International Journal of Behavioral Development
2007, 31 (3), 218–231
http://www.sagepublications.com

ijbd

DOI: 10.1177/0165025407074634

Associations between parents' marital functioning, maternal parenting quality, maternal emotion and child cortisol levels

Patricia Pendry and Emma K. Adam
Northwestern University, USA

Associations between family functioning and children's stress hormone levels are explored, by examining how aspects of the interparental relationship (parents' marital satisfaction and parent conflict styles), the mother–child relationship (maternal involvement and warmth) and maternal emotional functioning (depression, anxiety and self-esteem) relate to children's cortisol levels. Parents of 63 children (32 kindergarten-aged children, 31 adolescents) completed questionnaires regarding family and individual functioning, and children's salivary cortisol samples were collected on two consecutive weekdays at home immediately upon waking and at bedtime, such that wakeup, bedtime and average levels and the slope of their diurnal cortisol rhythms could be estimated. Higher marital functioning was significantly and independently associated with lower child cortisol levels (average levels and wakeup levels), while maternal parenting quality and emotional functioning were not significant when included in the same regression model. Associations between parents' marital functioning and children's bedtime cortisol levels and diurnal slopes were moderated by child age, with higher parent marital functioning being associated with a significantly greater lowering of bedtime levels and steeper diurnal slopes for kindergarten-aged children as compared to adolescents. Higher maternal parenting quality was found to be significantly related to steeper diurnal cortisol rhythms.

Keywords: child development; cortisol; family functioning; hypothalamic pituitary adrenal axis; marital discord; stress hormones

Research has consistently indicated strong associations between marital functioning and a wide range of child adjustment problems (Buehler et al., 1997; Emery, 1982, 1989, 1999; Grych & Fincham, 1990, 2001); however, the pathways that give rise to these associations are not clear. Several marital discord theories, including the cognitive-contextual model (Grych, 1998; Grych & Fincham, 1990, 1993; Grych, Fincham, Jouriles, & McDonald, 2000; Grych, Harold, & Miles, 2003), the emotional security hypothesis (Davies & Cummings, 1994, 1998; Davies, Harold, Goeke-Morey, & Cummings, 2002) and the specific emotions model (Crockenberg & Forgays, 1994, 1996; Crockenberg & Langrock, 2001a, 2001b) suggest that poor marital functioning constitutes a stressor leading to children's emotional arousal.

Although there has been considerable interest of late in integrating physiological measures into studies examining associations between parent's marital functioning and child outcomes (Ballard, Cummings, & Larkin, 1993; El-Sheikh, 1994; El-Sheikh, Ballard & Cummings, 1994; El-Sheikh, Cummings, & Goetsch, 1989; Gottman & Katz, 1989; Gottman & Levinson, 1992; Katz & Gottman, 1995, 1995b; Repetti, Taylor, & Seeman, 2002), surprisingly, there are no published studies with children examining how parent marital quality is related to the activity of one of the body's main physiological systems for responding to stressors, the hypothalamic-pituitary-adrenal axis (HPA axis), and its major end-product, cortisol. HPA axis activity, as measured by levels of salivary cortisol, is of interest in relation to marital functioning for several reasons.

First, cortisol levels are extremely sensitive to social stressors and supports, particularly those emerging from close interpersonal relationships (Adam, Klimes-Dougan, & Gunnar, in press; Gunnar & Donzella, 2002; Repetti et al., 2002;). Second, cortisol levels have effects on many physiological and behavioral processes. When secreted transiently cortisol aids survival by mobilizing energy, increasing cardiovascular tone, focusing attention and redirecting immune resources, while suppressing growth, reproduction, digestion and tissue repair processes that are less important for immediate survival (Johnson, Kamilaris, Chrousos, & Gold, 1992). However, excessive amounts of cortisol can disrupt learning and memory, affect synaptic plasticity and have deleterious physical consequences such as risks of insulin-resistant diabetes mellitus and chronic immune suppression, and as such, has potential implications for children's immediate functioning as well as their long-term physical, cognitive and emotional development (Repetti, Seeman, & Taylor, 2002; Scerbo & Kolko, 1994; Smider et al., 2002). Third, although there has been less human research on the topic, animal models suggest that frequent or chronic elevation of cortisol levels impairs

Correspondence should be sent to Patricia Pendry, Northwestern University, Program of Human Development and Social Policy, 2120 N. Campus Drive, Annenberg Hall 104, Evanston, IL 60208–0001, USA; e-mail: p-pendry@northwestern.edu

This research was supported by awards to the second author from the Social Sciences and Humanities Research Council of Canada, the Alfred P. Sloan Foundation, the Spencer Foundation, and the National Institute of Mental Health (NIMH RO3 MH63269) and awards from the Spencer Foundation and Northwestern University to the first author. We would like to thank the parents and children of the Sloan Working Families Study, without whom this work would not have been possible.

neurogenesis, causes atrophy of dendritic processes and, at an extreme, potentiates neurotoxic effects (Chrousos & Gold, 1992; McEwen, 1998). As such, frequent or chronic elevation of cortisol levels are thought to play a role in the development of emotional and physical disorder in humans (Sapolsky, 2000).

Previous research indicates strong interrelatedness of marital relations and parenting (Erel & Burman, 1995), marital relations and parent emotional functioning (Whisman, 2001), and parent emotional functioning and parenting quality (Adam, Gunnar, & Tanaka, 2004). In addition, there is ample evidence from the stress literature suggesting that multiple aspects of family functioning including conflict (Flinn, 1999; Flinn & England, 1995), expression of aggression and hostility (Granger et al., 1998), parenting quality (Gunnar, 1998; Gunnar, Brodersen, Nachmias, Buss, & Rigatuso, 1996; Gunnar & Donzella, 2002) and parent emotional functioning, such as withdrawal (Bugental, Martorell, & Barraza, 2003), maternal depression (Ashman, Dawson, Panagiotides, Yamada, & Wilkinson, 2002; Essex, Klein, Cho, & Kalin, 2002; Halligan, Herbert, Goodyer, & Murray, 2004) and anxiety (Warren et al., 2003) are associated with children's stress hormone functioning. As a result, in examining associations between marital functioning and child cortisol, it is important to understand whether associations between marital functioning and children's stress hormone levels occur independently of, or are attributable to, parenting quality and parent emotional functioning. Hence, rather than merely examining the role of parents' marital functioning on children's cortisol levels, the current study examines associations of parent marital functioning, maternal parenting quality and emotional functioning on children's cortisol levels *simultaneously*.

Of particular relevance to this work is a recent review of the literature on family functioning and child outcomes by Repetti et al. (2002), who concluded that two dimensions of family functioning may be especially "risky" or harmful for children's development: high levels of conflict, and unsupportive parenting (including low levels of parental involvement, support, and warmth). They proposed that the effects of these variables on children's HPA axis activity may be an important pathway by which the effects of these family factors influence children's outcomes.

The present study

Given prior research suggesting the potential importance of multiple family context variables, the present study examines effects of parents' marital[1] functioning, maternal parenting quality and maternal emotional functioning on children's cortisol levels *simultaneously*, to understand whether the effects of parent marital functioning on children's cortisol levels occur independently of, or in interaction with, maternal parenting quality and maternal emotional functioning. Children's cortisol levels are sampled immediately upon awaking and just prior to bedtime on two consecutive weekdays in the home setting in order to capture children's cortisol levels at their probable high points and nadirs, and to provide an estimate of the slope of their diurnal cortisol rhythms across the waking day. Elevated cortisol near what should be the lowest point of the diurnal rhythm of the HPA axis (in the evening) is thought to be of particular importance to dysregulation of the HPA axis (Gunnar & Vasquez, 2001 for a review), the early onset of depression (Dahl et al., 1991), the occurrence of sleep disturbances (Gillan, Jacobs, Fram, & Snyder, 1972) and impaired memory consolidation (Plihal & Born, 1999).

This study investigates aspects of family functioning and their associations with child cortisol levels in a *normal*, *low-risk* population, to examine whether variations in parent marital functioning, maternal parenting quality, and maternal emotional functioning in a relatively normal range are associated with child cortisol levels. In addition, we examine whether these associations vary by the age of the child, and include both kindergarten aged children and adolescents[2] in our study for that reason. We chose these particular age groups because they represent distinct developmental periods in children's lives, particularly with regards to levels of dependence on parents in regulating emotions, and abilities to make cognitive attributions about and derive explanations for negative interactions in the family. It is therefore of interest to examine whether family functioning variables are more salient for younger children's HPA axis functioning, or whether they are equally important for HPA axis functioning in both age groups.

Method

Participants

Participants were 63 children (32 kindergarten-aged and 31 adolescents) and their parents,[3] from two-parent, primarily middle-income families. Participants were recruited as a follow-up to the Sloan Working Family Study (also called the 500 Family Study), conducted by the Alfred P. Sloan Center on Parents, Children and Work at the University of Chicago, which was designed to study how two-parent working families balance the demands of work and family life. Sloan families were originally drawn from seven communities across the United States and were recruited through schools, solicitations by phone, mail, and newspaper advertisements.

Kindergarten-aged children (23 girls and 9 boys) had a mean age of 6.1 years (ranging from 5.4 to 7.2 years) and adolescents (15 girls and 16 boys) had a mean age of 15.7 years (ranging from 13.3 to 18.1 years). Mothers of kindergarten-aged children had a mean age of 40.1 and mothers of adolescents had a mean age of 47.2 years; mothers' partners' mean ages were 40.6 and 50.21 for kindergarten-aged children and adolescents respectively. Most children were living in married families (n = 56), while some children lived with parents who were in marriage-like, committed relationships (n = 7). Fifty-four children were living with both their biological mother and father, while seven children lived with their

[1] The term *marital functioning* is used to refer to relationship functioning between mothers and their partners regardless of their marital status, and as such refers to relationships of mothers with married spouses as well as non-married cohabitating partners, two of whom are same-sex partners.

