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The Role of Daily Activities in Youths' Stress Physiology

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Abstract

Purpose—This study examined links between diurnal patterns of the stress hormone, cortisol, and adolescents' time in nine common daily activities.

Method—During eight consecutive nightly telephone interviews, 28 youths ($n = 12$ girls), 10–18 years of age, reported their day's activities. On four days, four saliva samples also were collected and assayed for cortisol. Multilevel models assessed within- and between-person associations between time in each activity and cortisol Area Under the Curve (AUC), cortisol awakening response (CAR), morning peak (30 minutes after wake up) and daily decline (morning peak to bedtime).

Results—Links with AUC were found for most activities; significant associations with cortisol rhythms suggested that most effects were due to anticipation of the day's activities. Specifically, on days when youths spent more time than usual on videogames and TV they had lower AUCs, with lower morning peaks. Youths who spent more time reading (within-person) and in computer activities (between-person) had higher AUCs, with stronger CARs (within-person). Youths who slept more had lower AUCs, with lower morning peaks on both the between- and within-person levels. Amounts of time spent in clubs, and for older adolescents, sports, were also linked to lower AUCs. Finally, youths who spent more time in school/schoolwork had lower AUCs, but on days when youths spent more time than usual in school, they had higher AUCs, stronger CARs, and steeper daily declines.

Conclusion—Beyond their known implications for psychological adjustment, youths' everyday activities are linked to stress physiology.

Keywords

stress; salivary cortisol; daily activities; time use

Introduction

The daily activities of children and adolescents are ecologically meaningful and developmentally significant (Bronfenbrenner, 1979). How youths spend their time—in sports, watching TV, doing schoolwork—reflects opportunities and supports as well as demands and constraints in their environments (Lareau, 2003), and a body of research

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documents links between youths' daily activities and psychological adjustment (Larson & Verma, 1999). We know much less about the role of daily activities in youths' physical health. Our study addressed this topic, using a daily diary design to illuminate links between youths' time in 9 common activities-- sleep, school/homework, chores, sports, video/computer games, other computer activities, television, clubs, and reading--and their daily stress physiology, indexed by diurnal patterns of the stress hormone, cortisol.

How youths spend time may affect their psychological health through several mechanisms. In daily activities, youths develop and practice skills and build social ties; their involvement in particular activities also shapes their identities, for example, as jocks or geeks (Eccles & Barber, 1999). Although daily activities also can be a source of stress, such as when responsibilities or performance expectations tax youths' capacities (Lareau, 2003), we know little about the links between youths' daily activities and stress physiology.

We examined hypothalamic-pituitary-adrenal axis (HPA) activity, reflected in diurnal salivary cortisol patterns, to illuminate how youths' daily activities can get under the skin to affect their health. The HPA-axis plays a vital role in linking stressor exposure to physical health (McEwen, 1998) in that cortisol can affect many biological systems essential to healthy functioning. Early studies documented elevated salivary cortisol responses to laboratory-controlled stressors in youth (Gunnar, Talge, & Nerrera, 2009), but this research increasingly focuses on naturally-occurring stressors (Adam, 2006). We examined diurnal cortisol Area Under the Curve (AUC), an estimate of total daily cortisol output, to index HPA-axis response to youths' everyday experiences; in prior research, more stressful life circumstances (violence exposure; economic hardship) were reflected in higher AUCs in children and adolescents (Gustafsson, Gustafsson, & Nelson, 2006; Suglia, Staudenmayer, Cohen, & Wright, 2010). Following recent research (e.g., Zeiders, Doane & Adam, 2011), we also examined three components of diurnal rhythm: the *cortisol awakening response* (CAR; increase in cortisol 30 minutes following wake up), *morning peak* (level of cortisol at 30 minutes), and *daily decline* (from peak until bedtime). The former two indices reflect anticipation of the days' activities, whereas the latter reflects the body's ability to wind down across the day in preparation for sleep. Examining AUC and diurnal rhythm is important given that lower AUCs can reflect a healthy pattern of daily decline, but lower AUCs with blunted CARs and morning peaks may reflect health problems (Suglia et al., 2010).

