 13-point scale from 1 (<$5000/year) to 13 (>$90,000/year).
[b] An 8-point scale from 1 (less than 9th grade) to 8 (graduate or professional degree).

2.2. Measures

2.2.1. Sleep quantity

Adolescents and parents were asked at what time the adolescent usually goes to bed and wakes up, separately for weekdays and weekends or holidays. The bedtime and waking times were used to compute typical sleep duration on weekday and weekend nights, respectively. Then, the average daily amount of sleep was derived for a typical week consisting of five weekdays and two weekend days, separately for each reporter.

2.2.2. Sleep problems

A 22-item scale from the Sleep History section of the Adolescent Sleep Habit Survey [34] was used to measure adolescents' sleep problems. The items inquired about the frequency of various sleep problems during a typical week, including disruptions to the wake-sleep cycle (e.g., staying up late), insomnia (e.g., difficulty falling or staying asleep), daytime sleepiness (e.g., falling asleep during the day), parasomnias (e.g., nightmares), sleep disordered breathing (e.g., snoring, gasping for breath), and general sleep quality (e.g., satisfied with sleep; reverse coded). The same questions were completed by adolescents and parents using a 5-point scale ranging from 'Never' (1) to 'Every day' (5). Factor analyses confirmed that all items loaded on a single dimension. The responses were averaged (adolescent $\alpha = .73$; parent $\alpha = .64$).

2.2.3. Trier social stress test

After getting acclimated to the lab environment and being interviewed for approximately 30 min, adolescents completed the TSST-C [7]. Adolescents were given five minutes to prepare the ending to a story and then five minutes to tell that story in front of two judges. Next, the judges asked the participants to perform serial subtraction for 5 min (subtracting 7 starting at 758). However, if the adolescents made five mistakes in a row, they were given an easier task (subtracting 3 starting at 307). The judges wore white coats and provided no positive feedback; the participants were also videotaped during the test.

2.2.4. Saliva collection and determination of cortisol

Whole saliva samples were collected by passive drool [16] immediately before the TSST began (pre-test), 30 min after the 15-min test began (15 min post-test), and 70 min after the test began (55 min post-test). Samples were immediately frozen at −20 °C and later shipped on dry ice overnight to the Johns Hopkins University's Interdisciplinary Salivary Bioscience Center where they were kept frozen at −80 °C until assayed. Cortisol was assayed in duplicate by commercially available enzyme immunoassay without modification to the manufacturers recommended protocol (Salimetrics, Carlsbad, CA). Sample test volume was 25 μl, the range of sensitivity was from .007 to 3.0 μg/dL, and the inter- and intra-assay coefficients of variation were, on average, less than 15% and 10%, respectively. The average of the duplicate assays was used in all statistical analyses. Units of cortisol are presented in μg/dL (micrograms/deciliter).

2.2.5. Covariates

Possible covariates included time of day when saliva samples were taken, adolescents' age and gender, family income and parental education (reported by parents on 13- and 8-point scales, respectively), adolescents'