[2] Note that when we are referring to the kindergarten and adolescents together, we call them *children* or *child*; when we are referring only to the younger age group, we refer to them as *kindergarten-aged children*, and only to the older age group, we refer to them as *adolescents* or *teens*.

[3] Note that the term *parents* is used to refer to mothers and their partners, regardless of their marital or parental status. Hence partners may include biological fathers who may or may not be married to the mother, adoptive mothers or fathers, stepfathers and cohabitating partners who may be involved as social fathers or mothers.

biological mother and stepfather or their mother's live-in partner. One child in our sample lived with their biological father and stepmother and one child lived with two adoptive parents.

Procedures

After informed consent was obtained over the phone and in writing, parents were sent questionnaires asking about aspects of recent marital functioning (marital satisfaction, conflict tactics), parent–child functioning (parent involvement, parent warmth) and emotional functioning (anxiety, depression, self-esteem). Although we use reports of marital functioning from both mothers and their partners,[4] we focus on maternal parenting and maternal emotional functioning for the current study, because although all partners were in committed relationships with the mother, partners had been involved in children's lives for substantially varying amounts of time.[5]

Using materials and instructions sent to the home, parents of kindergarten-aged children assisted their child in obtaining salivary cortisol samples immediately upon wakeup and at bedtime on each of two consecutive weekdays, while adolescents collected saliva samples on their own at these times without assistance from their parents. Parents were also asked to sample their own saliva several times throughout the day over the same sampling period, as well as record their daily activities, emotions and cognitions according to the Experience Sampling Method (Chikszentmihalyi & Larson, 1987). Findings regarding these parent data have been published elsewhere (Adam, 2005).

Parents of kindergarten-aged children also provided information about their child's health status and use of medications. For adolescents, both parents and adolescents reported on adolescent health status and medication use, while both male and female adolescents provided information on their own pubertal development, and female adolescents provided information about the phase of their menstrual cycle during saliva sampling and their use of birth control.

Cortisol sampling and assay procedures

Parents of kindergarten-aged children collected small samples of saliva (approximately 1.0 mL) from their children, immediately upon waking and immediately prior to the child's normal bedtime, on two consecutive weekdays and recorded the exact time each sample was taken. Adolescents collected their own saliva independently, over a two-day period during the week agreed upon by participants, immediately upon waking and immediately prior to their normal bedtime and noted sampling times accordingly. Adolescents provided four other samples across the day in addition to their wakeup and bedtime samples; for the sake of consistency and comparison with the kindergarten data, we focus on wakeup and bedtime samples here.[6] Each family received a sampling kit including the saliva sampling materials, along with written and pictorial instructions. We also instructed parents and adolescents thoroughly by telephone on how to collect, record, store and ship saliva samples. Although electronic monitoring of compliance with sample timing was not available in the current study, substantial efforts were made to impress upon participants the importance of compliance with the study's procedures, particularly with regards to the timing of saliva sampling immediately upon waking (Kudielka, Broderick, & Kirschbaum, 2003). These efforts included having participants take a practice sample at least one day before the study began, explaining to participants *why* exact timing of the samples was essential to our study, asking participants to note any sampling issues that had occurred, and suggesting that participants conduct a third day of sampling if saliva sampling of the wakeup sample had been delayed for any reason. We also conducted (previously scheduled and agreed upon) reminder calls with each participant the evening before they were scheduled to begin saliva collection, at which time sampling procedures were reviewed and suggestions were given to help ensure compliance, e.g. putting sampling materials on a bedside table.

Our experience and those of other experts in the field of salivary cortisol collection with young children has shown that young children tend to have trouble producing an adequate amount of saliva necessary for reliable analysis without controlled use of stimulants. Hence, all kindergarten-aged children were given 1/16 teaspoon of sweetened Kool-aid crystals in order to stimulate saliva, which was absorbed with sterile cotton (placed in the child's mouth for 30 seconds), and expressed through a needleless syringe into a sterile vial. While the use of stimulants such as Kool-aid can affect cortisol values (Schwartz, Granger, Susman, Gunnar, & Laird, 1998), the effects of stimulants are negligible for certain assays, and recent work by Talge, Donzella, Kryzer, Gierens, & Gunnar (2005) found that the correlation between stimulant-treated (Kool-aid) and untreated samples ranges from .95 to .97. Parents were instructed to use no more than 1/16 teaspoon of stimulant (with the help of a clear visual guide for the correct amount) and samples were visually inspected for signs of stimulant overuse. Although the High Sensitivity Salivary Cortisol Enzyme Immunoassay Kit by Salimetrics LLC used in this study is minimally affected by changes in sample pH associated with stimulant use (Schwartz et al., 1998) the pH value of all samples were tested to identify samples with a pH <3.5 or >9.0, which may artificially inflate or lower cortisol values. All our saliva samples were found to have pH values within the acceptable range.

Adolescents in the study were provided with one piece of Trident gum and were instructed to chew until it was soft and pliable to help stimulate saliva flow, a procedure which has been shown not to influence cortisol values (Schwartz et al., 1998). Participants then expelled saliva through a small straw into a sterile 2 mL vial.

[4] While analyses predicting child cortisol using only maternal reports of marital functioning yielded slightly stronger results, we felt that combining these with partners' reports of marital functioning where available (n = 51 out of 61), provided a more accurate and less biased representation of the quality of the interparental relationship than maternal reports alone.

[5] When separate analyses were conducted predicting child cortisol levels using only paternal (i.e. partner) reports of marital functioning, paternal parenting quality and paternal emotional functioning, few significant effects were observed. However, it is impossible to know whether these null results are due to a lack of true effects, the added noise due to variations in length of amount of involvement of maternal partners in children's lives, or the smaller sample size (n = 51) due to missing data on the case level for some partners.

[6] Analyses repeated with the inclusion of these additional data points for adolescents do not alter the nature or interpretation of the reported results. An additional paper (Adam, 2006) makes use of the adolescent within-day repeated measures of cortisol to examine within-day variations in adolescent cortisol in relation to within-day changes in adolescent mood states.

Only children who provided three or more of the four requested samples were included in our analyses. For those who provided only three samples (three children), we replaced the missing cortisol value with that child's own cortisol value taken at the same time on the other sampling day, rather than exclude them from the analyses. Two kindergarten-aged children were dropped from the sample due to insufficient number of samples or the use of asthma and allergy medications potentially influencing cortisol production (Kirschbaum & Hellhammer, 1989, 1994), reducing the total number of children included in our analyses to 61.

Parents and adolescents were instructed to refrigerate samples as soon as possible after they were taken. Since experimental research has shown that salivary cortisol levels are not affected by variations in temperature and motion similar to those experienced during a trip through the mail system (Clements & Parker, 1998; Kirschbaum & Hellhammer, 2000), parents were asked to return the samples to our university-based laboratory by mail. When samples reached our laboratory they were then frozen at –20 degrees Celsius until all data for the study had been collected. Samples were then sent to Salimetrics, LLC® laboratory on dry ice, where they were assayed by enzyme immunoassay. The test used for this study (Salimetrics, LLC, High Sensitivity Radioimmune Assay) has a range of sensitivity from .007 to 1.8 µg/dl, and average intra- and inter-assay coefficients of variation less than 3% and 7% respectively.

Measures

Parent marital functioning. We assessed marital functioning as reported by both mothers and partners separately using two measures in the parent questionnaire: marital satisfaction and conflict tactics (i.e. approaches to conflict resolution).

Marital satisfaction. We assessed marital satisfaction by using the ENRICH Marital Satisfaction Scale (EMS; Fowers & Olson, 1993) on which participants reported on a scale from 0 (*strongly disagree*) to 5 (*strongly agree*) the extent to which they endorse statements such as "I am not pleased with the personality characteristics and personal habits of my partner" and "I am very happy with how we handle role responsibilities in our marriage".

Conflict resolution tactics. Using items from the adjusted Conflict Tactics Scale (CTS-2; Straus & Hamby, 1996) participants indicated how often they and their partner generally employ avoidant, constructive, verbally aggressive or physically aggressive conflict styles when disagreement arises. Participants reported on a scale from 0 (*never*) to 4 (*very often*) how often they "just keep their opinion to themselves" (*avoidant*), "discuss their disagreements calmly" (*constructive*), "argue heatedly or shout at their partner" (*verbally aggressive*) and "pushed, grabbed or hit their partner" (*physically aggressive*) during a disagreement. We later excluded the physically aggressive and avoidant items due to a limited range of responses for these items.

Maternal parenting quality. We assessed the quality of the mother–child relationship by using two convergent measures in the parent questionnaire: parental involvement and parent warmth.

Parental involvement. Parental involvement with the child was measured by averaging scores on an activities checklist designed for the purposes of this study. Mothers described how often they engaged in 28 different activities with their child, such as eating meals together, cooking together, discussing the events of the day, indicating how often they are involved in this activity with their child on a scale of 1 (*rarely or never*) to 4 (*everyday*). The parental involvement checklist varied slightly by child age to ensure that items were age-appropriate for both kindergarten-aged children and adolescents. The parental involvement checklist has a Chronbach's alpha coefficient of .82.