Sleep is one activity with established links to cortisol rhythms in youth. Poor sleep quality predicted higher AUC during a stress response task and higher morning and afternoon cortisol levels in young children (Hatzinger, Brand, Perren, et al., 2008; El Sheikh, Buckhalt, Keller, et al., 2008). In a diary study of older adolescents and young adults, more hours of sleep predicted steeper daily declines in cortisol (Zeiders, Doane, & Adam, 2011). We aimed to replicate these findings in an adolescent sample.

Research on links between cortisol and *school attendance* reveals elevated cortisol in young children's transition to school (Bruce, Davis, & Gunnar, 2002). We built on this work to test links between cortisol and time in school and homework, reasoning that performance pressures would be linked to higher AUCs, including stronger CARs, higher morning peaks, and possibly, lower daily declines. Research, primarily on adults, shows that cortisol levels may be higher on weekdays than weekends (e.g., Kunz-Ebrecht, Kirschbaum, Marmot & Steptoe, 2004); by directly measuring youths' time in school-related activities, we extend this work to illuminate proximal factors in weekday-weekend differences in AUC.

Household chores are another common activity for youths. Although not yet linked to cortisol, adolescents' family responsibilities were linked to higher levels of C-reactive

protein, a measure of inflammation associated with stress (Fuligni, Telzer, Bower, et al., 2009). Accordingly, we predicted that time in chores would be positively associated with cortisol AUC, CAR and peak, and negatively linked to daily decline.

One study that examined links between cortisol levels and *physical activities* showed that a regular exercise regimen resulted in lower 24-hour urinary cortisol in adolescent girls with depressive symptoms (Nabkasorn, Miyai, Sootmongkol, et al., 2006), but Kertes and Gunnar found higher bedtime cortisol in school age boys on days they were involved in structured activities, particularly team sports. We build on this work, studying a non-clinical sample of girls and boys and examining AUCs as well as CAR, morning peak, and daily decline as a function of daily sports involvement.

A study of youths' time spent on *information and communication technology* (Wallenius, Hirvonen, Lindholm, et al., 2010) found links with lower AUCs, and the investigators suggested that emotional arousal may have blunted cortisol activity. Activities ranging from telephone conversations to homework on computers were collapsed into one category, however, and low versus high technology users were compared. We extended this work, splitting apart technology activities into *video/computer games*, *other computer activities* (e-communications; internet surfing), and *television*, measuring involvement in each in terms of temporal duration, and including parameters of diurnal rhythm in addition to AUC.

We also explored links between cortisol patterns and activities that have been associated with psychological health, though not yet to stress physiology. Youths' involvement in organized activities such as *clubs*, for example, is related to less risky behavior (Eccles & Barber, 1999) and time spent *reading* is linked to achievement (Mol & Bus, 2011). We tested whether time in these activities showed corresponding associations with healthful cortisol patterns.

We used a daily diary design to assess links between youths' daily activities and cortisol, an approach that is increasingly used to assess the role of daily experiences for cortisol (Adam, 2006; Almeida, 2005; Zeiders et al., 2011). Collecting *daily* data on activities helps to alleviate memory distortions and self-concept biases that can occur in questionnaire and interview methods wherein individuals are asked to recall experiences over a long and often unspecified time (Huston & Robins, 1982). Obtaining information about daily activities also circumvents concerns about the ecological validity of laboratory studies of stress (Adam, 2006). A diary design also allows assessment of within-person processes, shifting attention from the usual focus on *between-person* associations to day-to-day variations in stress physiology *within individuals* and linking these to variations in individuals' daily experiences (Almeida, 2005). Importantly, this within-person approach allowed us to rule out stable personality and contextual factors as third variable explanations for activity-cortisol linkages.

Methods

Participants

The data came from the Hotel Work and Well-Being Study of employees in full-service hotels across the U.S. (Almeida, Davis, Crouter, et al., in press). Hotel workers are part of a service industry that operates 24 hours a day, 7 days a week, making them an ideal focus for our larger study of work-family stress. Participants were recruited from full-service hotels across the U.S. From referrals by the President of the American Hotel & Lodging Association and representatives from municipal hotel associations, 121 hotel general managers were invited, and 53.7% agreed to participate.

