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Marital Satisfaction, Recovery From Work, and Diurnal Cortisol Among Men and Women

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Design: Multilevel modeling was used to model relationships between salivary cortisol, daily diary ratings of work experiences, and Marital Adjustment Test scores (Locke & Wallace, 1959), in a sample of 60 adults who sampled saliva 4 times per day over 3 days. ***Results:*** Among women but not men, marital satisfaction was significantly associated with a stronger basal cortisol cycle, with higher morning values and a steeper decline across the day. For women but not men, marital satisfaction moderated the within-subjects association between afternoon and evening cortisol level, such that marital quality appeared to bolster women's physiological recovery from work. For both men and women, evening cortisol was lower than usual on higher-workload days, and marital satisfaction augmented this association among women. Men showed higher evening cortisol after more distressing social experiences at work, an association that was strongest among men with higher marital satisfaction. ***Conclusion:*** This work has implications for the study of physiological recovery from work, and also suggests a pathway by which marital satisfaction influences allostatic load and physical health.

Keywords: hypothalamic-pituitary-adrenal (HPA) axis, cortisol, allostatic load, marital satisfaction, unwinding, gender

A hormone secreted by the hypothalamic-pituitary-adrenal (HPA) axis in response to stress, cortisol has attracted interest among both experimental and naturalistic researchers. Experimentally, an extensive body of research work has found reliable cortisol responses to laboratory stressors ranging from electric shock to public speaking (Dickerson & Kemeny, 2004). However, much of the naturalistic cortisol research to date has been inconclusive. A recent meta-analysis of 14 studies (Hjortskov, Garde, Orbæk, & Hansen, 2004) concluded that there is insufficient evidence for a consistent connection between everyday stress and cortisol output. A study of 91 working parents (Kurina, Schneider, & Waite, 2004) found only two significant associations between daily stressors and cortisol out of 24 comparisons, a rate close to chance. In addition, there is ambiguity within the research literature about how to measure cortisol and what types of cortisol patterns represent maladaptive or adaptive functioning. For example, both hypercortisolism, or high cortisol across the day, and hypocortisolism, chronically low cortisol, have been associated with impaired psychological functioning (Burke, Davis, Otte, & Mohr, 2005; Fries, Hesse, Hellhammer & Hellhammer, 2005).

Wide individual variability in daily patterns of cortisol excretion contributes to the difficulty of conducting naturalistic research. Cortisol levels can vary due to time of day and behaviors including smoking, eating, and exercise, whereas diurnal cortisol cycles may be affected by time of awakening, medication, and the menstrual cycle (Kudielka & Kirschbaum, 2003). Cortisol levels show a strong circadian rhythm, typically peaking in the early morning hours (within 20 or 30 minutes of awakening), decreasing rapidly during the morning, and then declining more gradually as the day continues. However, this "typical" rhythm is not universal. In two recent studies, the percentage of participants exhibiting normal diurnal cortisol slopes ranged from 48% to 60%, with remaining participants producing flat or inconsistent slopes (Ice, Katz-Stein, Himes, & Kane, 2004; Smyth et al., 1997).

Diurnal Cortisol Slope and Psychosocial Functioning

A number of researchers have found links between the "flat" diurnal cortisol slope and measures of chronic stress or psychosocial maladjustment. This pattern, in which cortisol levels are low in the morning and fail to show the typically steep decline across the day, signals a "weak" basal cortisol rhythm and may indicate allostatic load, or a blunting of the body's self-regulation processes resulting from chronic wear (McEwen, 1998). Flat diurnal cortisol rhythms have been linked to adverse health outcomes, as in a study of breast cancer patients that found earlier mortality among women with flat cycles (Sephton, Sapolsky, Kraemer, & Spiegel, 2000).

Flattened cortisol slopes have been observed in a number of populations with compromised psychosocial functioning, such

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as patients with posttraumatic stress disorder (Lauc, Zvonar, Vuksic-Mihaljevic, & Flogel, 2004), parents of children with cancer (Miller, Cohen, & Ritchey, 2002), women high in repressed or anxious coping (Giese-Davis, Sephton, Abercrombie, Durán, & Spiegel, 2004), and women reporting high stress and low perceived social support (Abercrombie et al., 2004). Flattened rhythms have also been linked specifically with marital dissatisfaction. A study that examined middle-class mothers of toddlers found flatter diurnal cortisol slopes among women with more insecure attachment styles and less rewarding marital relationships (Adam & Gunnar, 2001). Another study found the steepness of the diurnal cortisol slope to be positively correlated with marital satisfaction among women (Vedhara, Tunistra, Miles, Sanderman, & Ranchor, 2006). Although the majority of the studies cited above recruited only female participants, a study that sampled both men and women (Barnett, Steptoe, & Gareis, 2005) found that participants who reported higher marital-role concerns had a significantly flatter cortisol slope over the day.

In the current study, we expected participants high in marital satisfaction to produce stronger basal cortisol cycles, defined in terms of higher morning cortisol values and steeper declines over the day. We expected the relationship between marital adjustment and cortisol slope to be stronger for women because of evidence (discussed below) that women may be more physiologically sensitive to marital quality.

Gender and Relationship Factors in Stress Responding

Like flattened diurnal slope, insufficient physiological recovery from stressful events might also indicate allostatic load (McEwen, 1998). Related, individual differences in "unwinding," or the change in physiological arousal after the workday, may be associated with chronic stress burden and coping resources (Dienstbier, 1989; Frankenhaeuser, 1989). Several researchers have found differences in men and women's physiological responses to the transition from work to home. A Swedish study found after-work decreases in male managers' blood pressure, norepinephrine (NE) and cortisol excretion, whereas female managers' evening blood pressure, NE, and cortisol levels stayed closer to daytime levels (Frankenhaeuser et al., 1989). A follow-up study found elevated after-work epinephrine and NE levels in white-collar working women compared to working men (Lundberg & Frankenhaeuser, 1999). Other researchers have discovered that working women exhibit higher levels of physiological arousal on "rest days" than working men do, signaling a lack of recovery, and that women with children tend to excrete more evening cortisol than women without children (Luecken et al., 1997; Pollard, Ungpakorn, Harrison, & Parkes, 1996). These differences may extend from women's greater share of domestic responsibilities or the greater perceived importance of marital and family relationships to their self-concept (Kiecolt-Glaser & Newton, 2001). Interpersonal relationship variables may also be more closely linked to women's stress responding than men's, with several studies finding greater physiological reactivity to marital conflict and disagreement among women, despite men's typically stronger response to laboratory stressors (c.f. Brown & Smith, 1992; Kiecolt-Glaser & Newton, 2001). If marital stressors are more salient for women's "unwinding" than men's, it might help to explain why, although men derive an overall health benefit from marriage, women's health outcomes appear more strongly related to the quality of their marriage than to the simple fact of being married (Gallo, Troxel, Matthews, & Kuller, 2003; Kiecolt-Glaser & Newton, 2001). Women living with marital conflict or an inequitable share of housework may experience greater allostatic wear, diminishing the health benefits of marriage.

