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Evening Activities as a Potential Confound in Research on the Adrenocortical System in Children

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The relation among children's evening activities, behavioral characteristics, and activity of the hypothalamic-pituitary-adrenocortical axis was assessed in normally developing children ages 7 to 10 years. Salivary cortisol at bedtime was compared on evenings when children had structured activities outside of the home with unstructured evenings at home in relation to parental reports of children's behavioral characteristics. Participating in evening activities, particularly sport activities, was associated with small increases in bedtime cortisol levels in boys but not in girls. Differences in cortisol on activity versus no-activity nights were negatively related to children's social isolation. These results show that in studies with children, nights on which participants engage in sport activities should be avoided when collecting ambulatory measures of salivary cortisol concentrations.

With the advent of noninvasive salivary cortisol sampling procedures, interest in documenting hypothalamic-pituitary-adrenocortical (HPA) functioning in children has burgeoned. Concern with activity of this neuroendocrine system is predicated on the growing body of literature implicating elevated cortisol levels in the etiology of both mental and physical disorders (Buske-Kirschbaum et al, 1997; Cohen et al., 2002; de Kloet, Vreugdenhil, Oitzl, & Joels, 1998; Granger, Weisz, McCracken, Ikeda, & Douglas, 1996; Haskett, 1993; Heim, Ehlert, & Hellhammer, 2000; Heim, Owens, Plotsky, & Nemeroff, 1997; Lovallo, 1997; Nieman, 2002; Rosch, 1999; Ryan & Dahl, 1993). Although much of the research on HPA axis activity is still conducted using laboratory paradigms, investigators are increasingly using ambulatory assessments in the context of participants' everyday lives (Adam & Gunnar, 2001; Pruessner et al., 1997; Smyth et al., 1998). Such ambulatory measurements allow determination of whether individuals experience elevated cortisol levels in response to the typical events in their lives. For example, in toddlers and young preschoolers, ambulatory assessments have documented increases in cortisol over the day in relation to full-day, out-of-home child care (Dettling, Gunnar, & Donzella, 1999; Tout, de Haan, Kipp Campbell, & Gunnar, 1998; Watamura, Donzella, Alwin, & Gunnar, 2003). Ambulatory measures of salivary cortisol also allow researchers to determine whether, over time, higher levels of cortisol are associated with behavioral or health impairments. For example, in studies of aging, increasing ambulatory cortisol levels over time have been shown to be related to increasing memory deficits and hippocampal atrophy (Lupien et al., 1998; Lupien et al., 1994). In young children, ambulatory salivary cortisol data obtained in preschool settings have documented relations between cortisol and social competence (Gunnar, Tout, de Haan, Pierce, & Stansbury, 1997).

As ambulatory measures of cortisol in research on children gain in popularity, the proximal factors that affect these measures need documentation. A considerable literature exists regarding the factors that affect baseline cortisol levels in adults (Kirschbaum & Hellhammer, 1989, 1994). Less attention has been paid to the parameters that need to be controlled in studies of children. This article focuses on factors affecting ambulatory measures of cortisol obtained at bedtime near the nadir of the HPA rhythm. The assessment of evening or bedtime cortisol levels is of concern for several reasons. First, elevated cortisol near the lowest point of the HPA rhythm is believed to be of particular note in assessing dysregulation of the axis such as in early onset depression (Dahl,

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1996; Dahl et al., 1991). Furthermore, when glucocorticoids are administered near bedtime, they disturb nighttime sleep and affect neural processes involved in memory consolidation (Gillin, Jacobs, Fram, & Snyder, 1972; Plihal & Born, 1999). Thus, assessing individual differences near bedtime may be important in research on the role of HPA axis activity in human development. In addition, there is evidence that the nadir of the rhythm is a particularly sensitive time for detecting responses to stressors (Dallman et al., 1992). If the axis is more responsive to stimulation during the evening hours, assessing differences among individual children may require attention to the activities they engage in during the hours before bedtime. Imposing restrictions on evening activities, though, adds a burden to participants and increases the likelihood of attrition and missing data. Thus, it is important to determine whether such constraints are necessary in studies with children.

Over the past few decades, structured after-school and evening activities have gained in popularity, with parents reporting pressure to enroll their children in relatively more activities at increasingly younger ages. Lay reports about children's increasingly scheduled lives are supported by research indicating that children's overall free time has decreased dramatically over the past two decades. According to Hofferth and Sandberg (2001), this decrease is largely due to increases in the time children spend in school, child care, and structured activities, including sports and training in the arts. Over the same period, children reportedly spend less time in unstructured leisure activities. Such changes appear to be related to changing social views that value structured evening activities as skill-learning opportunities for children's academic and intellectual advancement. Although these activities may stimulate the development of varied social and cognitive skills, children's demanding schedules may also tax their emotional resources and coping competencies and result in intermittent stimulation of stress-sensitive physiological systems, including the HPA system. If so, this may not only be important to researchers hoping to assess accurately individual differences in salivary cortisol levels near the nadir of the HPA rhythm but may contribute to discussions of the wisdom of filling children's evenings with scheduled activities (Kirn & Cole, 2001; Quindlen, 2002; Rosenfeld, Wise, & Coles, 2001).

