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Sex-specific effects of mindfulness on romantic partners' cortisol responses to conflict and relations with psychological adjustment

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Abstract Mindfulness is known to improve individuals' and couples' subjective stress regulation, but little is known about how it impacts hypothalamic—pituitary—adrenal (HPA) axis responses to acute psychosocial stress. The current study tested effects of dispositional mindfulness facets on young adult couples' cortisol responses to a conflict discussion stressor, as well as associations with psychological adjustment. One hundred heterosexual couples completed the five facet mindfulness questionnaire one week before engaging in a conflict discussion task. Each partner provided five saliva samples from pre- to post-conflict, which were assayed for cortisol. Measures of adjustment — depression and anxiety symptoms and global well-being — were also completed at this session. Hierarchical linear modeling of cortisol trajectories revealed sex-specific effects; whereas women's mindfulness (nonreactivity facet) predicted higher conflict stress cortisol levels, men's mindfulness (describing facet) predicted less pronounced cortisol reactivity/recovery curves. These patterns were related to better adjustment—lower depression symptoms for women and greater well-being for men. Implications for sex differences in mindfulness benefits are discussed.

The cultivation of mindfulness — defined as intentional present-moment, nonjudgmental awareness (Kabat-Zinn, 1990) — shows promise for enhancing the well-being of individuals and couples (Keng et al., 2011; Barnes et al., 2007). In particular, mindfulness-based interventions increase mindful

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qualities such as attentional control, emotional awareness, and nonreactivity to thoughts and feelings, which help people regulate their subjective and neural responses to stressful stimuli (e.g., Creswell et al., 2007; Farb et al., 2012; Hölzel et al., 2011). Rather than simply dampening responses, this research suggests mindfulness helps people respond appropriately to the situation at hand, neither minimizing nor amplifying the experience. However, there is little available information regarding the impact of mindfulness on acute responsiveness of the major neuroendocrine stress system, the hypothalamic—pituitary—adrenal (HPA) axis. Given well established links between HPA reactivity/recovery and both mental and physical health (Danese and McEwen, 2012; Golden, 2007; Palazidou, 2012), it is important to discern how mindfulness shapes HPA response to psychosocial stressors encountered in daily life. The current study was designed to assess effects of dispositional mindfulness on young adult romantic partners' HPA responses to conflict stress. Secondarily, relations between HPA responses and partners' psychological adjustment were examined to contextualize mindfulness-related effects.

Initial evidence for associations between mindfulness and stress physiology is mixed, likely because of variability in sample characteristics (i.e., healthy college students vs. cancer patients vs. long-term meditators), operationalizations of mindfulness (i.e., self-report measures vs. mindfulness-based intervention effects vs. meditation practice effects), and stress measurement (Matousek et al., 2010). The majority of previous mindfulness—HPA studies have measured diurnal cortisol levels. Whereas some research demonstrates reductions in cortisol output following mindfulness intervention (Brand et al., 2012; Carlson et al., 2007; Jensen et al., 2012; but see Gex-Fabry et al., 2012; Lengacher et al., 2012; Lipschitz et al., 2013 for null effects), other studies show increases in cortisol and/or a mix of increasing and decreasing trajectories from pre—post intervention (Bränström et al., 2013; Carlson et al., 2004; Matousek et al., 2011). The latter findings have been interpreted as a normalization of HPA function because those with higher initial levels tend to decrease, whereas those with lower initial levels tend to increase. Although these studies differ in focus on afternoon/evening cortisol vs. cortisol awakening response, they converge in showing that mindfulness intervention-related HPA changes are accompanied by improvements in subjective stress, quality of life, and psychological and somatic symptoms. What is largely missing from this literature is an understanding of how mindfulness impacts acute responses to psychosocial stressors. Furthermore, most prior research has focused on group-wide pre—post intervention changes, rather than on individual differences in self-reported mindfulness, even though the latter may be more decisive for effects on the HPA axis (Jacobs et al., 2013).

To our knowledge, only a handful of studies have addressed effects of mindfulness on cortisol during acute stress, and only one demonstrated a link between dispositional mindfulness and psychosocial stress response. Specifically, participation in a brief mindfulness intervention predicted lower cortisol responses to cognitive stress (a mental arithmetic task) in one study (Tang et al., 2007), whereas another study using a similar stressor (mental arithmetic plus speech tasks without direct social evaluation) showed reduced blood pressure, but no differences in cortisol (Nyklíček et al., 2013). Finally, the one study involving a psychosocial stress task (the Trier Social Stress Test; TSST) revealed lower cortisol reactivity, anxiety and negative affect among participants higher in self-reported mindfulness (Brown et al., 2012). These findings offer preliminary support for the stress-buffering role of mindfulness, though many questions remain. One question is whether mindfulness affects cortisol in response to common interpersonal stressors, which may elicit different responses than performance stressors such as the TSST (Stroud et al., 2009). Because the Brown et al., 2012 study used an overall mindfulness score, it is also unknown whether particular aspects of the larger construct of mindfulness — i.e., nonreactivity to and nonjudgment of internal experience, the ability to observe and describe one's experiences, and acting with awareness (Baer et al., 2006) — are especially important for HPA regulation. Finally, Brown's study comprised a mostly female (82%) sample. Given that cortisol responses may vary by sex, particularly in the context of interpersonal stress (see Stroud et al., 2002), it is important to examine mindfulness effects separately in men and women.