In this study, we examined after-work recovery, or "unwinding," by exploring associations between self-reported daily work stress and evening cortisol levels. We focused on three potential indicators of workday stress: afternoon cortisol level, workload, and negative social interactions at work. The latter two indicators have been linked with changes in evening mood and behavior among husbands and wives (Repetti, 1989; Story & Repetti, 2006), but have not yet been specifically examined by naturalistic cortisol researchers. We expected that elevations in all three of these potential markers of work stress would be associated with higher than usual cortisol levels in the evening. However, we expected that men would show stronger "recovery" effects than women, in terms of a steeper reduction of cortisol after a stressful day, and that marital satisfaction would moderate this relationship for women, such that greater marital adjustment would be associated with more effective evening recovery.

The Current Study

The current study examined diurnal cortisol in the context of daily self-report measures and questionnaire data. We focused on two research questions:

RQ1: How does marital satisfaction relate to basal cortisol cycle? Within this study, participants with lower marital satisfaction scores were expected to exhibit flatter diurnal cortisol rhythms than those who reported better marital adjustment. We expected this result to be stronger for women than for men.

RQ2: How do men and women recover physiologically from work? To our knowledge, there is no published research using diurnal cortisol data to test this specific question, so our expectations were speculative. We expected both men and women to show higher than usual cortisol in the evening after a stressful workday. However, we expected men to show stronger cortisol recovery from stressful work experiences than women, specifically a larger decrease from afternoon to evening cortisol levels on challenging workdays. We also expected marital satisfaction to moderate this relationship among women.

Method

Sample

Thirty-two families in a Southwestern U.S. city were recruited for a study of two-earner middle-class families. Eligibility for inclusion in the study was based on the following criteria: (a) each family included two cohabitating adults; (b) both parents worked full-time, at least 30 hr per week; (c) the family included two to three children, one of whom was between 8 and 10 years of age at the time of the study; and (d) the family had a mortgage on its home.

The present study used data collected from the two adults in each family, with 30 participating couples. Of the 60 adults included in the final sample, the median age was 41 years for both men and women, with a range of 32 to 58 years among men and a range of 28 to 50 years among women. The average number of children per participating family was 2.3, with a median of 2. The couples in the study had been married for a median of 13 years, with a range of 3 to 18 years. The median annual family income was $100,000, ranging from $51,000 to $196,000.

Procedure

The study sought to capture a “week in the life” of each family. During the week of the family’s participation, family members were videotaped by researchers for 4 days. On 3 separate weekdays, 2 of which overlapped with filming days, participating family members completed four daily diary measures of mood and workload and provided four self-collected saliva samples for cortisol analysis. Therefore, although the days of daily data collection are sometimes referred to as data from Day 1, Day 2, or Day 3, these were not necessarily consecutive days. At a separate session, after completing the study week, parents filled out a questionnaire on marital quality.

Cortisol Collection

Family members were instructed to self-collect saliva samples and report collection times at four timepoints: (a) early morning, sampled on awakening; (b) late morning, sampled just before lunch; (c) afternoon, sampled just before leaving work, and (d) evening, sampled before going to bed. Mean collection times were 6:25 a.m. (early morning), 12:20 p.m. (late morning), 4:30 p.m. (afternoon) and 10:10 p.m. (evening). The standard deviation of collection time across all participants was largest in the afternoon (87 minutes) and smallest in the morning (49 minutes).

Equipment for collecting saliva (labeled vials, straws, thermoses, and reminder beepers) was dropped off at families’ homes before the study week began, along with daily self-report questionnaire forms, by a research assistant who also reviewed procedures, including instructions for saliva sampling and storage, and programmed reminder beepers for each family member.

Participants were asked not to eat or drink anything other than water in the half hour preceding saliva collection. If they indicated on their diary form that they had eaten within half an hour of saliva collection, that sample was eliminated from analyses. Participants were also asked to record the time of each sampling as well as any medications consumed or cigarettes smoked during the preceding hours. Family members were given thermoses in which to keep saliva vials collected at work or at school, and were asked to store vials in the refrigerator until they were picked up by a research assistant the following day. Saliva vials were then frozen and shipped under climate-controlled conditions to Salimetrics, a research facility specializing in saliva immunoassay testing. Samples were assayed using a highly sensitive enzyme immunoassay U.S. Federal Drug Administration (510k) cleared for use as an in vitro diagnostic measure of adrenal function (Salimetrics, State College, PA). The test used 25 ul of saliva, had a lower limit of sensitivity of .007 ug/dl, range of sensitivity from .007 to 1.8 ug/dl, and average intra- and interassay coefficients of variation of less than 5% and 10%. The average of duplicate assays for each sample was used in all analyses and units are reported in ug/dl (micrograms per deciliter). To correct for positive skewness, a natural log transformation was performed on the cortisol data before analyses were conducted.

Questionnaire and Diary Measures

At the same time they sampled saliva, family members filled out daily diary questionnaires. For adults, the second and third diaries of the day (late morning and afternoon timepoints) included questions about workload and social interactions at work. A measure of marital adjustment was completed after the daily report week.