In middle childhood it is common for children to engage in a variety of structured sport, lesson, and youth group activities in addition to child care and unstructured activities such as playing at home or in the neighborhood. Among these activities, participation in organized sports seems most likely to elevate evening cortisol levels. The link between increased cortisol and exercise are well established; cortisol increases in response to both short bouts of high-intensity (i.e., anaerobic) exercise and longer durations of submaximal intensity exercise (i.e., aerobic exercise exceeding 60% VO_2max; Viru, 1992). Typically, cortisol levels peak immediately following exercise and return to baseline levels in roughly 1 to 2 hr. Cortisol response to vigorous physical exercise has been observed in children, adolescents, and adults (del Corral, Mahon, Duncan, Howe, & Craig, 1994; Fry, Morton, Garcia-Webb, & Keast, 1991; Passelergue & Lac, 1999). Research in adults has also shown that daytime exercise may lead to lower nighttime cortisol levels relative to days with no exercise performed (Hackney & Viru, 1999; Kern, Perras, Wodick, Fehm, & Born, 1995).

The pressure to perform or compete may further contribute to activation of the HPA system. Among elite adolescent athletes, competition increases cortisol concentrations such that cortisol tends to be high immediately preceding and during competition and falls quickly at the end of a competition to baseline levels (Passelergue & Lac, 1999). Psychological stress related to athletic competition is also associated with elevated plasma cortisol concentrations in nonaerobic sports such as shooting (Guezennac, Lafarge, Bricout, Merino, & Serruier, 1995). It is unclear whether younger, less experienced athletes would exhibit as rapid a recovery in cortisol as do adults or whether they would show prolonged activation well after cessation of sport activities.

Research on physiological responses to competitive activities suggests that catecholamine and cortisol secretion may be especially pronounced in boys. Frankenhauser and colleagues have demonstrated that urinary excretion of adrenaline, 3-methoxy-4-hydroxy-phenylethylene glycol, and, to a lesser degree cortisol and noradrenaline, is higher in adolescent boys than girls following a 6-hr matriculation exam (Frankenhauser et al., 1978). One recent study with normative and psychiatric school-aged children suggests that boys also respond to laboratory physical challenge test with greater change in both negative mood (fear, anxiety, and aggression) and cortisol than do girls (Jansen et al., 1999). These results are consistent with findings from children and adults suggesting that when sex differences are found, females tend to be less prone than males to respond to competitive situations with increased catecholamine secretion (Johansson, Frankenhauser, & Magnusson, 1973) and cortisol secretion (Davis & Emory, 1995; Kirschbaum, Wust, & Hellhammer, 1992). The possibility of sex differences in children's cortisol responses to athletic and other extracurricular activities warrants investigation.

It is unclear whether nonathletic, noncompetitive activities may also stimulate the HPA axis. Participation in individualized lessons such as for art or music, as well as youth group activities such as Boy or Girl Scouts, choir, or religious-based clubs is common in children ages 7 to 12 (Hofferth & Sandberg, 2001). Although the pressure of performance or social engagement may activate stress-sensitive systems, such activation is unlikely to be as universal or pronounced as for more active and competitive activities such as sports.

The purpose of this study was to assess whether children's structured evening activities are associated with activation of the HPA axis. This question has both theoretical and practical importance. With the increasing popularity of evening activities outside of the home for school-aged children, it is important to know whether the demands of structured, busy evening schedules activate stress-sensitive physiological systems. In addition, examining child characteristics that are associated with activation of the HPA axis may shed light on whether certain children may be vulnerable to experiencing evening activities as stressful.