Warmth. Maternal warmth was measured by averaging scores of six items adapted from the Inventory of Parent and Peer Attachment (IPPA; Armsden & Greenberg, 1987). Mothers reported on a scale of 1 (*never true*) to 5 (*always true*) the extent to which they endorse statements such as "I make my child feel better when they talk over their worries with me" and "I cheer my children up when they are sad". The parental warmth measure has an alpha-coefficient of .85.

Emotional functioning. In an attempt to get a broad picture of mothers' emotional well-being, we assessed emotional functioning using three measures: depressive symptoms, anxiety and self-esteem.

Depressive symptoms. We assessed mothers' depressive symptoms using the Center of Epidemiologic Studies Depression Scale (CED-D; Radloff, 1977), a 20-item self-administered questionnaire that assesses the frequency and duration of symptoms associated with depression in the preceding week. Participants indicated how often they experienced cognitive, behavioral, affective and somatic symptoms of depression on a scale from 0 (rarely or none of the time/less than once a day) to 3 (most or all of the time/5–7 days) resulting in a total maximum score of 60 with higher scores reflecting greater distress. Participants in our sample have mean total CES-D scores of 8.51, which is comparable to average CES-D scores found in large samples of community samples, which have found to range from 7.5 to 12.7 (Devins, Orme, Costello, Binik, et al., 1988). Chronbach's coefficient alpha in our sample was .85, suggesting adequate reliability.

Anxiety and self-esteem. We assessed mother anxiety and self esteem using 11 items of the anxiety and self-esteem scales of the Taylor's Measures of Dysphoria, Anxiety, Anger and Self-esteem (Taylor & Tomasic, 1996). Examples for anxiety items include reports by participants about how often they perceived themselves as "feeling on the edge, like something awful is going to happen", "feeling nervous for reasons I can't put my finger on", "having trouble concentrating" and "forgetting things readily". Examples of self-esteem items include participants' report on the extent to which they "feel good about themselves" or feel that they "don't have much to be proud of". Participants indicated the extent to which these statements apply to them on a scale of 0 (*never*) to 4 (*very often*). Chronbach's coefficient alpha for this scale was .79.

Puberty, menstrual status and menstrual timing. Stage of pubertal development was reported using the Pubertal Development Scale (Peterson, 1988). It consists of a series of questions about physical development that ask the adolescent to evaluate the degree to which a specific physical change such as pimply skin, growth spurt, breast development, and facial hair has occurred. A composite score of these four items was used as an overall measure of pubertal development (M = 3.21, SD = .84). We assessed adolescent girls' menstrual functioning using several questions in a health questionnaire asking them to report on "whether they had started menstruation" (n = 12) and "whether their menstrual cycle was regular" (n = 12) for which dummy variables were constructed (*0 = no*, *1 = yes*). We also asked them to report the number of days since the beginning of the first day of their last menstrual cycle from which we constructed a series of dummy variables indicating the phase of girls' menstrual cycle during saliva sampling resulting in the following variables: "whether menstruating or 1 to 6 days since starting menstrual period" (*0 = no*, *1 = yes*; n = 6), "whether follicular or 7–10 days since starting menstrual period" (*0 = no*; *1 = yes*; n = 0), whether periovulatory or 11–14 days since starting menstrual period (*0 = no*; *1 = yes*; n = 1), and "whether luteal or 15+ days since starting menstrual period" (*0 = no*; *1 = yes*; n = 3). An additional dummy variable was constructed indicating "whether the adolescent reported using an oral contraceptive" (*0 = no*, *1 = yes*; n = 2). Each of these variables is suspected to have an influence on cortisol levels (see Kirschbaum & Hellhammer, 1989; 1994; Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Kudielka & Kirschbaum, 2002; Netherton, Goodyer, Tamplin, & Herbert, 2004) and it is therefore important to measure these variables and statistically control for their effects when significant in order for the associations of interest to be properly revealed.

Data reduction

Participants' use of constructive and verbally aggressive conflict styles were significantly negatively associated with each other (r = –.64, p = .00). Constructive styles were positively (r = .43, p = .02), and verbally aggressive styles were negatively (r = –.34, p = .06) related to marital satisfaction. Hence, we standardized and aggregated scores representing constructive and verbally aggressive (reverse-scored) conflict styles with those of the EMS, to create a composite score for *marital functioning* for each participant. Mothers' and partners' scores of marital functioning were significantly associated with each other (r = .306, p = .016), hence we averaged their scores to create a jointly reported *marital functioning* score for each couple. We also standardized and aggregated the maternal involvement and warmth scores in order to create a *parenting quality* composite variable for each mother. The alpha coefficient for the composite maternal parenting scale is .75. A logarithmic transformation was applied to the scores for anxiety and depressive symptoms to adjust for skewness of the distributions. Since correlations between depressive symptoms and anxiety (r = .64, p = .00), depressive symptoms and self-esteem (r = –.60, p = .00) and anxiety and self-esteem (r = –.45, p = .01) were high and significant, the scores for depressive symptoms, anxiety and self-esteem (reverse-scored) were standardized and aggregated to create an *emotional functioning* composite score for each mother. For each variable, the higher end of the scale reflects better functioning.

We used composite variables for marital functioning, maternal parenting quality and emotional functioning, rather than individual variables, in order to reduce the possibility of Type I error, decrease collinearity among the constructs included in the model, and increase the reliability of measurement of each construct. Aggregation techniques have previously been demonstrated to improve the relations between personality variables and cortisol parameters (Pruessner et al., 1997).

Data reduction of cortisol values

We performed paired samples t-tests and found that children's wakeup cortisol levels of sampling day 1 and sampling day 2 were similar, $t(58)$ = .587, p = .560, as were the bedtime levels for sampling day 1 and day 2, $t(59)$ = .214, p = .831. We also note that there were no statistically significantly differences in wakeup sampling times, $t(58)$ = –.013, p = .990, and bedtime sampling times across the two days, $t(59)$ = –.303, p = .76. We were more interested in typical or trait wakeup and bedtime levels, and wished to reduce the impact of day-to-day variation on our cortisol measure. Hence, we combined the two wakeup cortisol values to derive an *average wakeup cortisol* value for each child, and combined the two bedtime cortisol values to derive an *average bedtime cortisol* value for each child. To limit the influence of extremely high or low individual cortisol values, we windsorized wakeup and bedtime cortisol values to three standard deviations above and below the mean before averaging.

We then estimated the child's *average cortisol* level across waking hours by calculating the area under the line fitted through children's wakeup and bedtime cortisol values (with cortisol level plotted on the y-axis, and time of day on the x-axis), and dividing by the total time awake. This was done separately for each day, then values were averaged, resulting in an estimate of the average cortisol level per waking hour, controlling for the length of the child's waking day. For analyses we used a natural logarithmic transformation for each cortisol parameter (average, wakeup, and bedtime cortisol) to reduce positive skewness of the data.

We derived the slope value of the child's diurnal cortisol curve for each sampling day, by dividing the difference between the child's natural log transformed wakeup and natural log transformed bedtime cortisol level with the difference between wakeup and bedtime sampling time. There were no statistically significant differences between the slopes across the two sampling days, $t(58)$ = .209, p = .835. We combined the two slope values to derive at an *average slope* value for each child.

General analytic plan

Our analyses proceeded in several steps. We first prepared descriptive statistics for each of our independent and dependent variables and conducted t-tests comparing the means of kindergarten-aged children and adolescents on each of these variables. Next, we calculated simple correlations among the constructs of interest (marital functioning, maternal parenting quality, maternal emotional functioning) and dependent variables (children's average, wakeup, and bedtime cortisol levels and the slope of the diurnal curve). Then we conducted a series of hierarchical regression analyses for each outcome by proceeding according to the following steps. We first examined effects of marital functioning, child age, and their interaction on children's cortisol variables. When the interaction effect of marital functioning and child age was not found to be statistically significant, we did not include the interaction terms in subsequent models. Next we examined whether the main or interaction effects of parent marital functioning and child age on our cortisol variables are mediated by, or independent of, levels of maternal parenting quality and maternal emotional functioning by adding these variables to the model and observing whether marital functioning effects remain the same or are diminished by the addition of the maternal parenting quality and maternal emotional functioning variables. In addition, when significant associations were found between sampling times and cortisol levels, or between total time awake and cortisol levels, we included those variables in the final model, to ensure that the family functioning effects are independent of these family schedule variables. Given that we used natural log transformations of our dependant variables, we used inverse natural log transformations (100 (e^{β} – 1)) to obtain interpretable estimates of our β coefficients; after this transformation they represent the percentage change in the dependant variable (cortisol level) for each 1 unit change in each independent variable.

To assess the extent to which collinearity among the independent variables affected the parameter estimates, we examined collinearity diagnostics – Variance Inflation Factor (VIF) – for each model, to ensure that VIF values did not exceed 10, which may lead to instability of the regression model and estimates (Allison, 1977, 1999; Neter et al., 1996). We noted that VIF values for marital functioning, maternal parenting quality and maternal emotional functioning – variables at greatest risk for collinearity – did not exceed 2.4 suggesting that modeling them simultaneously is appropriate.