Workload. The five-item Busy Day scale (Repetti, 1989; Repetti & Wood, 1997) included items such as “There were more demands on my time than usual” and “I could have used more time for a break,” and used 4-point response scale ranging from 1 (*completely inaccurate*) to 4 (*completely accurate*). Previous analyses indicate significant day-to-day associations between this scale and objective measures of daily workload in a sample of air traffic controllers (Repetti, 1989). In the current study, Cronbach’s alpha ranged from .89 to .90 over 3 days. The mean score was 2.19 (scored ranged from 1 to 4; $SD = 0.83$).

Social interactions. The 14-item Negative Social Interactions at Work scale inquires about negative feelings (e.g., resentment, tension, distance) experienced during social interactions at work. The same seven emotions were rated on a 4-point scale ranging from 1 (*rarely*) to 4 (*almost always*) to describe feelings during interactions with supervisors and with coworkers. The Negative Social Interactions at Work scale has been shown to correlate reliably with independent measures of satisfaction with social relationships at work and social support in the workplace (Repetti, 1993). Across the different days of saliva collection, Cronbach’s alphas in this study ranged from .86 to .89. The mean score was 1.18 (scored ranged from 1 to 2.79, $SD = 0.23$).

MAT. The Marital Adjustment Test (MAT) is a 16-item measure that assesses spouses’ satisfaction with their marriage and the degree of closeness they feel to their partner (Locke & Wallace, 1959). The MAT has been found to have split-half reliability of .90, and is used extensively by researchers to discriminate between happy and unhappy couples. In this study, Cronbach’s alpha was .82 for women and .81 for men. On the MAT, higher scores are associated with better marital functioning, with average scores typically around 115, scores below 100 indicating distress in the marriage, and scores below 70 signaling serious distress. In this sample, both the mean and median score was 111 (range 64 to 154), with a median of 116 for men (range 67 to 150) and a median of 109 for women (range 64 to 154). Before analyzing these data using Hierarchical Linear Modeling (HLM), we centered scores on the sample mean and divided them by the standard deviation (22.3).

Data Analysis of Cortisol

All data were analyzed using multilevel modeling techniques, with HLM (Version 6.01; Raudenbush, Bryk, & Congdon, YEAR; SSI Scientific Software International). Multilevel modeling is ideal for representing how variables change across time and how those changes are associated with trait level (between-person) and state level (within-person) factors. In HLM, the effects of trait factors can be seen not just at baseline (intercept) but also in terms of their impact on state-related, or within-person change (slope). HLM is optimal for cortisol analysis (Hrushka, Kohrt, & Worthman, 2005) because of the strong diurnal rhythm of cortisol. In addition, HLM is able to calculate slopes and intercepts even when some values are missing, so there does not need to be equal numbers of observations across individuals for data analysis to be performed, nor do observations need to be evenly spaced (Hrushka et al., 2005).

Missing data. Almost a third of the participants (31%) either skipped one or more of the 12 timepoints for saliva collection over the 3 days of study or reported eating in the half hour before a saliva timepoint. If a sample was skipped or taken after eating, that data point was eliminated from analyses. Missing data varied by timepoint, and there tended to be more missing data as the day went on. The total percentage of cortisol samples that were missed ranged from 5% to 11.7% of the total possible samples for each timepoint. Altogether, 70 cortisol samples were omitted from the dataset out of 720 possible samples, 9.7% of the total.

Combining data. Participants' average cortisol levels from Day 1 to Day 2 were significantly correlated, $r = .54$, $p < .001$, as were cortisol levels from Day 1 to Day 3, $r = .65$, $p < .001$, and Day 2 to Day 3, $r = .64$, $p < .001$. These correlations are similar to that reported by Adam and Gunnar (2001), $r = .65$, $p < .001$ over 2 days of study. Given this stability, the 3 days of data were combined for the first set of analyses reported here, so that each participant's diurnal slope was modeled based on all 12 cortisol samples. This is a common strategy used by researchers using multilevel modeling to study cortisol (Adam, 2006; Adam & Gunnar, 2001; Smyth et al., 1997), because it increases the number of data points for each individual, allowing for a more representative picture of that individual's typical diurnal rhythm.

Time-adjusted evening cortisol. For the second research question, which tested associations between daytime work experiences and evening cortisol, we calculated a time-adjusted evening level for each day that approximated cortisol values at 8 p.m. This was done to adjust for the fact that participants sampled evening cortisol at slightly different times on each of the 3 days. This variable was created by regressing logged afternoon and evening cortisol values by collection time to plot a linear slope (because diurnal cortisol rhythms typically show a linear decline or plateau by the end of the day). This slope was then used to estimate cortisol levels at 8 p.m. for each participant, on each day, for each of the 3 days of study.

Results

After presenting basic descriptive analyses of cortisol levels across the day, we focus on each of the two main research questions. All HLM results reported here represent the final estimation of fixed effects, with robust standard errors.

Cortisol Patterns Across the Day

As seen in Figure 1, participants' cortisol data showed the expected diurnal rhythm: cortisol levels were highest shortly after waking, declined most rapidly across the morning, then tapered off until bedtime. The change in cortisol levels across the 3 days was modeled separately for each individual in a Level 1 model, using log-transformed cortisol as the outcome variable and collection time as the predictor. We tested both a linear and a curvilinear Level 1 model, and, like other researchers who have used this approach (Adam, 2005; Vedhara et al., 2003) found that the best-fitting Level 1 equation included both time and time^2:

$$Y_{ij} = \pi_{0i} + \pi_{1i}\text{TIME}_{ij} + \pi_{2i}\text{TIME}^2{}_{ij} + \varepsilon_{ij},$$

where Y_{ij} corresponds to the cortisol value of person i at sampling occasion j; π_{0j} is participant i's cortisol intercept, or starting value (cortisol at 5 a.m. in this case); $\pi_{1i}\text{TIME}_{ij}$ and $\pi_{2i}\text{TIME}^2{}_{ij}$ are regression coefficients for the association of time and time squared, respectively, with participant i's cortisol level, and ε_{ij} is the error term for person i at occasion j.