Children's ability to regulate behavior and emotions may affect how they deal with the social demands of group or competitive activities. Temperamental wariness, shyness, or fearfulness has been of particular interest to researchers studying stress reactivity, though research on the relation between this temperamental characteristic and HPA activity has yielded mixed results. Kagan and colleagues have reported that extremely inhibited 5-year-olds have higher levels of cortisol during a series of challenging events than do extremely fearless and outgoing children (Kagan, Reznick, & Snidman, 1987). Kagan has argued that shyness or inhibition reflects a tonically lower threshold for physiological and behavioral reactivity. Studies of older, clinic-referred children have similarly noted that HPA reactivity is associated with social withdrawal, social inhibition, and social anxiety (Granger, Weisz, & Kauneckis, 1994). In other studies, high or increasing cortisol has been observed in children who are outgoing or aggressive, not shy and withdrawn (Dettling et al., 1999). It is important to note that the samples observed in the studies just described differ. Studies that have linked shyness or inhibition with physiological indicators of stress reactivity have been conducted with the most extremely inhibited toddlers or clinic-referred children; studies linking outgoing or aggressive behavior to HPA activity have used normative samples of children (Gunnar, 2001). Among normative samples, children who are outgoing may actually exhibit higher cortisol levels than shy or inhibited children when presented with new social challenges (Bruce, Davis, & Gunnar, 2002; Davis, Donzella, Krueger, & Gunnar, 1999).

In addition to negative emotionality and shyness or sociability, the ability effortfully to regulate behavior has also been linked with individual differences in HPA activity. Attention focusing and the ability to inhibit prepotent responses form the core of effortful control, which Posner and Rothbart have argued reflect the development of an attentional network involving the anterior cingulate gyrus (Rothbart, Derryberry, & Posner, 1994). In animals, the anterior cingulate also plays a role in containing the cortisol stress response (Diorio, Viau, & Meaney, 1993). Links among effortful control, negative affect, and cortisol have been observed in children. Children high in effortful control tend to be rated low in negative affect (Eisenberg et al., 1994). Presumably, children who are able to shift and focus attention are better able to modulate their negative affect by turning their attention away from stimuli generating negative feelings (Fabes et al., 1999; Rothbart, 1989). In preschool-aged children, parent- and teacher-reported effortful control is negatively correlated with cortisol levels and cortisol responsivity assessed in a classroom setting (Gunnar et al., 1997). The extent to which children's ability to regulate attention and emotion may modify older children's cortisol response to common structured activities outside of the home is unknown.

In sum, the present study examined the relation between evening activities and bedtime cortisol activity in school-aged children, with attention to child characteristics that may moderate this relationship. Although researchers have documented the relation between out-of-home day care for preschoolers and HPA activity, they have not previously examined the effects of children's schedules on HPA activity in middle childhood. Studies of school-aged children have in the past focused largely on clinic-referred samples of children with internalizing or externalizing disorders and have used laboratory-based stressors. To our knowledge, this study is the first to assess the relation between children's daily routines and HPA activity in a normative sample of school-aged children.

We predicted that children would exhibit elevated cortisol levels on evenings when they were out of the home for structured activities in relation to evenings spent at home. Elevations in cortisol were not predicted to be equal across type of evening activity; rather, sport activities were expected to more clearly elevate cortisol levels than individualized lessons or youth group activities. Because of the interest in the HPA axis in the etiology of affective disorders, particular attention was paid to whether fearful, anxious, or socially isolated children or children with less capacity for behavior regulation might be more likely to exhibit elevated cortisol levels on evenings with structured, out-of-home activities. Gender differences were examined because of the previous literature that indicates that boys may be more likely to elevate cortisol in competitive situations.

Method

Participants

Participants included children 7 to 10 years of age. School-aged populations were sampled on weekdays to ensure a narrow range in wake-up time and bedtime. The diurnal cycle of cortisol is related to the sleep–wake cycle, and variation in daytime schedules may influence cortisol assessment. Thus, more constrained schedules facilitated the comparison of cortisol levels across age groups. Based on known interference of particular medications on the HPA system, children on psychotropic or steroid medication and children with endocrine disorders (e.g., diabetes) were not included in the study. Protection of human participants was approved by the University of Minnesota Institutional Review Board.

Participants were recruited from a registry of parents at the University of Minnesota who indicated their interest in participating in research following the birth of their child. The demographic characteristics of the sample reflected that of the registry. The median maternal education was college degree and ranged from high school to graduate or professional degree. Most of the sample was Caucasian (97%).

A total of 115 families were recruited for the study, of which 92 (80%) completed all components of the study. Daily diaries were examined for compliance with the requested procedure. Participants were excluded from analyses if they failed to comply with the requested procedure. Participants dropped from analyses included: 3 children with severe respiratory illness during the study, 1 child whose height and weight indicated extreme obesity suggestive of a possible endocrine disorder, 13 children who did not provide cortisol samples on active evenings, and 6 children who did not provide samples on baseline evenings. Thus, data from 72 children are reported in this analysis, 33 boys and 38 girls, with each of the four ages represented roughly equally. Mean ages in years (with standard deviations in parenthesis) were: 7.3 (.2), 8.3 (.2), 9.3 (.2), and 10.4 (.4). The majority of children were prepubertal (90% of girls and 89% of boys reporting development equivalent to Tanner Stage I/I).