Results

Descriptive statistics

The means and standard deviations of the primary independent variables included in the analyses are presented in Table 1. Participants' reports on variables related to the interparental relationship were similar for adolescents and kindergarten-aged children; marital satisfaction, $t(59) = -.325$, $p = .747$; use of verbally aggressive conflict style, $t(59) = .826$, $p = .412$; constructive conflict style, $t(59) = .740$, $p = .462$ and composite of marital functioning, $t(59) = -.317$, $p = .752$. Mothers' reports on emotional functioning were mostly similar across age groups; self-esteem, $t(59) = -0.709$, $p = .481$; depression, $t(59) = .185$, $p = .854$; composite of emotional functioning, $t(59) = -.668$, $p = 0.506$, but mothers of adolescents reported slightly higher levels of anxiety, $t(59) = 2.79$, $p = .007$. While mothers of kindergarten-aged children and adolescents reported similar levels of warmth, $t(59) = 1.39$, $p = .168$, mothers of kindergarten-aged children reported higher levels of involvement, $t(59) = 2.63$, $p = .011$; and higher scores on the maternal parenting quality composite $t(59) = .2.57$, $p = .013$ than mothers of adolescents.

Table 1 also presents descriptive statistics for children's cortisol measures and sampling times. Untransformed values are presented here for ease of interpretation; natural logarithmic transformed values were used in all analyses. A series of independent samples *t*-tests were performed to identify statistically significant differences between adolescents and kindergarten-aged children for wakeup and bedtime levels of cortisol as well as sampling times. As expected, kindergarten-aged children reported significantly earlier bedtime sampling times than did adolescents, $t(59) = -1.58$, $p = .000$; while wakeup sampling times were similar, $t(59) = -.334$, $p = .157$, resulting in significantly shorter hours of awake time for kindergarten-aged children, $t(59) = -1.99$, $p = .000$. While kindergarten-aged children's cortisol levels at wakeup are significantly lower than adolescents, $t(59) = -.109$, $p = .016$; bedtime cortisol levels are similar, $t(59) = .001$, $p = .964$; resulting in a trend toward flatter slopes for kindergarten-aged

Table 1
Means and standard deviations for parent marital functioning, maternal parenting characteristics, maternal emotional functioning, child cortisol levels and sampling times

Variable	*Min*	*Max*	M	SD
Mother marital satisfaction (ENRICH)	13.72	95.00	52.20	14.7
Mother avoiding conflict (CTS-2)	1.00	4.00	2.52	.81
Mother discussing calmly (CTS-2)	1.00	5.00	3.63	.89
Mother arguing heatedly (CTS-2)	1.00	5.00	2.33	.98
Mother hitting/throwing (CTS-2)	1.00	2.00	1.04	.81
Partner marital satisfaction (ENRICH)	15.98	81.18	51.70	13.1
Partner avoiding conflict (CTS-2)	1.00	5.00	2.69	.75
Partner discussing calmly (CTS-2)	2.00	5.00	3.73	.76
Partner arguing heatedly (CTS-2)	1.00	4.00	2.33	.77
Partner hitting/throwing (CTS-2)	1.00	2.00	1.02	.77
Maternal involvement	1.37	2.65	2.08	.30
Maternal warmth (IPPA)	2.67	5.00	4.17	.49
Maternal depression (CES-D)	0.00	26.00	8.76	6.41
Maternal anxiety (Taylor)	.25	3.25	1.46	.62
Maternal self-esteem (Taylor)	1.25	4.00	2.95	.61
Wakeup cortisol[a]	0.23	1.00	0.52	0.18
Bedtime cortisol[a]	0.01	0.54	0.08	0.11
Average cortisol[a]	.13	.79	.32	.16
Diurnal cortisol curve (Slope)	–.084	.007	–.032	.016
AM sampling time[b]	5.75	10.05	7.37	0.91
PM sampling time[b]	19.00	24.55	21.64	1.16

[a] Cortisol values are averaged over two days and reflect untransformed values, in μg/dl.
[b] Sampling times are expressed on a 24 hour scale with one hour equal to one unit on the scale.

children, $t(59) = –.008$, $p = .058$. We also conducted a series of independent samples t-tests to identify differences between boys and girls for each age group for average, wakeup and bedtime levels of cortisol as well as slope values. There were no statistically significant differences by gender within each age group. We found no differences between adolescent girls and boys in average cortisol levels, $t(29) = .0049$, $p = .940$, wakeup cortisol levels, $t(29) = .0528$, $p = .477$; bedtime cortisol levels, $t(29) = .005$, $p = .863$; or slope values, $t(29) = –.002$, $p = .776$. Average cortisol levels, $t(28) = .084$, $p = .111$, wakeup cortisol levels, $t(28) = .026$, $p = .631$; bedtime cortisol levels; $t(28) = .091$, $p = .103$ and slope values $t(28) = .007$, $p = .202$ of kindergarten-aged girls and boys were similar also similar. We also found no significant differences in cortisol levels between females who reported having started menstruating regularly for average levels of cortisol, $t(59) = –.065$, $p = .206$; wakeup cortisol, $t(59) = –.147$, $p = .081$; bedtime cortisol, $t(59) = –.003$, $p = .940$; or slope, $t(59) = .008$, $p = .274$ nor did we note statistical differences by phase of the menstrual cycle. We also did not note differences in adolescents' cortisol levels by pubertal status.

Simple correlations of marital functioning, maternal parenting quality and emotional functioning and children's cortisol levels. Intercorrelations of the composite variables for marital functioning, maternal parenting quality, maternal emotion and children's cortisol parameters (average, wakeup and bedtime cortisol, and slope of diurnal curve) are presented in Table 2. The marital functioning composite variable is negatively and significantly related to children's cortisol levels ($r = –.363$, $p = .004$ for average cortisol; $r = –.310$, $p = .015$ for wakeup cortisol; $r = –.356$, $p = .005$ for bedtime cortisol and $r = –.298$, $p = .020$ for slope of diurnal curve), such that children in higher marital functioning families have lower average, wakeup and bedtime cortisol levels and steeper diurnal cortisol curves. Better maternal parenting quality and better maternal emotional functioning were associated with lower bedtime cortisol levels ($r = –.252$, $p = .050$ for maternal parenting quality; and $r = –.369$, $p = .003$ for emotional functioning) and steeper diurnal cortisol curves ($r = –.265$, $p = .039$ for maternal parenting quality and $r = –.358$, $p = .005$ for emotional functioning). Associations with average and wakeup cortisol levels were not significant for maternal parenting quality ($r = –.093$, $p = .476$; $r = –.017$, $p = .894$) or for maternal emotional functioning ($r = –.184$, $p = .157$; $r = –.072$, $p = .584$).

Multivariate associations among parent marital functioning, maternal parenting quality, maternal emotion, child age and children's cortisol. Given that each of marital quality, maternal parenting quality and maternal emotional functioning showed associations with cortisol, in order to examine their independent effects, we next examined them simultaneously in a regression model. We perform hierarchical linear regressions for each of our major cortisol outcome variables, including: average cortisol levels, diurnal cortisol slopes (rate of change in cortisol from wakeup to bedtime), and wakeup and bedtime levels. Since average levels of cortisol and diurnal slopes are examined, analyses for wakeup and bedtime levels may seem redundant, but are performed in order to understand whether slope effects are driven by wakeup values, bedtime values, or both, a distinction which helps shed some light on the potential psychoneurobiological mechanism for the slope effects.

Average cortisol levels. In predicting average cortisol levels across the day we found no significant interaction between marital functioning and child age dummy. Hence, subsequent regression analyses for average cortisol levels were performed without the marital functioning by child age dummy interaction term in the model. In Model 1 of Table 3, we note a significant main effect of marital functioning on children's average cortisol levels; for every 1 *SD* higher marital functioning children's average levels of cortisol are lower by approximately .36 of a *SD* or 16.6%, compared to children whose parents' marital functioning is at the mean level. We also note a significant main effect of child age (whether the child is a kindergartner) on children's average cortisol levels; kindergarten-aged children have average cortisol levels across the day that are approximately .25 of a *SD* (17.7%) lower than those of adolescents.

In Model 2 of Table 3, we find that the associations between marital functioning and children's average cortisol levels are independent of maternal parenting quality and emotional functioning. Mother's parenting quality ($\beta = .001$, $p = .990$) and emotional functioning ($\beta = .010$, $p = .886$) were not significantly associated with children's average level of cortisol across the day when marital functioning and child age are in the model, but the significant effect of marital functioning remains ($\beta = –.188$, $p = .012$). Even after maternal parenting quality and emotional functioning are entered in the model, 1 *SD* higher marital functioning is associated with .38 *SD* (17.2%) lower average cortisol levels for both kindergarten-aged children and adolescents. There were no significant

Table 2

Intercorrelations among composites of parent marital functioning, maternal parenting quality, maternal emotional functioning and child cortisol levels and slope of diurnal cortisol curve

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. Marital functioning	–						
2. Maternal parenting	.267*	–					
3. Maternal emotion	.547**	.261*	–				
4. Average cortisol	–.363*	–.093	–.184	–			
5. Wakeup cortisol	–.310*	–.017	–.072	.872**	–		
6. Bedtime cortisol	–.356**	–.252*	–.369**	.611**	.238	–	
7. Slope	–.298*	–.265*	–.358**	.312*	–.089	.916**	–

Note. $^{+}p < .10$; $^{*}p < .05$; $^{**}p < .01$.