Using this model, time of day accounted for 73% of the variation in participants' cortisol levels. This is consistent with results reported by Adam (2005) and Adam and Gunnar (2001), who found time of day to account for 67% and 72% of the variation in cortisol levels, respectively. Our Level 1 model predicting cortisol values from time of day included significant effects of both the time and time^2 predictors (see Table 1). As expected, the estimated slope coefficient was negative, reflecting a –.22 decrease in logged cortisol for each subsequent hour, and the "time^2" predictor was positive (.005 change in logged cortisol for each unit of time^2), reflecting a normal diurnal cortisol cycle that shows an initially steep decline and then levels off.

We next added Level 2 predictors to our Level 1 model that included time and time^2. In two-level HLM models, Level 2 is often used for between-person variables; adding a Level 2 predictor such as gender score to our existing HLM model generates three additional equations defining the intercept (π_{0i}), slope by time (π_{1i}), and slope by time^2 (π_{2i}) of our Level 1 equation. For example, the equation defining π_{0i} is:

$$\pi_{0i} = \gamma_{00} + \gamma_{01}(\text{Gender}_i) + \varepsilon_{ij},$$

where π_{0j} is predicted by γ_{10}, the sample's average cortisol at 5 a.m., and $\gamma_{11}(\text{Gender}_i)$, which reflects the overall difference in 5 a.m. cortisol as a function of gender. Likewise, $\pi_{1i}\text{TIME}_{ij}$ is modeled as a function of γ_{10}, the overall change per unit of time during the day and $\gamma_{11}(\text{Gender}_i)$, the added increase or decrease in that slope attributable to gender.

There was no significant Level 2 effect of gender on the model that included time and time^2, suggesting that men and women showed similar cortisol patterns across the day. However, because the genders might differ in patterns of associations between cortisol and other variables, we split the sample by gender and tested data from men and women separately in the following analyses.

Research Question 1: Marital Satisfaction Predicting Cortisol Rhythms

To examine associations between typical diurnal slope and marital satisfaction, we added MAT scores at Level 2 to the basic Level 1 HLM model that included time and time^2.

Results are reported in Table 1. Women's MAT scores had a significant positive association with the intercept or starting value of estimated cortisol at 5 a.m., suggesting that women with higher marital satisfaction started out the day with higher cortisol levels. Women's MAT scores had a significantly negative effect on the time slope, indicating that higher marital satisfaction was associ-

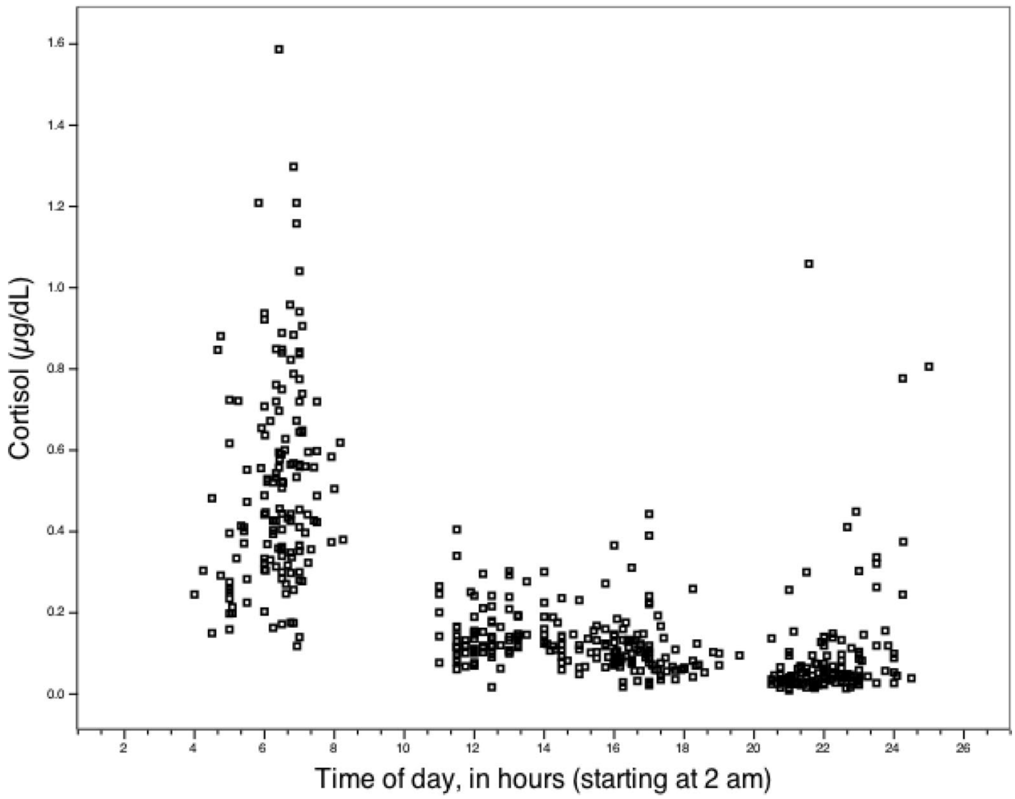

Figure 1. Cortisol values for all participants over three days of study (n = 60 participants, approximately 12 samples per participant).

ated not only with higher morning cortisol values but also with a steeper cortisol decline across the day. The association between MAT score and the slope of time^2 for women was marginally significant but positive, also in keeping with expectations because time^2 is an indicator of curvilinear steepness.

For men, there were no significant associations between MAT score and cortisol at 5 a.m. or diurnal cortisol change over time.

To summarize, the data suggest that women who report greater marital satisfaction tend to have stronger basal cortisol cycles, as defined by higher morning cortisol levels and a steeper decline

Table 1
Time of Day and Marital Satisfaction Predicting Cortisol Level for Men and Women Using HLM

Fixed effect	Coefficient (standard error)	t ratio
Women (n = 30)		
Intercept (average cortisol value at 5 a.m.)	$-.45^{**}$ (.11)	−4.51
Level 2 effect of MAT score on intercept	$.27^{**}$ (.10)	2.78
Average slope of time (change in cortisol per 1-hr change in time)	$-.23^{**}$ (.02)	−10.79
Level 2 effect of MAT score	$-.04^{*}$ (.02)	2.08
Average slope of time^2 (change in cortisol per one-unit change in time^2)	$.005^{**}$ (.00)	3.73
Level 2 effect of MAT score	.002† (.00)	1.68
Men (n = 30)		
Intercept (average cortisol value at 5 a.m.)	$-.50^{**}$ (.09)	−5.43
Level 2 effect of MAT score on intercept	.04 (.01)	0.44
Average slope of time (change in cortisol per 1-hr change in time)	$-.22^{**}$ (.03)	−8.74
Level 2 effect of MAT score	−.01 (.00)	0.46
Average slope of time^2 (change in cortisol per one-unit change in time^2)	$.005^{**}$ (.00)	3.65
Level 2 effect of MAT score	.001 (.00)	0.42

Note. HLM = Hierarchical Linear Modeling; MAT = Marital Adjustment Test.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$.

from morning to evening cortisol. Men's diurnal cortisol rhythms did not appear to be significantly related to their reported marital satisfaction.