Materials

Activity of the HPA system was estimated by measuring cortisol, which can be assessed in small samples of free-flowing saliva. Salivary cortisol has been shown to provide an accurate index of free plasma cortisol (Kirschbaum & Hellhammer, 1994), and home sampling procedures have been used in several studies effectively (e.g., de Haan, Gunnar, Tout, Hart, & Stansbury, 1998). The saliva collection kit provided to parents included five sets of supplies, one for each of the four saliva sampling days plus an extra set in case the parent needed to repeat a sampling day. Each kit included a piece of Trident™ original flavor gum, a 3-in. straw, and a plastic vial (CRYOS, Vanguard Int., Neptune, NJ) with a label for parents to indicate the date and time of sampling. These materials were stored in zip-locked bags. An instruction sheet for saliva sampling was enclosed.

Instruments

In addition to the saliva collection materials, the kit included a daily diary for parents to complete each evening of the sampling. The diary requested information regarding the child's evening activities (scheduled sports, lessons, homework, leisure activities), negative mood before bedtime (e.g., angry/irritable, sad/weepy), and quality of sleep (latency to sleep, night waking, hours slept). The diary also included questions regarding the child's schedule (wake up, meals, bedtime) and the child's health (medications taken, health rating) to assess any aberrations in the child's typical schedule or health status that might affect evening cortisol levels.

Parents were also provided a questionnaire packet to be completed once. Information was requested regarding demographic information and the child's general health. These questions were included for general reporting purposes and as a check on exclusion criteria.

Children's behavioral characteristics were assessed using several subscales from the Children's Behavior Questionnaire (CBQ; Ahadi, Rothbart, & Ye, 1993) and the Child Adaptive Behavior Inventory (CABI; Miller, 1987). The CBQ is a widely used measure of children's temperament. It has been employed with school-aged children through age 11 and has been validated in Western and non-Western samples (Ahadi et al., 1993; Jyoth, Kapur, & Shanmugan, 1995). Five CBQ subscales were used in the present study: Anger/Frustration ($\alpha = .83$), Fear ($\alpha = .79$), and Sadness ($\alpha = .66$), which are key scales constituting the dimension of Negative Affect as well as Attentional Focusing ($\alpha = .79$) and Inhibitory Control ($\alpha = .82$), which are key scales constituting the dimension of Effortful Control. Internal consistency reliabilities are reported for the present sample.

The CABI is designed to capture subtle (i.e., nonclinical) behavioral problems in children related to emotional and cognitive functioning. Grotevant and McRoy (1997) have used this measure with grade school children up to age 12. A short form containing 21 items developed by Grotevant and van Dulmen (2000) using only those questions with the highest loading on each of the subscales was used. The CABI yields four subscales, three of which were used in the present analysis: Poor Emotional Control ($\alpha = .85$), Social Isolation ($\alpha = .82$), and Intellectual Engagement ($\alpha = .89$).

Stressful family life events were assessed using a scale developed by Boyce (Boyce et al., 1995) based on work by Coddington (1972) and Monaghan (Monaghan, Robinson, & Dodge 1979). This scale is an expanded version of Coddington's 30-item questionnaire and obtains occurrence and distress for 37 major life events. Events include items such as parental divorce, death of a loved one, or birth of a sibling. This instrument was used to examine events during the past 3 months along with parent-perceived impact on the child ranging from 0 (*none*) to 3 (*a great deal*) This measure was used to control for individual differences in recent life events when evaluating the impact of daily stressors. The inventory has been used with several samples and has good test–retest reliability ($r > .85$; W. T. Boyce, personal communication, April 29, 1998).

Procedure

Families were contacted by telephone. The study was described, and if parental and child assent was obtained and children met criteria for inclusion, the family was mailed the saliva collection kits (which included written consent forms for children and parents). Parents were asked to sample the child's saliva on 4 weekday school nights near bedtime (between 8:00 p.m. and 9:00 p.m.). This stabilized children's daily schedules, constrained wake-up times and bedtimes, and provided more stable estimates of salivary cortisol levels. Two weekday evenings were selected on which the child had a scheduled evening activity and 2 weekday evenings when the child had no scheduled evening activities. Previous data have shown that averaging across 2 days of cortisol sampling provides a reasonably reliable index of the individual's typical cortisol levels while minimizing response burden (correlation is approximately .5 for evening values; Gunnar, Morison, Chisolm, & Schuder, 2001). Parents were also asked to detail the frequency of their child's scheduled evening activities in the past month.