Table 3

Linear regression analyses for parent marital quality, maternal parenting quality and maternal emotional functioning predicting children's average cortisol levels (N = 61)

Variable	B	SE	β	p-*value*
Model 1 (R^2 = .194)				
Constant	–1.142	.064		
Parent marital functioning	–.182	.059	–.363	.003
Whether kindergarten-aged children	–.195	.092	–.250	.038
Model 2 (R^2 = .195)				
Constant	–1.142	.066		
Parent marital functioning	–.188	.073	–.375	.012
Whether kindergarten-aged children	–.195	.094	–.250	.042
Maternal parenting quality	.001	.068	.002	.990
Maternal emotional functioning	.010	.068	.021	.886

Note. Dependent variable is average cortisol values, natural log transformed.

associations between wakeup sample time (r = –.129, p = .322) or bedtime sample time (r = .148, p = .255) or the length of children's waking day (r = .233, p = .071) with average cortisol levels and these variables are therefore not included in the model. Model 2 shows that even after maternal parenting quality and emotional functioning are entered in the model, 1 *SD* higher marital functioning is associated with .38 *SD* (17.2%) lower average cortisol levels for both kindergarten-aged children and adolescents.

The associations between parent marital quality and child and adolescent average cortisol levels, controlling for maternal parenting quality and emotional functioning are represented in Figure 1. As is apparent from our analyses, children in both age groups living in homes where mothers and their partners report poorer marital functioning have significantly higher average cortisol levels than children in homes where parents report higher marital functioning. The main effect of child age on cortisol levels is also apparent, with adolescents having higher average cortisol values than kindergarten-aged children.

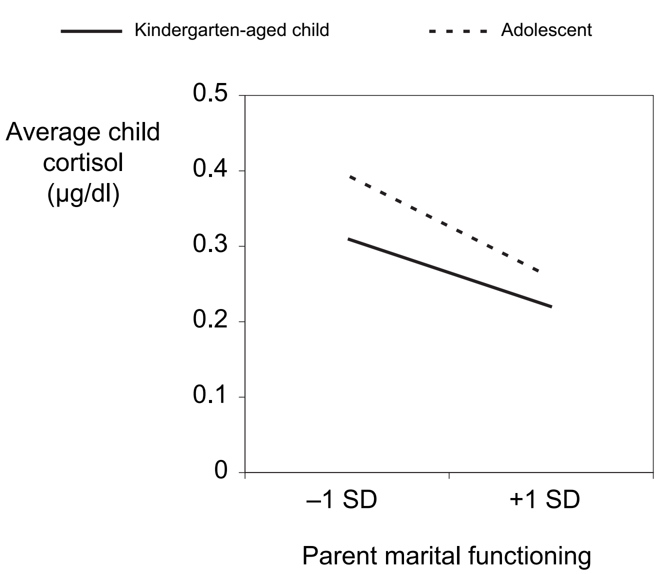

Figure 1. Effect of parent marital functioning on children's average cortisol level while maternal parenting quality and emotional functioning are at mean levels.

Slope of children's diurnal cortisol curve. Table 4 presents hierarchical regression analyses predicting the slope of children's diurnal cortisol curve. In Model 1, we note a highly significant interaction effect between marital functioning and child age in predicting diurnal slope (β = –.068, p = .000), indicating that the effect of marital functioning on the slope of children's diurnal cortisol curves depends on whether the child is a kindergartner or adolescent, with significantly steeper slopes for kindergarten-aged children whose parents report better marital functioning. Considering the presence of a significant product term in our model, we refrain from interpreting the significance (or lack thereof) of the main effects of the two variables of the product term (Allison, 1977, 1999).

Model 2 of Table 4 shows that the interaction effect of marital functioning and child age on children's cortisol slopes remains highly significant (β = –.069, p = .000) and is independent of maternal parenting quality and emotional functioning. We also note a significant negative association between maternal parenting quality and cortisol slope, indicating that for each 1 *SD* increase in maternal parenting quality, children's diurnal cortisol slope are steeper by .24 *SD*. Maternal emotional functioning was not significantly related to the slope of children's diurnal cortisol curve (β = .010, p = .312). Because we noted significant simple correlations for the slope of the diurnal curve with the total hours of awake time (r = .369, p = .003) and wake-up time (r = –.287, p = .025) these variables were included in the final regression model to ensure they did not account for the effects of marital functioning on cortisol slope. Neither total time awake (β = .002, p = .875) or wakeup sampling time (β = –.013, p = .163) accounted for the marital functioning or parenting effects. Examination of the β coefficients indicates a total effect of parents' marital functioning on kindergarten-aged children's slope of –4.3% (β Marital functioning + β (Marital functioning × Child age interaction) = –.044 converted to $100(e^{-.044} - 1)$). T-tests of the simple slopes (Aiken & West, 1991) indicate that kindergartener's slopes are 4.3% steeper for each 1 *SD* increase in marital functioning, a significant effect, whereas adolescents' slopes are 2.5% flatter, an effect which was not significant (p = .358).

The associations between parent marital quality, child age and child cortisol slopes, controlling for maternal parenting quality and emotional functioning, are presented in Figure 2.

Table 4

Linear regression analyses for parent marital functioning, maternal parenting quality and emotional functioning predicting children's diurnal cortisol slopes (N = 61)

Variable	B	SE	β	p-*value*
Model 1 (R^2 = .350)				
Constant	–.138	.009		
Parent marital functioning	.011	.012	.141	.358
Whether kindergarten-aged children	–.034	.013	–.276	.012
MF × WK interaction	–.068	.017	–.615	.000
Model 2 (R^2 = .456)				
Constant	–.138	.073		
Parent marital functioning	.025	.012	.312	.052
Whether kindergarten-aged children	–.032	.019	–.262	.103
MF × WK interaction	–.069	.017	–.626	.000
Maternal parenting quality	–.021	.009	–.244	.030
Maternal emotional functioning	–.010	.009	–.131	.312
Wakeup sampling time	–.013	.009	–.193	.163
Total time awake (hrs)	–.002	.012	–.031	.875

Note. Dependent variable is slope of the diurnal cortisol curve, natural log transformed.

The lines illustrate differences in the steepness of the slope of the diurnal cortisol curve for kindergarten-aged children and teens whose parents report 1 *SD* above the mean on marital functioning, compared to the slope value of kindergarten-aged children and teens whose parents report 1 *SD* below the mean on marital functioning. Note that the graphed lines and the slope values they represent were derived using the regression equations resulting from our analyses. As is apparent from our analyses, kindergarten-aged children living in homes where parents report better marital functioning have significantly steeper slopes, compared to adolescents, for whom marital functioning does not have a statistically significant effect on diurnal cortisol slopes.

Wakeup and bedtime cortisol levels. To understand whether slope effects are driven by wakeup values, bedtime values, or both, we conducted identical sets of hierarchical regression analyses for children's wakeup and bedtime levels of cortisol, the final models of which are presented in Table 5. Prior research has suggested that bedtime cortisol levels are thought to be more subject to immediate environmental influences, whereas wakeup levels may reflect more long term influences on the HPA axis (Gunnar & Vasquez, 2001). As a result, these analyses may provide some insight into the mechanism for the overall slope effects. Table 5 shows that when maternal parenting quality and emotional functioning are in the model, 1 *SD* higher marital functioning is associated with .40 *SD* lower (or 15.4%) wakeup cortisol levels for *both* kindergarten-aged children and adolescents, suggesting that differential effects of parent marital functioning on children's diurnal cortisol slopes by child age are not driven by children's cortisol levels at awakening.

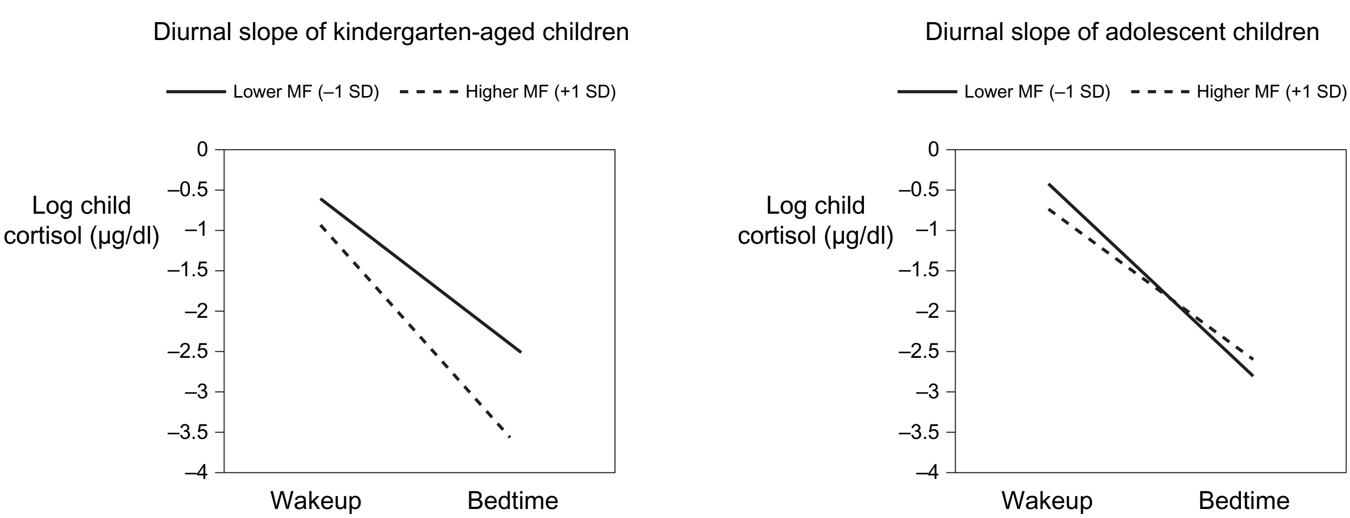

Figure 2. Effect of parent marital functioning on diurnal cortisol slopes while maternal parenting quality and emotional functioning are at mean levels.