Research Question 2: After-Work Recovery: Workday Experiences Predicting Evening Cortisol

For our next set of analyses, we focus on within-person change across days rather than on between-person predictors of "typical" daily slope. We explored recovery from work by testing associations between evening cortisol and three potential indicators of workday stress: afternoon cortisol level, afternoon workload rating, and afternoon rating of negative social interactions at work. For the first set of analyses, testing the association between afternoon and evening cortisol, our Level 1 equation was

$$Y_{ij} = \pi_{0i} + \pi_{1i}\text{AftCort}_{ij} + \pi_{2i}\text{TimeLapse}_{ij} + \varepsilon_{ij},$$

where Y_{ij} corresponds to the evening cortisol value of participant i on day j, and $\pi_{1i}\text{AftCort}_{ij}$ is the coefficient for the within-subject effect of afternoon cortisol level on evening cortisol level (i.e., do day-to-day fluctuations in afternoon cortisol predict changes in evening cortisol?). The evening cortisol value used in this case was not time-adjusted, because, as described in the Method section, time-adjusted cortisol was calculated using afternoon cortisol level, which we use as a predictor in this equation. Therefore, we also included $\pi_{2j}\text{TimeLapse}_{ij}$ as a control variable representing time elapsed between afternoon and evening samples (that is, afternoon sampling time subtracted from evening sampling time) on day i. Next, we added the Level 2 predictor of MAT score to this equation, creating Level 2 equations defining π_{0i} and π_{1i} (we did not examine the effect of MAT score on the sampling time difference, as this was not of a priori interest). For these analyses, the residual parameter variance for the Level 1 coefficient of "TimeLapse" was set to zero.

Results are presented in Table 2. Afternoon cortisol was not a significant predictor of evening cortisol either for men or for women. When MAT score was added as a Level 2 predictor, however, an interesting relationship emerged among women, such that greater marital satisfaction had a negative effect on the slope coefficient for afternoon cortisol. In other words, although less happily married women tended to show higher than usual evening cortisol on days of higher than usual afternoon cortisol, more happily married women did not show this relationship. This finding is illustrated in Figure 2: average slopes representing the association between afternoon and evening cortisol are estimated for women with marital satisfaction ratings at the mean, one standard deviation above the mean, and one standard deviation below the mean. For women reporting higher marital satisfaction, there appeared to be no relationship or even a slightly negative relationship between afternoon and evening cortisol.

For the next two sets of analyses, the time-adjusted cortisol score, an estimate of logged cortisol levels at 8 p.m. on each day, served as the outcome variable. Therefore, time did not need to be included as a Level 1 predictor.

Workload. Results are presented in Table 3 and Figure 3, with time-adjusted "cortisol at 8 p.m." values as the outcome, afternoon workload score as the Level 1 predictor, and MAT score as the Level 2 predictor. Unexpectedly, for both men and women, a higher afternoon workload rating significantly predicted lower cortisol at 8 p.m. that evening. As in the previous analyses, MAT scores were not significantly associated with men's evening cortisol intercept or slope. However, women's MAT scores moderated the association between afternoon workload and evening cortisol, such that women with higher MAT scores had lower evening cortisol after a busier day. Thus, marital satisfaction appeared to amplify women's recovery from busy days.

Negative social interactions at work. Next, afternoon ratings of negative social interactions at work were entered as the Level 1 predictor in an HLM model with MAT score as the Level 2 predictor and time-adjusted evening cortisol as the outcome. See Table 4 and Figure 4 for results. Both MAT and negative social interactions were significant predictors of evening cortisol for men but not women.

Table 2
Afternoon Cortisol and MAT Score Predicting Evening Cortisol for Men and Women

Fixed Effect	Coefficient (standard error)	t ratio
Women ($n = 30$)		
Evening cortisol intercept	-3.04^{**} (.13)	−22.24
Level 2 effect of MAT score on intercept	0.07 (.00)	0.65
Slope of afternoon cortisol (change in evening cortisol per unit change in afternoon cortisol)	0.21 (.13)	1.41
Level 2 effect of MAT score on afternoon cortisol slope	-0.59^{***} (.01)	−5.10
Slope of afternoon to evening sampling time lapse (change in evening cortisol per 1-hr change)	−0.06 (.00)	−0.94
Men ($n = 30$)		
Evening cortisol intercept	-2.76^{**} (.14)	−20.27
Level 2 effect of MAT score on intercept	0.01 (.14)	0.05
Slope of afternoon cortisol (change in evening cortisol per unit change in afternoon cortisol)	−0.29 (.31)	−0.96
Level 2 effect of MAT score on afternoon cortisol slope	−0.27 (.60)	0.45
Slope of afternoon to evening sampling time lapse (change in evening cortisol per 1-hr change)	0.11 (.00)	1.41

Note. Residual parameter variance for the Level 1 coefficient of "time lapse" was set to zero. MAT = Marital Adjustment Test.
$^{**}p < .01$. $^{***}p < .001$.