Evenings with activities were selected on days when children were out of the home after 5:00 p.m. for scheduled activities such as music lessons, organized sports, or Scouts. For children with two or more types of scheduled activities, parents were asked to collect saliva on 2 active evenings with different activities (e.g., basketball one evening, Scouts another evening) so that children's cortisol levels could be assessed following different types of activities. Evenings without activities were selected on days when the child was home by 5:00 p.m. and played at home or only in the neighborhood, accompanied a parent on an errand, and had only normal homework on which to work. If a child did not participate in any scheduled evening activities that met the criteria for this study (representing 13.5% of the recruited sample), four samples were collected on evenings without activities and were not included in the present analysis. Parents were asked not to allow their child to consume caffeine 2 hr before sampling and to avoid sampling on days when the child was ill or on days that represented a significant departure from the child's or family's normal schedule.

Saliva was collected using procedures developed by Granger (Schwartz, Granger, Susman, Gunnar, & Laird, 1998). The experimenter reviewed these procedures with the parent over the telephone and encouraged the parent to refer to the instruction sheet on sampling days. After rinsing the mouth, the child chewed a piece of original flavor Trident™ gum for 1 min. The child then spit through a straw into a cryos vial. The vial was capped tightly, labeled with the date and time and stored in a zip-locked bag in the family's refrigerator. The experimenter maintained regular contact with parents throughout data collection to help select sampling days, review procedures, and answer questions.

Parents were also asked to complete the daily diary on evenings when saliva was sampled and to complete the questionnaire packet at their convenience. In addition to the parent materials, a progress chart was enclosed for the children to use. Once the samples were collected, they were mailed along with the diaries and questionnaire in a preaddressed, stamped mailer to the laboratory. On receipt, the family was mailed a \$10 gift certificate and was thanked for their participation. The cortisol samples were stored at -20^{o} C until assayed. These storing and mailing procedures do not affect cortisol levels (Kirschbaum & Hellhammer, 1994). Samples were assayed in duplicate for cortisol concentration using a time-resolved fluorescence immunoassay (DELFIA). Batches were balanced for age and sex. Approximately 7% of the samples assayed were blind controls from pooled saliva. These controls were used to compute intra- and inter-assay coefficients of variation, which were 4.2% and 14.7%, respectively.

Data Reduction and Preliminary Analyses

Cortisol. For the 72 children included in this study, daily diaries were examined for compliance with the requested procedure on each day of sampling. Individual cortisol samples were dropped if they were collected on days when the child was ill or experienced a significant departure from the normal routine (e.g., plane trip). The cortisol values were then examined for outliers defined as those with standard scores greater than 2. Four outliers were detected and reassigned a value equaling 2 *SD* above the mean. Outliers were not discarded because all occurred on evenings when diaries reflected potentially stressful events (i.e., fights with siblings, soccer game) and are thus likely to reflect true cortisol responses. To normalize the cortisol distributions, the convention of $\log_{10}$ transformations was used.

Summary cortisol measures were computed to reflect two aspects of HPA activity. Home evening cortisol was defined as the mean for each child's cortisol values over 2 days spent at home with no scheduled activities. Change scores were also computed by taking the mean of two samples taken on days with active evenings (i.e., those with structured activities) and subtracting averaged unstructured evening cortisol values. Time of sampling variables for unstructured and active nights were computed accordingly.

Cortisol sampled on active nights were used to create additional composite scores representing HPA activity following different types of evening activities: sports (hereafter referred to as sportCORT), individual lessons, and club or social activities. If two active cortisol samples were taken following the same type of activity, those values were averaged. No differences were observed for cortisol values obtained on evenings children participated in lessons or clubs; thus, cortisol data were collapsed across these two activity types. The percentage of children providing samples on evening with sports and lessons or clubs was 69.4% and 55.5%, respectively.

Behavioral data. The number of stressful life events ranged from 0 to 9 with a median of 2. Total life events score, calculated as the number of events weighted for impact, ranged from 0 to 13, with a mean of 2.76 and standard deviation of 0.30. The range of events are similar to previous samples (W. T. Boyce, personal communication, April 29, 1998); however, the median score and total life events scores were substantially lower than in previous reports, suggesting a low occurrence of stressful life events in the present sample.

Phone interview records were used to tally the frequency of sports, lessons, and club activities for each child in the calendar month during which saliva was collected. Interview records were coded by two trained raters; intraclass correlations averaged .98. As with the data from the diaries, the frequencies of lessons and clubs were collapsed into one category. Of the 72 children included in the present analysis, most participated in one to three structured evening activities per week ($M = 2.10$, $SD = 1.14$, *range* $= 1-5$ evening activities per week, *unrestricted range* $= 0-11$ activities per week). There was a nonsignificant trend for girls to participate in more club and lesson activities than boys, $t(68) = 1.77$, $p = .08$.