As part of this project, we conducted a diary study of hourly (non-salaried) hotel workers with 10-18 year old children, the focus of these analyses. Criteria for employee participation included: (a) working for an hourly wage; (b) proficiency in English; and (c) having a child, age 10 to 18 years, living at home and willing to participate. Of the 105 eligible hourly employees, we recruited 64 employee-child dyads, and 36 youths participated in the diary and saliva collection. We excluded youths who completed the diary in summer due to differing time demands, $n = 5$, and those who provided insufficient saliva samples or timing information to calculate AUC, $n = 3$, leaving 28 youths for these analyses. Youths averaged 13.30 years of age ($SD = 2.30$) and 60% were boys. Most (68%) were from African American, 7% were from Hispanic, and the rest were from non-Hispanic-White families. About two thirds came from two-parent families, and annual family income averaged \$26,766 ($SD = \$10,637$). About 60% of employee parents had high school educations or less, and 20% had a college degree. The University Institutional Review Board approved the protocol, and (audio-recorded) oral consent (from parents) and assent (from youths) were obtained. Youths were sent a \$50 gift card for their participation.

Procedures and Measures

Daily activities were assessed in each of eight consecutive nightly interviews using the Daily Inventory of Stressful Events-Youth Version (Almeida, 2005). We used a cued-recall procedure to obtain youths' reports of how much time they spent in 8 activities: *TV, videogames, other computer activities* (e.g., internet surfing; e-communication), *sports, clubs, school/homework, reading and chores*. *Sleep* duration also was assessed on saliva collection days 2, 3 and 4 via youths' reports of their bedtime and wake up saliva collection times. Although these reports may overestimate sleep duration, they likely capture between- and within-individual differences in sleep time.

Daily stress physiology was assessed via salivary cortisol, assayed from 4 samples (wake up, 30 minutes after wake up, after school, before bed) collected on diary days 2, 3, 4, and 5 (a total of 16 samples), using a saliva collection kit mailed to each youth with instructions for completing the samples and recording collection times (Granger & Kivlighan, 2003). Instructions were also reviewed during the first phone interview, and interviewers reminded youths on the evenings prior to scheduled collections. Youths rolled a cotton swab across their tongue for two minutes without chewing, placed the swab into its tube without touching it, capped the tube, and refrigerated the sample. When all 16 tubes were ready, parents used a pre-addressed, paid courier package for return mailing to our laboratory for assay.

Salivary cortisol levels were assayed in duplicate in a single assay batch at the university's General Clinical Research Center using commercially available enzyme immunoassay kits (DSL, State College, PA). The sample test volume was 25 μ l. The assay had a lower limit of sensitivity of 0.08 μ g/dl, with average inter- and intra-assay covariances of less than 10% and 5%, respectively. The assay sensitivity (0.011 μ g/dl) is based on the minimum cortisol concentration required to produce a three standard deviation from assay A_0 . Samples from each youth were tested in duplicate in a single batch. Values for data analyses were the averages of duplicate tests. Cortisol data were converted to nmol/ml (μ g/ml $\times$ 27.6) for comparison with published reports. On each day of assessment, we estimated cortisol AUC with respect to ground (AUC-G) using a formula that accounts for variable time intervals between samples (Pruessner, Kirschbaum, Meinlschmid, et al. 2003) as well as the CAR, morning peak, and daily decline.

Results

Preliminary Analyses

Figure 1 shows the estimated average diurnal pattern of cortisol for the four days of measurement. Mean AUC was 186.06 ($SD = 88.51$). Consistent with prior research (Rosmalen, Oldehinkel, Ormel, et al., 2005), 54% of youths exhibited a CAR based on the adult criterion (equal to or greater than 2.5 nmol/l above baseline), 71% exhibited an absolute increase, and all but two exhibited daily declines. Table 1 provides descriptive data on activities. Correlations between activities were generally non-significant to modest, reflecting that time use is zero sum. Weekend-weekday comparisons via t -tests for dependent samples revealed that youths spend more time on TV, videogames and sleeping, but less time on school work on weekend days. Intra-class correlations ($ICCs$) were generally low, indicating that youths tended to be more different from themselves across days (within-person) than they were different from other youths (between-person).