Table 5

Linear regression analyses for parent marital quality, maternal parenting quality and maternal emotional functioning predicting children's wakeup and bedtime cortisol levels (N = 61)

Variable	B	SE	β	p-*value*
Wakeup cortisol (R^2 = *.198)*				
Constant	–.613	.054		
Parent marital functioning	–.165	.060	–.396	.008
Whether kindergarten-aged children	–.188	.077	–.291	.018
Maternal parenting quality	.024	.056	.054	.668
Maternal emotional functioning	.051	.056	.131	.369
Bedtime cortisol (R^2 = *.389)*				
Constant	–2.705	.124		
Parent marital functioning	.131	.176	.124	.462
Whether kindergarten-aged children	–.373	.177	–.228	.040
MF × WK interaction	–.724	.236	–.491	.003
Maternal parenting quality	–.223	.130	–.198	.092
Maternal emotional functioning	–.138	.131	–.140	.300

Note. Dependent variables are wakeup and bedtime cortisol level, natural log transformed.

Instead, age differences in effects of marital functioning on children's diurnal cortisol slopes appear to be driven by elevations of kindergarten-aged children's cortisol levels at bedtime (Table 5). Note the significant interaction effect of marital functioning and child age on children's cortisol level at bedtime (β = –.724, p = .003), indicating lower bedtime cortisol levels for kindergarten-aged children in higher marital functioning families even after controlling for maternal parenting quality and maternal emotional functioning. Examination of the β coefficients indicates a total negative effect of marital functioning on kindergartner-aged children's cortisol levels at bedtime of 44.7% (β Marital functioning + β (Marital functioning × Child age interaction) = –.593 converted to $100(e^{-.593} - 1)$, suggesting that bedtime cortisol levels of kindergarten-aged children are 44.7% higher when marital functioning is lower by 1 *SD*. There were no significant associations between wakeup (r = –.185, p = .153) and bedtime sampling times (r = .097, p = .459) and bedtime cortisol, nor did we find that the length of awake time (r = 217, p = .093) predicted children's cortisol levels at bedtime; hence these variables were not included in the final model. There is a trend for an effect of maternal parenting quality on bedtime levels of cortisol (β = –.223, p = .092), with higher quality parenting associated with lower bedtime cortisol levels.

Additional analyses. In addition to the primary analyses presented in detail above, we examined two-way interactions between other composite variables (maternal parenting quality, maternal emotional functioning) and child age, and two-way interactions between all composite variables and child gender. We also tested whether high maternal parenting quality might buffer against the negative effects of poor marital and emotional functioning on cortisol levels by testing two-way interaction between marital functioning and maternal parenting quality, and tested whether poor emotional functioning of the mother might exacerbate the negative effects of poor marital functioning by testing the interaction between participants' marital and emotional functioning.

We tested two-way interactions between child age and child gender on each of our dependent variables to explore if the impact of age on children's cortisol level varied by child gender. Although we had limited degrees of freedom to do so, we also explored whether the impact of marital functioning varied by combinations of child age and gender by running a three-way interaction between marital functioning by child age by child gender. We also examined whether teens' pubertal development, adolescent girls' menstrual status, or the phase of girls' menstrual cycle on the days of testing modified the impact of marital functioning on cortisol. There was no sign that the impact of marital functioning on child cortisol was greater for any particular age-gender combination and no sign that its impact was modified by teens' pubertal development, adolescent girls' menstrual status or menstrual phase.

Discussion

Our study is the first naturalistic study to simultaneously examine associations between parent marital functioning, maternal parenting quality, maternal emotional functioning and children's cortisol levels in a low-risk sample. This investigation finds that poor marital functioning (i.e. low level of marital satisfaction, frequent use of a verbal aggression during interparental disagreements and infrequent use of calm discussion to solve disagreements), is associated with higher average and wakeup cortisol levels in both adolescent and kindergarten-aged children. It also suggests that poor marital functioning is associated with higher bedtime cortisol levels and flatter slopes of the diurnal cortisol curve, but this association is qualified by child age. While kindergarten-aged children whose parents report poor marital functioning have higher bedtime cortisol levels and flatter slopes than children whose parents report high marital functioning, adolescents' cortisol levels at bedtime and slopes of their diurnal cortisol curves are not significantly associated with marital functioning. We also find that higher maternal parenting quality by the mother, as indicated by higher involvement and warmth, is associated with increased steepness in the slope of the diurnal cortisol curve, for both kindergarten-aged children and adolescents. It is important to note that these effects are independent of one another, and of maternal emotional functioning, which does not have a significant independent effect when marital functioning and maternal parenting quality are in the model. That is, the significant simple associations between maternal emotional functioning and child cortisol, in this study, are most likely due to the fact that impaired emotional functioning (high depression and anxiety, low self-esteem) occurs in the context of poor marital functioning and poor maternal parenting.

Poor marital functioning and elevated levels of cortisol

Our findings suggest that the nature of the conflict resolution style employed during interparental disagreements (calmly discussing disagreements versus being verbally abusive) and the level of marital satisfaction have important associations with children's stress hormone levels. As such, our work expands on work by Flinn and England (1995) and Flinn (1999) who examined children's cortisol in a sample of Caribbean children and adolescents. They reported that traumatic family events, especially conflict, quarreling and fighting, predicted acute elevations in child cortisol levels more strongly than any of the other variables measured. They did not, however, simultaneously consider other aspects of family functioning such as maternal emotional functioning and maternal parenting quality and their effects on children's cortisol levels. In addition, they did not examine whether the strength of associations between marital functioning and child cortisol level varied by child age.

While it is clear how acute exposure to conflict would elevate child cortisol, how might marital satisfaction and individual differences in conflict resolution strategies influence children's average cortisol levels, as was observed in the current study? Several possibilities exist. Children whose parents frequently engage in verbally aggressive conflict rather than calm discussion, might feel threatened more often and/or come to anticipate conflict more often, causing a chronic anticipatory elevation of cortisol levels. In addition, children whose parents report low marital satisfaction may less often witness expressions of love, cooperation and affection between their parents, leading them to appraise instances of conflict as more threatening, because they are less certain about the occurrence of resolution. This may lead the child to more frequently worry about conflict occurring, to anticipate escalation of interparental disagreements, and cause them to worry about parental separation, the loss of a parent, and/or loss of stability of family life. Any of these psychological threats, or combinations thereof, could result in more frequent or prolonged elevations of the HPA-axis, which in turn could cause changes in the underlying neurobiological regulation of cortisol levels (Carlson & Earls, 1997; De Bellis et al., 1999; Gunnar, 2000). Clearly, additional studies are needed to examine which, if any, of these mechanisms are responsible for associations between poor marital functioning and individual differences in child basal cortisol levels.

If confirmed, our findings may provide initial evidence of physiological processes underlying what marital discord theorists have described as sensitization (Davies et al., 2002). The sensitization hypothesis suggests that the associations between exposure to high levels of conflict and child distress are a result of individual differences in child response to interparental problems, which, over time, become stable adaptational behavioral patterns. It is possible that these behavioral adaptational patterns are supported by similarly stable, adaptational patterns of physiological arousal which influence behaviors, cognitions and emotions that accompany child distress in the face of marital discord.

Maternal parenting quality and children's cortisol levels

This study finds that decreased parenting quality by the mother (i.e. lower involvement, lower warmth), is associated with flatter slopes of children's diurnal cortisol curve independent of associations between parents' marital functioning and maternal emotional functioning. While there is previous evidence to suggest that young children in neglectful rearing environments exhibit a lack of a normal daytime pattern of cortisol production (Gunnar & Vasquez, 2001), our study is the first to show associations between children's diurnal cortisol slope and maternal parenting quality within the normal range of parent behavior. These results seem to imply that warm, supportive and highly involved maternal parenting may constitute a coping resource for children and as such help children's regulate their physiological arousal, particularly towards the end of the day, regardless of the quality of marital functioning. Although we recognize that it is more difficult for maritally distressed parents to maintain positive parent–child interactions, high quality parenting by the mother in the context of marital discord may constitute a coping resource for children either by avoiding the erosion of children's emotional security (Davies & Cummings, 1994, 1998), or may lead children to make positive cognitive appraisals (Grych, 1998) about their ability to "handle" the (anticipated or incurred) psychological threat posed by interparental discord and as such help them regulate physiological arousal. We find it interesting that effects of maternal parenting quality on the diurnal slope are similar across our full sample, suggesting that high parental involvement by the mother may still represent a coping resource to adolescents under stress, despite their quest for independence from adults.

Emotional functioning and child cortisol levels

Our findings indicate that while maternal emotional functioning is associated with children's cortisol levels as a simple correlation, this association is not independent of associations between parents' marital functioning, maternal parenting quality and children's levels of cortisol levels. Our results may imply that mother's emotional functioning is less likely to be detected by the child (other than through parent–child interactions or its effects on marital interactions), whereas low maternal parenting quality and poor marital functioning are more likely to pose more immediate and salient threats to the child's well-being or goals, resulting in the activation of the HPA axis. This interpretation may be especially reasonable given that maternal emotional functioning in our sample is mostly within the normal range. It is possible that we would have found stronger independent associations between children's cortisol levels and maternal emotional functioning if the mean level of mothers' depressive symptomatology in our sample were closer to the clinical range (CES-D scores of 16 and up; Radloff, 1977) or when preceded by exposure to clinical levels of depression during infancy (see Essex et al., 2002). Although we did not have appropriate data to examine whether exposure to depression during infancy might potentiate the effects of current depression on cortisol, to further explore the impact of severity of mother depression, we conducted hierarchical regression analyses to examine the impact of "whether the mother had CES-D scores 16 or up" (n = 5) and "whether the mother had ever been diagnosed with a mental illness" (n = 7) but found no statistically significant associations or trends. Given these results, we believe that maternal emotional problems are mostly likely to influence child cortisol levels if they impact on aspects of marital functioning that are observable to the child, or are reflected in the mother's behavior towards the child.