Data Analysis Plan

To examine whether evening activities elevated children's evening cortisol levels relative to unstructured evenings, a repeated measures analysis of variance (ANOVA) was used to compare children's cortisol values on unstructured and active evenings. To test for the possibility that behavioral characteristics may moderate children's HPA activity in response to evening activities, a series of hierarchical regressions were computed. Significance levels were set at $\alpha = .05$ for all analyses. Individual differences and behavioral characteristics were related first to cortisol on unstructured evenings, next to cortisol change scores, and finally to cortisol values sampled on evenings with sports and evenings with clubs and lessons separately. Nonsignificant predictors were removed from regression equations where noted and analyses were estimated again to obtain the best fitting model.

Results

The CBQ, CABI, and life events scales were examined for possible age and sex differences. No significant age differences were observed for any of the parent-reported measures. Parents reported higher levels of attention-shifting skills for girls, $t(69) = 2.07$, $p < .05$, and higher levels of fearfulness for boys, $t(69) = 2.06$, $p < .05$. No other sex differences in behavioral measures were observed.

To determine whether cortisol levels differed between unstructured and active evenings, a 2 (evening type) $\times$ 2 (sex) $\times$ 4 (age) repeated measures ANOVA was performed with evening type as a within-subjects factor. A main effect for evening activities on children's cortisol was observed, $F(1, 63) = 4.15$, $p < .05$, qualified by a significant interaction between evening activities and sex, $F(1, 63) = 8.47$, $p < .01$. Post hoc tests with Bonferroni correction indicated that cortisol levels for boys differed between unstructured evenings and evenings with activities, $F(1, 29) = 9.43$, $p < .01$. A similar difference was not evident among the girls. Boys' but not girls' cortisol levels were higher on evenings with activities than on evenings at home (see Figure 1).

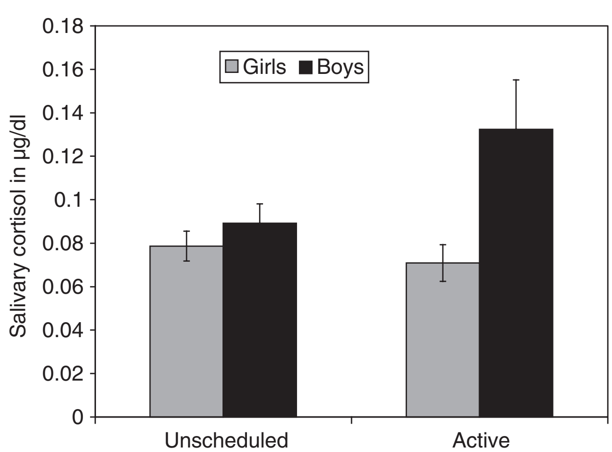

Figure 1. Mean cortisol level for active and unscheduled evenings by sex. Mean values were computed using $\log_{10}$ transformed values.

Hierarchical regressions were used to examine the moderating role of behavioral characteristics on children's HPA activity in response to evening activities. First, individual differences were assessed in relation to cortisol on unstructured evenings at home. There was a nonsignificant trend for time of sampling, $F(1, 69) = 3.74$, $p = .06$, $\beta = -.23$. Note that the direction of this relationship is predicted by a normal diurnal rhythm. Age, sex, stressful life events, mood, temperament, and CABI behavioral tendencies were unrelated to cortisol sampled on unstructured evenings at home.

Next, cortisol change scores were regressed onto individual difference variables. Age, sex, stressful life events, concurrent mood, and time of sampling were entered as a group on Block 1. The three CABI subscales (Emotional Control, Social Isolation, and Intellectual Engagement) were entered as a group on Block 2. Nonsignificant control factors from Block 1 (time of sampling, recent life events, mood, and age) were eliminated. With sex entered on Block 1 and CABI scores entered on Block 2, this resulted in an overall R^2 of .216. Regression analyses revealed that sex accounted for 11.2% of the variance for the change in cortisol between unstructured and active evenings, $F(1, 69) = 8.73$, $p < .01$, $\beta = -.34$. CABI scores accounted for an additional 9.4% of the variance, $F\Delta(3, 66) = 2.91$, $p < .05$. On further examination of the CABI variables, only social isolation contributed significantly, $\beta = -.34$, $p < .01$. The negative correlation between social isolation and cortisol change scores suggests that children rated low in social isolation (or more socially engaged children) exhibited greater differences between unstructured and active evenings than children rated high in social isolation (or low in social engagement). A similar regression analysis was performed using the CBQ Temperament scales in place of CABI scales on Block 2. Temperament was not a significant predictor of cortisol change scores.