Links between Youths' Daily Activities and Diurnal Cortisol Patterns

Given our sample size, separate analyses were conducted for each activity, in two steps. First, to study activity-AUC linkages, we used two-level, random intercept, multi-level models (days within individuals). At Level 1, the time-covarying predictors (i.e., person mean centered scores for time spent in each activity) were entered, and at Level 2, we included the time-invariant predictors (cross time average of activity time). In separate models we controlled for parent education and medication use. Education did not alter effects so was dropped; the effect of medication slightly altered results only for sleep, so we present findings for the baseline models in all other cases. We also tested whether the within-person links between activities and AUC were moderated by youth age or gender. Second, to follow up on significant activity-AUC links, we estimated three-level piecewise multilevel models; Level 1 focused on samples within day, Level 2 focused on days within person, and Level 3 was the person level (Stawski, Almeida, Lachman, Tun, Rosnick et al., 2011). These piecewise models captured the within day patterns of cortisol with two predictors (or "pieces") that represented the CAR and the daily decline, centered on the 30 minute collection (i.e., morning peak). Several models were estimated to determine the best-fitting model, including random intercepts and pieces; the best fitting model included a random intercept and two random slopes for CAR and decline at the between-person level and a random intercept at the within-person level. To examine how daily activities predicted these "pieces" we entered interactions between both CAR and decline and activity type.

Results revealed links with cortisol for most activities. Significant links between AUC and *time spent playing videogames*, and at trend level, *watching TV* emerged at the within-person level: On days when youths spent more time than usual in each of these activities, their AUCs were lower than on days when they spent less time (Table 2). Additionally, significant, negative, within-person effects emerged for morning peak in the cases of both TV and videogames, as well as CAR in the case of videogames (Table 3), but there were no effects for daily decline.

Time in *clubs* also was linked to lower AUCs at the within-person level, but there was no effect of club time on CAR, morning peak or daily decline, suggesting a healthful pattern of low, but not blunted, AUC. The within-individual effect of *sports* on AUC was significant, but a significant age X sports effect also emerged, $\gamma = -16.05$, $SE = 6.15$, $p < .01$. Follow-up simple slopes tests (Aiken & West, 1991) showed that, for older adolescents only, AUCs were lower on days when youth spent more time than usual in sports (Figure 2). We found no effects of sports on CAR, morning peak, or daily decline for older adolescents, again suggesting that sports time was linked to a healthful pattern of low, but not blunted AUC.

Effects of *reading* on AUC were significant at the within-person level. On days when youths spent more time than usual reading, they had higher AUCs, but follow-up tests revealed links between reading and higher morning peaks as well as steeper declines in cortisol across the day at both between and within-person levels; the latter effect was marginal at the within-person level. *Computer time* was positively related to AUC at the between-person level. It also was linked to steeper CAR and higher morning peak at the between-person level, higher morning peak at the within-person level, and trends for steeper daily declines at both the between and within-person levels.

Findings for time in *school/homework* revealed both within- and between-person effects: On average, youths who spent more time in academics had lower AUC scores, but *on days* when youths spent more time than usual in academics, their AUCs were higher. In addition, on days when youths spent more time in school activities than usual they exhibited a healthy pattern of stronger CARs, higher morning peaks, and steeper daily declines in cortisol than usual. The effects of *sleep* on AUC revealed that youths who slept more had lower AUCs, with negative associations between sleep time and morning peak at the between and within-person levels. There were no significant associations between AUC and time in *chores*.

Discussion

This study built on prior research on youths' stress physiology, indexed by the stress hormone, cortisol, and on research linking youths' daily activities to their psychological adjustment to examine the relations between salivary cortisol and youths' time spent in nine common daily activities. Our findings document clear linkages between youths' daily activities and cortisol. Most associations were at the within-person level and suggested that effects of activities on cortisol were due to anticipation of the day's activities or possibly, that cortisol levels early in the day motivated activity involvement.