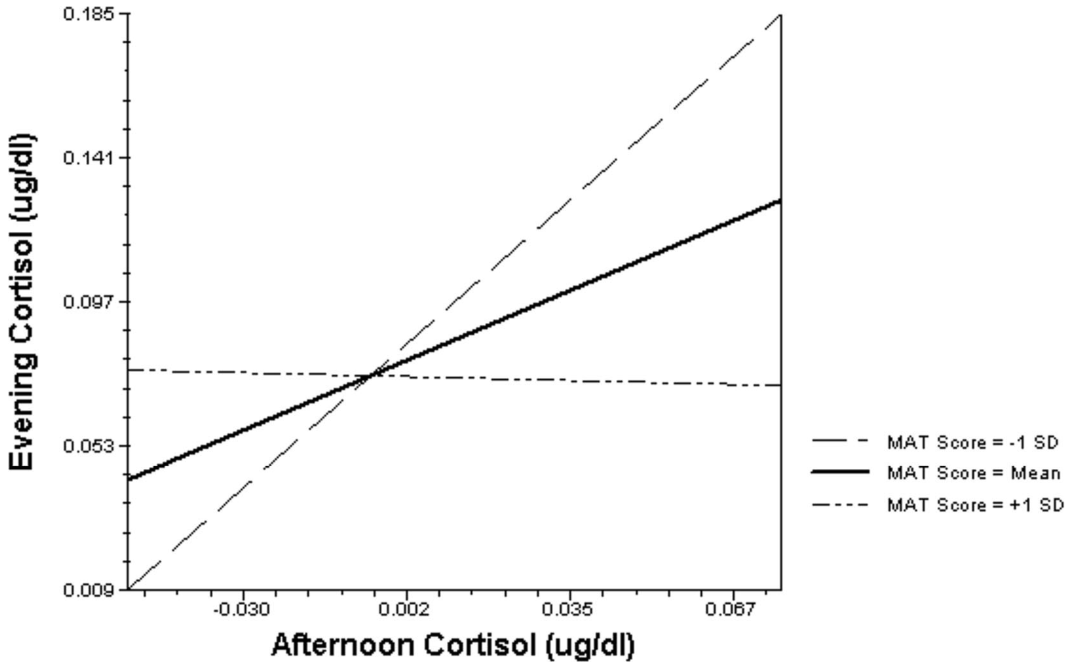

Figure 2. Women's afternoon cortisol and marital satisfaction predicting evening cortisol. This figure, generated by HLM 6.0, depicts average within-subjects associations between group-centered afternoon cortisol and evening cortisol for women ($n = 30$ women) with Marital Adjustment Test (MAT) scores at the sample mean, +1 standard deviation and −1 standard deviation from the mean. In this graph, time elapsed between afternoon and evening samples is held constant at the sample mean.

Men's time-adjusted evening cortisol was higher on days when men reported more negative social interactions at work, and this relationship was greater for men who reported more marital satisfaction.

Discussion

This study examined how cortisol variables were associated with marital satisfaction and daily stressful experiences at work in a sample of dual-earner married couples with school-age children. Although husbands and wives showed no significant overall differences in diurnal cortisol patterns, there were gender differences in the ways in which cortisol levels were linked with the psychosocial variables measured in this study. Our data suggest that marital satisfaction plays an important role for women. Wives who were more satisfied with their marriages had a stronger basal cortisol cycle (higher early morning cortisol levels and a steeper cortisol decline over the day) and what appeared to be an exaggerated "recovery" of cortisol following high workload days at work. The basal cortisol cycle of women in less happy marriages was not as strong, their data did not show the exaggerated recovery pattern after high workload days, and their high afternoon cortisol levels at work were more likely to persist into the evening after work. Husbands, regardless of marital satisfaction levels, displayed the same exaggerated recovery from high workload that was observed in more happily married women: more demanding days at work were followed by lower cortisol levels in the evening at home. Whereas negative social interaction at work appeared to have no impact on wives' evening cortisol, husbands' data were consistent with the hypothesized pattern of spillover, or the transfer of negative feelings or stress-induced arousal from the workplace into the home; more socially distressing days at work were followed by higher evening cortisol. However, the social distress spillover effect was augmented among men in happier marriages.

Table 3
Workload Rating and MAT Score Predicting Time-Adjusted Evening Cortisol at 8 p.m.

Fixed effect	Coefficient (standard error)	*t* ratio
Women ($n = 30$)		
Time-adjusted evening cortisol intercept	-2.83^{**} (.12)	−24.01
Level 2 effect of MAT score on intercept	0.17 (.11)	1.55
Slope of afternoon workload rating	-0.33^{*} (.17)	−1.95
Level 2 effect of MAT score on afternoon cortisol slope	-0.37^{***} (.14)	−3.45
Men ($n = 30$)		
Time-adjusted evening cortisol intercept	-2.60^{**} (.13)	−19.62
Level 2 effect of MAT score on intercept	0.01 (.11)	0.09
Slope of afternoon workload rating	-0.40^{*} (.17)	−2.43
Level 2 effect of MAT score on afternoon cortisol slope	−0.16 (.22)	0.74

Note. MAT = Marital Adjustment Test.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Cortisol Cycle and Marital Satisfaction

In keeping with our predictions, and in line with previous research (Adam & Gunnar, 2001; Abercrombie et al., 2004),