To determine whether particular types of evening activities were more likely to produce elevations in cortisol over unstructured evenings, sportCORT was regressed onto the same set of predictors with children's frequency of sport activities and time between sport activity to sampling as additional predictors. The results for sportCORT matched the results for predicting cortisol change scores. Age, life events, time of sampling, and activity frequency were not related to sportCORT. The difference between cessation of sport activity and time of sampling was also unrelated to cortisol. When sex was entered on Block 1 and CABI variables entered on Block 2, this model resulted in an overall R^2 of

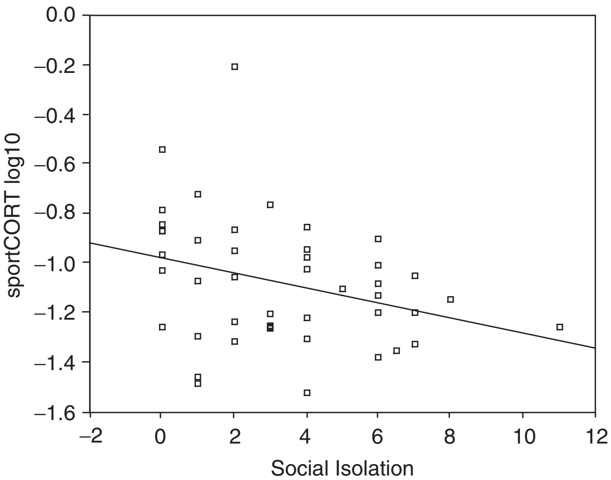

Figure 2. SportCORT as a function of social isolation.

.287. Sex accounted for 13.3% of the variance in sportCORT, $F(1, 47) = 7.22$, $p < .05$, $\beta = -.29$. The CABI scales accounted for an additional 15.4% of the variance in sportCORT, $F\Delta(3, 44) = 3.16$, $p < .05$. On further examination of the CABI variables, only social isolation contributed significantly, $\beta = -.35$, $p < .05$. No interaction between sex and CABI scores was apparent. Thus, boys and children of both sexes who were lower in social isolation had more elevated cortisol levels following organized sports than girls and children scoring high in social isolation (see Figure 2). A similar regression analysis was performed with cortisol on evenings with lessons or youth group activities as the criterion. No significant relations were found between any of the individual difference predictors and cortisol following these activities.

In an exploratory analysis we examined whether the sex difference in response to sport activities might be due to differences in girls' and boys' type of sports activities. Activity frequencies were examined and classified according to whether the sports could be characterized as team competitive (e.g., soccer, basketball, baseball) or characterized by individualized training (e.g., gymnastics, martial arts, dance). Of the children who played sports, 63% of boys played at least one team sport whereas only 21% of girls played team sports. The 6 girls who played team sports on sampled evenings were selected along with two comparison groups for further analysis: 8 boys matched on age and, when possible, on the specific sport, and 8 girls matched on age who participated in training sports. (Boys in training sports were not included in this analysis because of small sample size and extremely large variance). A t test revealed a significant sex difference in sportCORT for children doing team sports, $t(12) = 2.66$, $p < .05$. Boys who played team sports showed higher levels of evening cortisol than girls playing team sports. No difference in cortisol was observed between girls playing team sports and girls in training-style sports. As in the overall sample, no sex difference was observed in this subsample for cortisol on unstructured evenings spent at home.

Discussion

The primary purpose of this study was to determine whether out-of-home, structured evening activities is related to activation of the HPA system in elementary school children. The results suggest that evening activities can activate the HPA axis, though not for all children or all types of activities equally.

It was predicted that children would exhibit elevated levels of salivary cortisol on structured evenings relative to unstructured evenings at home. The results indicate that participating in evening activities was associated with heightened bedtime cortisol levels for boys but not for girls. This finding is consistent with other reports of sex differences in cortisol to competitive situations, indicating that when sex differences are observed, greater mean cortisol responses are found in males than in females (Davis & Emory, 1995; Kirschbaum et al., 1992).

Children's cortisol levels following athletic and nonathletic activities were also examined separately. It was predicted that differences in children's cortisol levels between structured and unstructured evenings would be especially pronounced following athletic activities. This prediction was also supported, again for boys only. Boys' cortisol levels were higher on evenings spent in structured sport activities than unstructured evenings spent at home. In contrast, no differences were observed in children's cortisol levels between evenings spent at home and evenings spent in either lessons or group or club activities. Although physical exercise normally leads to increased production of cortisol, it is typically only for short durations (1 to 2 hr). Moreover, sex differences in cortisol responses (elevated cortisol in males only) are consistently reported to psychological stressors but not physical stressors, suggesting that sex differences in cortisol responsivity may be linked with differences in cognitive or emotional processing of stressors (Kirschbaum et al., 1992). Thus, physical exercise is unlikely to be the sole explanation for elevated bedtime cortisol on evenings with organized sports.