Alternative explanations of children's cortisol levels

Although our interpretations thus far have focused on social–environmental factors, the possibility remains that associations between marital functioning, maternal parenting quality and children's cortisol levels may be due to genetic factors. It is conceivable that children with higher cortisol levels have one or both parents who also exhibit elevated cortisol levels, which are in turn related to personality or behavioral traits that make interparental conflict or poor maternal parenting more likely. We find that associations between mother's and children's bedtime cortisol levels are indeed significant (r = .554, p = .01), but note that associations between mother's and children's wakeup levels are not (r = .133, p = .66) suggesting that it more likely that state level variables, rather than trait level characteristics, are responsible for our findings. It is however beyond the scope of this paper to conclusively rule out genetic contributions to the reported associations. In addition, although we did not find any evidence to suggest that adolescents' pubertal development, adolescent girls' menstrual status or menstrual timing were associated with differences in children's cortisol levels, it is possible that other, underlying hormonal and neurobiological changes associated with puberty may play a role in the reported associations.

Another potential explanation for young children's higher cortisol levels at bedtime in homes where mothers report poor marital functioning is that they are a result of children's direct exposure to intense conflict during the two days of the study. However, an examination and comparison of diary reports completed by parents of kindergarten-aged children and by teens suggested that this explanation is unlikely – we did not note any episodes of intense, verbally aggressive conflict occurring in the families on the specific days of study participation.

Last, prior research (Kertes & Gunnar, 2004) has shown that children's participation in evening activities, particularly sports, is associated with small increases in evening cortisol levels in 7- to 10-year-old boys. Again, however, an examination of the diaries completed by parents of kindergarten-aged children and teens on the days of testing suggested that this explanation is unlikely.

Limitations and future directions

We recognize that no firm causal inferences can be made due to the correlational nature of our data. Future research would benefit from taking a longitudinal approach that combines measures of marital functioning, maternal parenting quality and emotional functioning over a longer timeframe in relation to repeated measures of children's cortisol levels in maritally distressed and non-distressed homes. In addition, the use of a larger sample would allow for measurement of a greater range of parental functioning across the domains of interest, as well as provide more degrees of freedom to conduct complex analyses taking into account the history of parent psychopathology, as well as other environmental stressors and sources of support. These caveats aside, the current study suggests that a detailed examination of family functioning may help us understand individual differences in children's HPA axis functioning, not only at the extremes of parental functioning such as domestic violence, abuse or neglect, and parent psychopathology, but also for more common variations in marital, parenting and emotional functioning in the normal range. The long-term implications of these subtle variations in family functioning and cortisol levels for later HPA-axis functioning and for child and adolescent well-being remain to be examined in future research.

References

Adam, E.K. (2005). Momentary emotion and cortisol levels in the everyday lives of working parents. In B. Schneider & L. Waite (Eds.), *Being together, working apart: Dual career families and the work–life balance* (pp. 105–134). Cambridge: Cambridge University Press.

Adam, E.K. (2006). Transactions among trait and state emotion and adolescent diurnal and momentary cortisol activity in naturalistic settings. *Psychoneuroendocrinology*, *31*, 664–679.

Adam, E.K., Gunnar, M.R., & Tanaka, A. (2004). Adult attachment, parent emotion, and observed parenting behavior: Mediator and moderator models. *Child Development*, *75*, 110–122.

Adam, E.K., Klimes-Dougan, B., & Gunnar, M. (In press). Social regulation of stress physiology in infancy, childhood and adulthood: Implications for mental health and education. In Coch, D., Dawson, G., & Fischer, K. *Human behavior, learning and the developing brain: Atypical development*. New York: Guilford Press.

Aiken, L.S., & West, S.G. (1991). *Multiple regression: Testing and interpreting interactions*. Newbury Park, CA: Sage.

Allison, P.D. (1977). Testing for interaction in multiple regression. *American Journal of Sociology*, *82*, 144–153.

Allison, P.D. (1999). Comparing logit and probit coefficients across groups. *Sociological Methods and Research*, *28*, 186–208.

Armsden, G.C., & Greenberg, M.T. (1987). The inventory of parent and peer attachment: Individual differences and their relationship to psychological well-being in adolescence. *Journal of Youth and Adolescence*, *16*, 427–454.

Ashman, S.B., Dawson, G., Panagiotides, H., Yamada, E., & Wilkinson, C.W. (2002). Stress hormone levels of children of depressed mothers. *Development and Psychopathology*, *14*(2), 333–349.

Ballard, M.E., Cummings, E.M., & Larkin, K. (1993). Emotional and cardiovascular responses to adults' angry behavior and to challenging tasks in children of hypertensive and normotensive parents. *Child Development*, *64*, 500–515.

Buehler, C., Anthony, C., Krishnakumar, A., Stone, G., Gerard, J., & Pemberton, S. (1997). Interparental conflict and youth problem behaviors: A meta-analysis. *Journal of Child and Family Studies*, *6*(2), 233–247.

Bugental, D.B., Martorell, G.A, & Barraza, V. (2003). The hormonal costs of subtle forms of infant maltreatment. *Hormones & Behavior*, *43*(1), 237–244.

Carlson, M., & Earls, F. (1997). Psychological and neuroendocrinological sequela of early social deprivation in institutionalized children in Romania. *Annals of the New York Academy of Sciences*, 807.

Chikszentmihalyi, M., & Larson, R. (1987). Validity and reliability of the experience-sampling method. *Journal of Nervous and Mental Disease*, *175*, 526–536.

Chrousos, G.P., & Gold, P.W. (1992). The concepts of stress and stress system disorders. *Journal of the American Medical Association*, *267*, 1244–1252.

Clements, A.D., & Parker, R.C. (1998). The relationship between salivary cortisol concentrations in frozen versus mailed samples. *Psychoneuroendocrinology*, *23*, 613–616.

Crockenberg, S., & Forgays, D. (1994). The role of emotion in children's understanding of and reactions to conflict. Paper presented in April 1994 at the Biennial Conference on Human Development, Pittsburgh PA.

Crockenberg, S., & Forgays, D. (1996). The role of emotion in children's understanding of and reactions to conflict. *Merrill-Palmer Quarterly*, *42*, 22–47.

Crockenberg, S., & Langrock, A.M. (2001a). The role of specific emotions in children's responses to interparental conflict: A test of the model. *Journal of Family Psychology*, *15*(2), 163–182.

Crockenberg, S., & Langrock, A.M. (2001b). The role of emotion and emotional regulation in children's responses to interparental conflict. In J. Grych & F.D. Fyncham (Eds.), *Child Development and Interparental Conflict: Theory, Research and Application*. New York: Cambridge University Press.

Dahl, R.E., Ryan, N.D., Puig-Antich, J., Nguyen, N.A., Al-Shabbout, M., Meyer, V.A., et al. (1991). 24-hour cortisol measures in adolescents with major depression: A controlled study. *Biological Psychiatry*, *30*, 25–36.

Davies, P.T., & Cummings, E.M. (1994). Marital conflict and child adjustment: An emotional security hypothesis. *Psychologically Bulletin*, *116*, 387–411.

Davies, P.T., & Cummings, E.M. (1998). Exploring children's emotional security as a mediator of the link between marital relations and child adjustment. *Child development*, *69*, 124–139.

Davies, P.T., Harold, G.T., Goeke-Morey, M.C., & Cummings, E.M. (2002). Child emotional security and interparental conflict. *Monographs of the Society for Research in Child Development*, *67*(3). Blackwell Publishers, US.

DeBellis, M.D., Baum, A.S., Birmaher, B., Keshavan, M.S., Eccard, C.H., Boring, A.M., et al. (1999). Developmental traumatology, Part I: Biological Stress Systems. *Biological Psychiatry*, *45*.

Devins, G.M., Orme, C.M., Costello, C.G, Binik, Y.M, Frizzell, B., Stam, H.J., et al. (1988). Measuring depressive symptoms in illness populations: Psychometric properties of the Center for Epidemiologic Studies Depression (CES-D) scale. *Psychology & Health*, *2*, 139–156.

El-Sheikh, M. (1994). Children's emotional and physiological responses to inderadult angry behavior: The role of history of interparental hostility. *Journal of Abnormal Child Psychology*, *22*, 661–678.

El-Sheikh, M., Ballard, M., & Cummings, E.M. (1994). Individual difference in preschoolers physiological and verbal responses to videotaped angry interaction. *Journal of Abnormal Child Psychology*, *22*, 303–320.

El-Sheikh, M., Cummings, E.M., & Goetsch, V.L. (1989). Coping with adults' angry behavior: Behavioral, physiological and verbal responses in preschoolers. *Developmental Psychology*, *25*, 490–498.

Emery, R.E. (1982) Interparental conflict and the children of discord and divorce. *Psychological Bulletin*, *92*, 310–330.

Emery, R.E. (1989). Family violence. *American Psychologist*, *44*, 321–328.

Emery, R.E. (1999). *Marriage, divorce and children's adjustment* (2nd ed.). Thousand Oaks, CA: Sage.

Erel, O., & Burman, B. (1995) Interrelatedness of marital relations and parent–child relations: A meta-analytic review. *Psychological Bulletin*, *118*(1), 108–132.