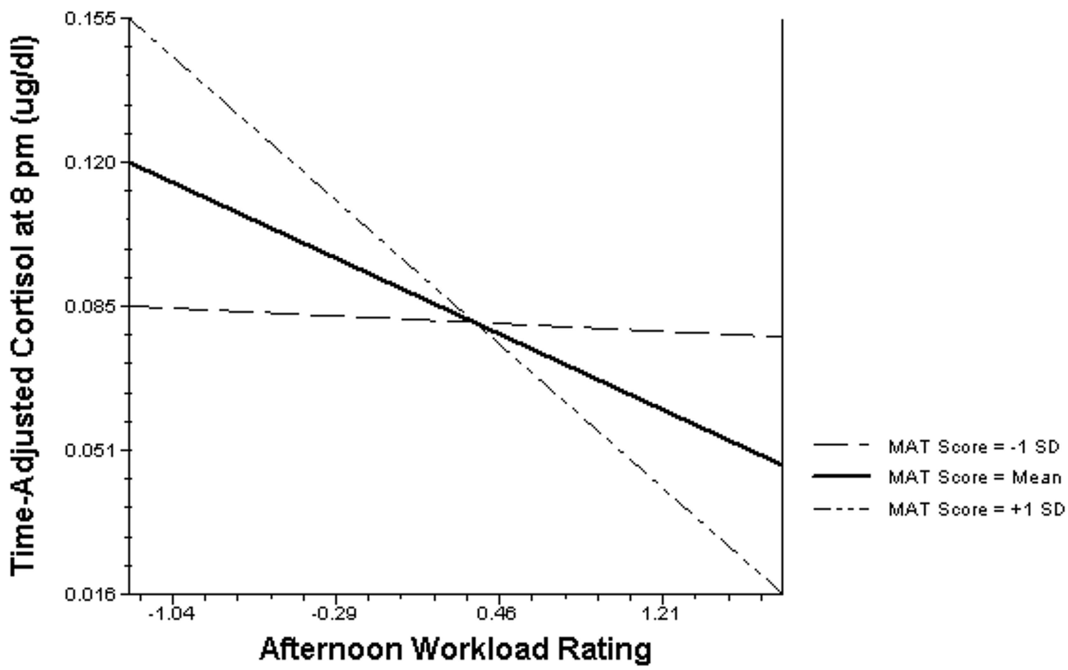

Figure 3. Women's group-centered afternoon workload rating and marital satisfaction predicting time-adjusted evening cortisol at 8 p.m. This figure, generated by HLM 6.0, depicts the average within-subject associations between afternoon workload and time-adjusted evening cortisol for women ($n = 30$) with Marital Adjustment Test (MAT) scores at the sample mean, +1 standard deviation and −1 standard deviation from the mean.

this study found marital satisfaction to be linked with a stronger basal cortisol cycle among women. This association did not emerge among men. Given that flattened diurnal cortisol cycles appear to be associated with deleterious physical health consequences (Sephton et al., 2000) and may be a sign of allostatic load or poor adaptation to everyday stress, these results are intriguing, and suggest a pathway by which the marital relationship may influence women's short- and long-term health. The emergence of stronger results for women than men would fit with research suggesting that, although men derive an overall health benefit from marriage, women appear to be more sensitive to the differential quality of marriage and are more physiologically responsive to marital processes than are men (cf. Kiecolt-Glaser & Newton, 2001).

Table 4
Negative Social Interactions at Work Rating and MAT Score Predicting Time-Adjusted Evening Cortisol at 8 p.m.

Fixed effect	Coefficient (standard error)	*t* ratio
Women ($n = 30$)		
Time-adjusted evening cortisol intercept	-2.86^{**} (.12)	−23.72
Level 2 effect of MAT score on intercept	0.13 (.11)	1.17
Slope of afternoon negative social interactions at work rating	−0.78 (.17)	−0.70
Level 2 effect of MAT score on afternoon cortisol slope	−1.29 (1.25)	−1.04
Men ($n = 30$)		
Time-adjusted evening cortisol intercept	-2.63^{**} (.13)	−20.52
Level 2 effect of MAT score on intercept	−0.02 (.11)	−0.18
Slope of afternoon negative social interactions at work rating	0.84^{*} (.33)	2.59
Level 2 effect of MAT score on afternoon cortisol slope	1.06^{*} (.45)	−2.37

Note. MAT = Marital Adjustment Test.
$^{*}p < .05$. $^{**}p < .01$.

Links Between Afternoon and Evening Cortisol

Fluctuations in daily evening cortisol were linked to several indicators of stress assessed that day at work, with some interesting distinctions between men and women. Overall, there was no correlation between afternoon and evening cortisol levels in either the men's or the women's data. However, among the women, the null finding masked significant differences between the more and less happily married. Wives who described less satisfying marriages excreted higher evening cortisol at home following days with higher than usual afternoon cortisol, but this continuation of elevated cortisol from work to home was not observed in women with higher levels of marital satisfaction. To our knowledge, this is the first published finding to point to a role for relationship quality in enhancing the process of postworkday cortisol recovery for women. This finding makes sense, however, given the research literature on the importance of marital quality to women's health (Kiecolt-Glaser & Newton, 2001) and gender differences in "unwinding" (Frankenhaeuser et al., 1989; Lundberg & Frankenhaeuser, 1999).

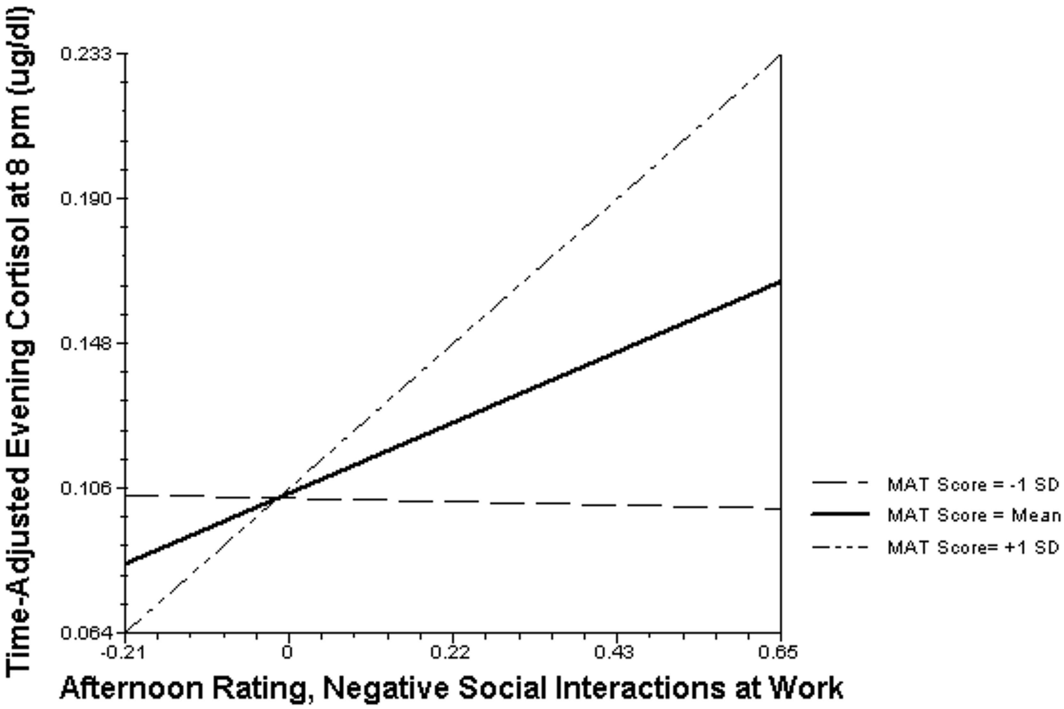

Figure 4. Men's group-centered rating of afternoon negative social interactions and marital satisfaction predicting time-adjusted evening cortisol at 8 p.m. This figure, generated by HLM 6.0, depicts the average within-subject associations between afternoon negative social interactions and time-adjusted evening cortisol for men ($n = 30$) with Marital Adjustment Test (MAT) scores at the sample mean, +1 standard deviation and −1 standard deviation from the mean.