Results revealed several patterns of activity-cortisol linkages and that activity-AUC linkages were best understood through also examining within-day levels (i.e., morning peak) and change patterns (CAR and decline). For both TV and videogames we found that lower AUCs--typically thought to reflect more healthful cortisol rhythms-- were characterized by lower morning peaks and weaker CARs. Such a pattern may reflect blunted arousal in anticipation of the day's activities or that low levels of arousal early on led to these more passive and often solitary activities. Notably, these activities were more common on weekend days, when AUCs may be lower (Kunz-Ebrecht et al., 2004). Reflecting a second pattern of activity-cortisol linkage, time in clubs, and for older adolescents, time in sports also were linked to lower AUCs, but in these cases there was no evidence of blunted CARs. A third pattern involved higher AUCs for both reading and computer time, and within-day effects revealed stronger CARs but also trends for steeper daily declines. Youths may use these activities throughout the day to escape from daily stressors. Findings on schoolwork likewise revealed higher AUCs, with stronger CARs and trends for steeper declines on high involvement days (within-person effects). Coupled with a negative link between school time and AUC at the between-person level, this may imply a generally healthful pattern of physiological arousal on especially demanding school days. Finally, links between sleep and lower AUCs were consistent with earlier work, but the analyses also revealed lower morning peaks. Youths slept more on weekend days, which may explain blunted morning arousal.

Importantly, most links between activities and AUC were at the within-person level. By treating the adolescent as his/her own control, we account for stable individual and contextual characteristics that lead some youths to be more involved in a particular activity than others (Raudenbush & Bryk, 1992). For example, in some communities adolescents may have more opportunities to attend clubs, and adolescents with certain genotypes or

those with more supportive parents and more involved friends may be more likely to do so. Prior research shows that youths who spend time in such organized activities are better adjusted (Barber & Eccles, 1999), but here we showed that time in clubs also was linked to stress physiology: Beyond stable individual and contextual differences, youth exhibited more healthful cortisol patterns on days when they spent more time in clubs.

The analyses revealed only one moderation effect: Sports time was linked to lower AUC only in older adolescents. Sports involvement declines across adolescence as youth become increasingly specialized in their extracurricular activities (Madsen, McCulloch, & Crawford, 2009). Sports activities are more common for younger children, but may they may lack the intensity that yields positive health effects.

In addition to its innovative focus on youths' activities, strengths of this study include the daily diary design, which allowed us to move beyond examination of between-individual differences to test whether and how day-to-day differences in youths' activities were linked to day-to-day differences in cortisol. By examining cortisol AUC as an index of total daily output and testing links between activities and three key components of cortisol daily rhythms, we were able to shed light on *how* daily activities may be linked to stress physiology.

A limitation of our study was the small sample, which could limit power to detect activity-cortisol linkages, though studies using this paradigm sometimes have even smaller samples (Stadler, Evans, Hucklebridge, & Chow, 2010). Our intensive within-person design meant that we collected over 200 days of data on youths' activities and almost 450 saliva samples, however, and we detected many of the significant linkages that prior research led us to predict. Also important is that our sample was comprised primarily of low income ethnic minority youths, a group that tends to be difficult to recruit. That more than half of youths recruited into the study completed our labor intensive protocol, together with the novel findings that emerged here, evidences the utility of a diary approach for illuminating the ways in which youths' activities get under the skin to affect their health.

With the exception of research on sleep and exercise, most prior research on youths' time use has focused on its links to psychological adjustment. Our findings suggest that studying physical health also is important--for researchers interested in the implications of youths' activities-- but also for parents, teachers, and community program leaders who are involved in promoting, organizing and supervising youths' daily activities. Examining youths' time use also contributes to the literature on youths' stress physiology in illuminating how diurnal cortisol patterns are linked to measures of ecologically meaningful, everyday experiences.