Essex, M.J., Klein, M.H., Cho, E., & Kalin, N.H. (2002). Maternal stress beginning in infancy may sensitize children to later stress exposure: Effects on cortisol and behavior. *Biological Psychiatry*, *52*(8), 776–784.

Flinn, M. (1999). Family environment, stress and health during childhood. In C.M. Worthman & C. Panter-Brick (Eds.), *Hormones, health and behavior: A socio-ecological and lifespan perspective*. Cambridge: Cambridge University Press.

Flinn, M.V., & England, B.G. (1995). Childhood stress and family environment. *Current Anthropology*, *36*, 854–866.

Fowers, B.J., & Olson, D.H. (1993). ENRIUCJ Marital Satisfaction Scale: A Brief Research and Clinical Tool. *Journal of Family Psychology*, *7*, 176–185.

Gillin, J.C., Jacobs, L.S., Fram, D.H., & Snyder, F. (1972). Acute effect of a glucocorticoid on normal human sleep. *Nature*, *237*(5355), 398–399.

Gottman, J.M., & Katz, L.F. (1989). Effects of marital discord on young children's peer interaction and health. *Developmental Psychology*, *25*, 373–381.

Gottman, J.M., & Levinson, R.W. (1992). Marital processes predictive of later dissolution: Behavior, physiology and health. *Journal of Personality and Social Psychology*, *63*, 221–233.

Granger, D.A., Serbin, L.A., Schwartzman, A., Lehoux, P., Cooperman, J., & Ikeda, S. (1998). Children's salivary cortisol, internalising behaviour problems, and family environment: Results from the Concordia Longitudinal Risk Project. *International Journal of Behavioral Development*, *22*(4), 707–728.

Grych, J.H. (1998). Children's appraisal of interparental conflict: Situational and contextual influences. *Journal of Family Psychology*, *12*, 437–453.

Grych, J.H., & Fincham, F.D. (1990). Marital conflict and children adjustment: A cognitive-contextual framework. *Psychological Bulletin*, *108*, 267–290.

Grych, J.H., & Fincham, F.D. (1993). Children's appraisal of marital conflict: Initial investigation of the cognitive-contextual framework. *Child Development*, *64*, 215–239.

Grych, J.H., & Fincham, F.D. (Eds.) (2001) *Interparental conflict and child development: Theory, research and application*. New York: Cambridge University Press.

Grych, J.H., Fincham, F.D., Jouriles, E.N., & McDonald, R. (2000). Interparental conflict and child adjustment: Testing the mediational role of appraisals in the cognitive-contextual framework. *Child Development*, *71*, 1648–1661.

Grych, J.H., Harold, G.T., & Miles, C.J. (2003). A prospective investigation of appraisals as mediators of the link between interparental conflict and child adjustment, *Child Development*, *74*, 1176–1193.

Gunnar, M.R. (1998). Quality of early care and buffering of neuroendocrine stress reactions: Potential effects on the developing human brain. *Preventive Medicine: An International Journal Devoted to Practice & Theory*, *27*(2), 208–211.

Gunnar, M.R. (2000). Early adversity and the development of stress reactivity and regulation. In C.A. Nelson (Ed.), *Minnesota symposia on child psychology, Vol. 31: The effects of early adversities on neurobehavioral development*. Mahwah, NJ: Lawrence Erlbaum Associates.

Gunnar, M.R., Brodersen, L., Nachmias, M., Buss, M., & Rigatuso, J. (1996). Stress reactivity and attachment security. *Developmental Psychobiology*, *29*(3), 191–204.

Gunnar, M.R., & Donzella, B. (2002). Social regulation of the cortisol levels in early human development. *Psychoneuroendocrinology*, *27*, 199–220.

Gunnar, M.R., & Vazquez, D.M. (2001). Low cortisol and a flattening of expected daytime rhythm: Potential indices of risk in human development. *Development & Psychopathology*, *13*(3), 515–538.

Halligan, S., Herbert, J., Goodyer, I.M., & Murray, L. (2004). Exposure to postnatal depression predicts elevated cortisol in adolescent offspring. *Biological Psychiatry*, *55*, 376–381.

Johnson, E.O., Karmilaris, T.C., Chrousos, G.P., & Gold, P.W. (1992). Mechanisms of stress: A dynamic overview. *Neuroscience and Biobehavioral Reviews*, *16*, 115–130.

Katz, L., & Gottman, J.M. (1995). Vagal tone protects children from marital conflict. *Development and Psychopathology*, *7*, 83–92.

Katz, L., & Gottman, J.M. (1996). Marital interaction and child outcomes: A longitudinal study of mediating and moderating processes. In D. Cicchetti & S. Toth (Eds.), *Rochester Symposium on Developmental Psychopathology, Vol. 6*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kertes, D.A., & Gunnar, M.R. (2004). Evening activities as a potential confound in research on the adrenocortical system in children. *Child Development*, *75*(1), 193–204.

Kirschbaum, C., & Hellhammer, D.H. (1989). Salivary cortisol in psychobiological research: An overview. *Neuropsychobiology*, *22*, 150–169.

Kirschbaum, C., & Hellhammer, D.H. (1994). Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology*, *19*(4), 313–333.

Kirschbaum, C., & Helhammer, D.H. (2000). Salivary cortisol. In G. Fink (Ed.), *Encyclopedia of Stress, Vol. 3* (pp. 379–383). San Diego: Academic Press.

Kirschbaum, C., Kudielka, B., Gaab, J., Schommer, N.C., & Helhammer, D.H. (1999). Impact of gender, menstrual cycle phase, and oral contraceptives on the activity of the hypothalamus-pituitary-adrenal axis. *Psychosomatic Medicine*, *61*, 154–162.

Kudielka, B.M., Broderick, J.E., & Kirschbaum, C. (2003). Compliance with saliva sampling protocols: Electronic monitoring reveals invalid cortisol daytime profiles in noncompliant subjects. *Psychosomatic Medicine*, *65*(2), 313–9.

Kudielka, B.M., & Kirschbaum, C. (2002). Awakening cortisol responses are influenced by health status and awakening time but not by menstrual cycle phase. *Psychoneuroendocrinology*, *28*, 35–37.

McEwen, B.S. (1998). Stress, adaptation and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *840*, 33–44.

Neter, J., Kutner, M.H., Nachtsheim, C.J., & Wasserman, W. (1996). *Applied linear statistical models*. Chicago: Irwin.

Netherton, C., Goodyer, I., Tamplin, A., & Herbert, J. (2004). Salivary cortisol and dehydroepiandrosterone in relation to puberty and gender. *Psychoneuroendocrinology*, *29*, 125–140.

Peterson, A.C. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence*, *17*, 117–133.

Plihal, W., & Born, J. (1999). Memory consolidation in human sleep depends on inhibition of glucocorticoid release. *NeuroReport*, *10*(13), 2741–2747.

Pruessner, J.C., Gaab, J., Hellhammer, D.H., Lintz D., Schommer, N., & Kirschbaum, C. (1997). Increasing correlations between personality traits and cortisol stress responses obtained by data aggregation. *Psychoneuroendocrinology*, *22*(8), 615–625.

Radloff, L.S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, *1*, 385–401.

Repetti, R.L., Taylor, S.E., & Seeman, T.E. (2002). Risky families: Family social environments and the mental and physical health of offspring. *Psychological Bulletin*, *128*, 330–366.

Sapolsky, R.M. (2000). Glucocorticoids and hippocampal atrophy in neuropsychiatric disorders. *Archives of General Psychiatry*, *57*(10), 925–935.

Scerbo, A.S., & Kolko, D.J. (1994). Salivary testosterone and cortisol in disruptive children: Relationship to aggressive, hyperactive and internalizing behaviors. *Journal of the American Academy of Child and Adolescent Psychiatry*, *33*, 1174–1184

Schwartz, E.B., Granger, D.A., Susman, E.J., Gunnar, M.R., & Laird, B. (1998). Assessing salivary cortisol in studies of child development, *Child Development*, *69*, 1503–1513.

Smider, N.A., Essex, M.J., Kalin, N.H., Buss, K.A., Klein, M.H., Davidson, R.J., et al. (2002). Salivary cortisol as a predictor of socioemotional adjustment during Kindergarten: A prospective study. *Child Development*, *73*, 75–92.

Straus, M.A., & Hamby, S.L. (1996). The Revised Conflict Tactics Scale (CTS2). *Journal of Family Issues*, *17*(3), 283.

Talge, N.M., Donzella, B., Kryzer, E.M., Gierens, A., & Gunnar, M.R. (2005). It's not that bad: Error introduced by oral stimulants in salivary cortisol research. *Developmental Psychobiology*, *47*(4), 369–376.

Taylor, J., & Tomasic, M. (1996) Taylor's measures of dysphoria, anxiety, anger, and self esteem. In R.L. Jones (Ed.), *Handbook of tests and measurements for black populations* (pp. 295–305). Hampton: Cobb & Henry.

Warren, S.L., Gunnar, M.R., Kagan, J., Anders, T.F., Simmens, J., Rones, M., et al. (2003). Maternal panic disorder: Infant temperament, neurophysiology, and parenting behaviors. *Journal of the American Academy of Child & Adolescent Psychiatry*, *42*(7), 814–825.

Whisman, M.A. (2001). Association between depression and marital dissatisfaction. In Beach, S.R.H. (Ed.), *Marital and family processes in depression: A scientific foundation for clinical practice* (pp. 3–24). Washington DC, US: American Psychological Association.