Recovery Following High Workload Days

Surprisingly, higher afternoon workload ratings were associated with lower cortisol that evening for both men and women, even after adjusting for sampling time. In other words, on days with greater than usual perceived workload, cortisol tended to be lower than usual that evening. This counterintuitive result may reflect an exaggerated recovery of cortisol following high workload days. Although stressful workdays were hypothesized to lead to spillover effects in the evening, social withdrawal is another common response that has been observed in both men and women following more stressful days at work (Repetti, 1989; Repetti & Wood, 1997; Schulz et al., 2004; Story & Repetti, in press). For example, male air traffic controllers were more socially withdrawn and expressed less anger during marital interactions following higher workload days (Repetti, 1989). In another study, mothers were observed to speak less and were less attentive toward their preschoolers during parent–child reunions that followed higher workload days at work (Repetti & Wood, 1997). In a recent replication of this pattern, both husbands and wives were more withdrawn from marital interaction on high workload days (Story & Repetti, in press). An early daily diary study found evidence for a "stress compensation process," whereby men and women were less likely to report doing "a lot of work" at home after days of greater work overload (Bolger, DeLongis, Kessler, & Wethington, 1989). A steeper decline in cortisol following a busy day would be consistent with a short-term drop in social interaction, emotional expression, and physical activity.

Among the wives in the present study, high marital satisfaction strengthened the apparent recovery process. Wives in happier marriages may have had greater access to the space, time, and support needed to recuperate after busy days. For example, in the air traffic controller study mentioned above, when daily levels of spouse support were included in the analysis, the marital withdrawal response to work overload was only observed on evenings when spouses reported providing a high level of emotional support, such as comfort or sympathy (Repetti, 1989).

Spillover From Negative Social Interactions at Work

In contrast to our findings for workload, more perceived social distress at work in the afternoon was associated with higher evening cortisol among husbands, more so as their marital satisfaction increased. There was no association between the wives' negative social interactions at work and their cortisol levels later at home. The patterns observed in the husbands' data suggest that distressing social events at work may trigger physiological processes that differ from responses to high workload, possibly due to differences in the valence of "stress" during the workday. Although busy days can be engaging, interpersonal conflict is almost always experienced as unpleasant, and social stress has been specifically tied to cortisol increases (Dickerson & Kemeny, 2004).

Negative social experiences at work might be more likely to trigger negative emotion spillover at home, particularly among men. For example, one study reported a same-day link between husbands' reports of "tensions or arguments" at work and "tensions or arguments" with their wives, but this pattern was not observed for wives (Bolger et al., 1989). An examination of parent–child interactions in the air traffic controller study found that fathers reported using more discipline with their children and described their interactions as more negative after more socially stressful days at work (Repetti, 1994). (In contrast, higher workload days were followed by the air traffic controllers' withdrawal from father–child interaction, the same effect found in their interactions with their wives.) Interestingly, in the study of the mothers of preschoolers, there was no evidence of a spillover from social interactions at work to mother–child interaction. It is surprising that more maritally satisfied men showed higher evening cortisol on more interpersonally stressful workdays than did the husbands in less happy marriages. Of course, given the within-subjects nature of this analysis, men's greater marital satisfaction was therefore also more strongly associated with lower cortisol following less stressful days. Allostatic load theory (McEwen, 1998) suggests that the responsivity and elasticity of the HPA axis might be a more meaningful sign of health than cortisol level alone. In this study, marital satisfaction appeared to augment both the *negative* within-subjects association between daily workload and cortisol among wives and the *positive* within-subjects association between daily social stress and cortisol among husbands. Thus, the less maritally satisfied individuals displayed a weaker responsiveness to perceived work stress, regardless of the direction of effects.

Limitations of the Study

The present study had a number of limitations. Most notably, the relatively small sample size and missing data limited statistical power. Also, participants self-reported their cortisol sampling times and their adherence guidelines, which could have led to inaccuracies in the data. Because this study was intensive, stress levels might have been higher than usual during saliva collection. However, this should have affected all of the participants and should not compromise the specific results reported here.

Our participant pool focused on intact middle-class families. A larger, more diverse sample might have captured a greater range of functioning. In addition, the four saliva sampling timepoints provided only a limited picture of fluctuations in cortisol across the day. Additional saliva collections scheduled before, during, and after the transition between work and home might have clarified apparent individual differences in physiological unwinding. Also, our study included only one early morning sample. Because cortisol levels rise over the first 20 to 40 minutes after waking, it is possible that slight differences in morning sampling time could have influenced early morning cortisol concentrations, even though sampling time was considered in the diurnal slope analyses reported here.

Conclusions

Although researchers have been interested in naturalistic cortisol paradigms that focus on everyday stressors, many of these studies have been inconclusive (Hjortskov et al., 2004; Kurina et al., 2004). This study underscores the importance of considering multiple predictors and cortisol outcome measures to capture the complexity of day-to-day changes in stress responding. When we split our sample by gender we found differences in associations between psychosocial variables and cortisol. These findings have interesting implications for research on health, marriage, and gender. For example, a number of researchers have observed that, although married men consistently enjoy better health and longevity than unmarried men, women's health benefit appears to depend on marital quality; unhappily married women fare no better, and may fare worse, than their single counterparts (cf. Kiecolt-Glaser & Newton, 2001). These results suggest a physiological mechanism by which the marital relationship might influence women's day-to-day functioning and ability to recover from stress. Further research using naturalistic cortisol paradigms might help to specify what aspects of marriage, and other characteristics of the work and family environments, have greatest impact on both men's and women's short- and long-term health.

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