An exploratory analysis was conducted to determine whether the observed gender difference might be due to differences in the types of sports in which children participated. In general, boys and girls did not differ in terms of how frequently they participated in sports, lessons, and youth group activities. They did differ with respect to type of sports. Boys tended to participate more frequently in competitive team sports whereas girls tended to participate more in sports that can be characterized by individual training. However, the type of sport that children participated in did not relate to children's cortisol level. This suggests that the gender difference in boys' and girls' cortisol levels following sports is unlikely to be due to differences in type of sport activities. What causes this gender difference is not entirely clear. This study included children ages 7 to 10 years; thus, it is unlikely to be due to hormonal changes associated with puberty. One possibility worthy of empirical investigation is that boys and girls may be responding to sports differently, perhaps based on messages from parents and coaches about the pressure to perform or the meaning of their participation in sports (Borman & Kurdek, 1987; Leff & Hoyle, 1995).

This study also addressed whether certain children might be more likely to have higher cortisol levels than others following evening activities. Several observations were noteworthy. First, children's cortisol levels taken on evenings spent at home were relatively low. These low levels reflect a normal circadian rhythm where the lowest levels of cortisol are typically near bedtime. Second, none of the individual difference characteristics reported by parents such as temperament or mood related to cortisol levels taken on unstructured evenings spent at home. This suggests that within nonclinical samples, perhaps especially those with few recent stressful life events, individual differences in children's personality and behavior do not disrupt a normal daily pattern of cortisol in the body. In contrast, children's typical behavior was related to cortisol levels on evenings spent in structured activities outside of the home. Specifically, children (both boys and girls) who were highly sociable (e.g., children who make friends easily, do not often feel lonely) had higher cortisol levels when they were out for structured activities than on evenings spent at home. Children who were less sociable (e.g., children who sometimes feel lonely according to their parents) did not show different levels of cortisol on evenings with structured activities and evenings spent at home. This contrasts previous research with younger children demonstrating increased HPA activity to psychologically stressful situations in anxious and withdrawn children. However, the present results are consistent with reports of smaller HPA responses to physical challenge among withdrawn children ages 6 to 12 years (Jansen et al., 1999). In addition, these findings are similar to other recent studies showing that highly sociable children show larger cortisol increases relative to less sociable children at the start of a new school year (Bruce et al., 2002; Davis et al., 1999). What these findings have in common is that highly sociable children respond with HPA activation to normative yet challenging social circumstances. It is noteworthy that the activities after which children showed the most pronounced effect were primarily sports. Sports tend to be seasonal in nature; thus, children are likely to be less familiar with their peers than in social, nonathletic activities such as Boy and Girl Scouts. Perhaps children who are highly socially engaged during structured activities may be activating physiological systems in the body to meet the challenges of that activity. It is also possible that the more socially engaged children challenge themselves more physically during athletic social events and thus experience more exercise-induced activation of the HPA axis. Although we have no evidence of this, we cannot ignore the possibility that this apparent personality difference might be mediated by more proximal physical as opposed to psychological processes.

The results of this study have practical implications for future research assessing HPA activity in school-aged children. Out-of-home scheduled evening activities were found to be directly related to children's evening cortisol. Thus, future studies investigating diurnal HPA functioning in children may need to restrict sampling to days on which children are at home or, at the very least, are not participating in sport activities. Thus, this study has important methodological implications because it indicates the necessity of documenting and controlling for evening activities when assessing ambulatory cortisol measures in children near bedtime. This is especially important for research aimed at understanding normal and atypical diurnal patterns of cortisol production. For example, an observed flat or rising pattern of cortisol production may be artificially induced or inflated if proximal mechanisms that may elevate cortisol near the nadir of the rhythm are not adequately controlled.

The present results also have theoretical implications because they indicate that structured evening activities may activate stress-sensitive physiological systems and that there are important individual differences in children's responses to such activities. Specifically, participation in evening activities was associated with elevated bedtime cortisol levels for boys in general, and for both boys and girls who were highly sociable. Cortisol differences were especially pronounced following sport activities. It is unclear whether such differences might be related to particular types of physical or social demands presented by these activities, although the observation that cortisol responses differed according to children's sociability supports the latter possibility.

The limitations of the present study stem from the nature of the sample. First, most children were of Caucasian descent and the average socioeconomic status level (as indexed by maternal education) was moderate to high. Second, there was some evidence that most participants in this study were relatively high-functioning children. Children with endocrine disorders or those on psychotropic medications were not included in the study, and a relatively low proportion of parents reported severe behavioral problems on the CABI scales (such as extremely poor emotional control or social isolation). Nonetheless, the fact that cortisol responsivity to active evening was found even in this restricted sample indicates that caution is warranted as these techniques are applied to higher risk samples of children, particularly those with clinical behavioral problems. Thus, although these limitations should be noted, evidence of a response in this sample may be particularly telling about the need to control the event context in which evening cortisol levels are assessed.

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