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Abbreviations

AUC	Area Under the Curve
HPA	Hypothalamic –Pituitary-Adrenal Axis
ICC	Intra-class correlation
ug/dl	microgram/deciliter
ul	microliter
nmol/ml	nanomoles per milliliter

Implications and Contribution

We advance research on youths' stress physiology, using a daily diary approach to collect ecologically valid data on everyday activities and to examine how day-to-day variations in youths' activities are linked to day-to-day variations in diurnal cortisol. We also extend research on youths' activities to document links to physical health.

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Figure 1.
Diurnal cortisol patterns.

Figure 2.
Follow up of age by sports activities interaction

Table 1

Descriptive Statistics; Bivariate Correlations, Intraclass Correlations, and Weekday and Weekend Means (and Standard Deviations) for Activities

Variables	1	2	3	4	5	6	7	8	9
1. Videogames	1.00								
2. Clubs	-.22	1.00							
3. TV	.28	-.11	1.00						
4. Sports	-.02	.40 [*]	-.08	1.00					
5. Sleep	-.14	.15	-.02	.03	1.00				
6. School	.01	.39 [*]	.02	.35 [†]	.33 [†]	1.00			
7. Read	-.18	.52 ^{**}	-.12	.24	-.00	.21	1.00		
8. Computer	.29	-.09	.17	-.18	-.64 ^{***}	-.21	-.04	1.00	
9. Chores	.36 [†]	-.03	-.03	.09	.03	-.05	.07	-.11	1.00
Intraclass correlation	.34	.00	.36	.03	.38	.03	.08	.41	.04
Weekday <i>M</i> (<i>SD</i>)	.27 (.45) ^a	.24 (.33)	1.17 (1.23) ^a	.30 (.39)	8.77 (1.42) ^a	4.41 (1.89) ^a	.14 (.17)	.21 (.34)	.38 (.47)
Weekend <i>M</i> (<i>SD</i>)	.58 (.99) ^b	.10 (.50)	2.34 (1.93) ^b	.43 (.92)	10.08 (1.86) ^b	.28 (.58) ^b	.14 (.50)	.26 (.68)	.54 (.67)

Note: Correlations and means are for person-mean variables.

^{a,b} Weekday and weekend days are significantly different.[†] $p < .10$.^{*} $p < .05$.^{**} $p < .01$.^{***} $p < .001$.

Table 2

Coefficients and Standard Errors for Main Effects of Youths' Activities on AUCs

	Between-Individual Effects		Within-Individual Effects	
	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>
Video/computer games	2.84	32.01	-24.46 [*]	11.57
Clubs	-39.42	61.69	-86.42 ^{**}	31.71
TV	-4.89	13.64	-10.43 [†]	5.80
Sports	-24.07	42.20	-19.00 [*]	8.67
Sleep	-30.69 [*]	12.63	-43.65	61.48
School/homework	-29.44 ^{**}	10.89	7.41 ^{**}	2.60
Read	120.17	85.70	114.44 ^{**}	45.01
Other computer	107.87 ^{**}	35.54	25.35	20.44
Chores	20.67	41.64	16.01	17.95

[†]
 $p < .10$.^{*}
 $p < .05$.^{**}
 $p < .01$.

Table 3
Coefficients and Standard Errors for Main Effects of Youths' Activities on Cortisol Diurnal Rhythm

	Between-Individual Effects						Within-Individual Effects					
	CAR			Decline			CAR			Peak		
	B	SE		B	SE		B	SE		B	SE	
Video games	2.85	4.42		-.43	3.47		.02	.42		-3.85*	1.65	
Clubs	-2.15	10.13		1.93	6.65		-.49	.98		.11	4.35	
TV	2.27	2.03		.25	1.50		-.19	.18		-.56	.93	
Sleep	-1.94 [†]	1.04		-2.65*	1.01		.26	.16		-4.32	3.36	
School/homework	-.91	1.76		-1.77	1.27		-.11	.18		.83*	.33	
Read	13.71	13.87		20.47*	9.03		-3.33**	1.18		13.26 [†]	7.66	
Other computer	19.20**	4.83		10.85*	4.35		-.89 [†]	.52		.77	2.36	

[†] $p < .10$.

* $p < .05$.

** $p < .01$.