Sex differences may especially matter in determining what constitutes a "good" cortisol response. There are mixed indications for which response parameters are problematic—high or low cortisol levels during stress and lack of recovery following stress have all been linked to mental health problems, including depression, anxiety, and posttraumatic symptoms (Burke et al., 2005; Graeff, 2007; Morris et al., 2012). Among other moderators of cortisol-adjustment links, sex appears to matter; while young women reporting elevated depression symptoms showed lower cortisol levels and a blunted reactivity/recovery curve in response to romantic conflict, young men with elevated depression symptoms showed the opposite pattern of higher cortisol levels (Powers et al., unpublished observations). Besides underlining the importance of sex differences, this research supports modeling the entire response trajectory to discern adjustment-relevant effects not only on cortisol levels, but also on dynamics of reactivity/recovery.

In the present study we tested effects of dispositional mindfulness facets on young adult couples' cortisol trajectories in response to romantic conflict. To better understand the mental health implications of any mindfulness effects, we also examined associations between young men's and women's cortisol responses and measures of psychological adjustment—depression and anxiety symptoms and global well-being. We were particularly interested in possible sex differences in paths between mindfulness and cortisol, and between cortisol and adjustment. We hypothesized that mindfulness would predict lower cortisol for men, but higher cortisol and sharper reactivity/recovery curves for women, which would relate to lower symptoms and greater well-being. We further hypothesized that nonreactivity and nonjudgment facets would most strongly predict partners' stress responses, given previous evidence for their role in well-being in non-meditator samples (Baer et al., 2008). In the absence of previous research examining sex differences in the effects of specific mindfulness facets, we made no a priori hypotheses about which facets would relate differently to cortisol for men vs. women.

1. Method

1.1. Participants

Heterosexual couples (n = 114) were recruited through an online student research participant pool and community flyers to participate in a two-part study of romantic relationships (see below). To be eligible, participants had to be at least 18 years old (M = 21.31, SD = 6.12) and in a romantic relationship for at least 2 months (M = 2.2 years). The majority of couples (93%) reported that they were in an exclusive committed relationship. On average, partners reported spending 58 h per week together (range 5—168) and were moderately satisfied with the relationship (M = 106.3, SD = 19.4 on the dyadic adjustment scale).[1] Reflective of the region from which the sample was drawn, the majority of participants (83%) were Caucasian. The current study is based on the subset of participants (n = 100 couples) who participated in both sessions and completed all of the measures described below. A comparison of these participants with those not included in the final sample revealed no significant differences on demographic and study variables.

1.2. Procedures

Couples completed questionnaire measures of trait-like constructs (including dispositional mindfulness) during an initial hour-long lab session. During the second session, scheduled approximately one week later and lasting 1.75 h, couples completed the conflict discussion task, had their saliva sampled for cortisol, and responded to questionnaire measures assessing stress-related outcomes (including depression, anxiety, and well-being). All of these sessions began at 16:00 h to control for diurnal variability in cortisol. Except for during the conflict discussion task, partners were placed in separate rooms.

To minimize extraneous sources of salivary cortisol variability, participants were instructed not to consume more than one alcoholic drink within 24 h of the session, not to smoke or use non-prescription drugs the day of the session, not to exercise vigorously or brush teeth within 3 h of the session, and not to eat or drink within 1 h of the session. Following a set of initial questions to determine compliance with these conditions, the first saliva sample was collected (entry sample). This and all subsequent samples were collected via passive drool, and their interpretation is based on the roughly 20-min lag between peak HPA response and measurement in salivary cortisol (Schlotz et al., 2008).

Next, participants were given a vivid description of the conflict task — prior to this point, they only knew they would engage in a video recorded interaction, not that this would involve conflict — and asked to nominate a topic of unresolved conflict in the relationship. Twenty minutes after receiving a description of the conflict task, the second saliva sample was collected (anticipatory stress sample). Partners were then brought together and given 15 min to discuss and attempt to resolve the chosen issue, which was selected by coin toss. This interpersonal stress paradigm has been used to elicit cortisol responses in many studies that have shown individual differences related to partner adjustment (i.e., Heffner et al., 2004; Kiecolt-Glaser et al., 1997; Laurent and Powers, 2007; Powers et al., 2006a,b).

Following the discussion, partners were again escorted to separate rooms to complete questionnaires. Ten minutes after the discussion had concluded, the third saliva sample was collected (conflict stress sample). The fourth and fifth samples were collected 15 and 30 min after the conflict stress sample to index recovery. All samples were immediately frozen (−20° C) until shipment on dry ice to the Johns Hopkins Center for Interdisciplinary Salivary Bioscience.

1.3. Measures

1.3.1. Dispositional mindfulness

The 39-item five facet mindfulness questionnaire (FFMQ; Baer et al., 2006) assesses distinct components of mindfulness: observing (noticing or paying attention to internal and external stimuli, such as thoughts, emotions and sensations), describing (mentally labeling these stimuli with words), acting with awareness (paying attention to one's actions, as opposed to acting absent-mindedly), nonjudging (refraining from evaluation of inner experience), and nonreactivity (allowing emotions and thoughts to come and go without ruminating, worrying, or acting on them). The five facet scales demonstrated good internal consistency (Cronbach's alpha) in this sample (ranging from .74 for the nonreactivity facet to .90 for the describing facet).

1.3.2. Cortisol

The saliva samples were analyzed with the commercially available salivary cortisol enzyme immunoassay (Salimetrics, State College, PA) without modification to the manufacturer's recommended protocol. The test volume was 25 μl, and range of sensitivity from .007 to 3.0 μg/dl. The intra-assay coefficient of variation was on average less than 5%, and the inter-assay coefficient of variation was on average less than 10%. Cortisol scores were natural log-transformed prior to analysis to correct positive skew.

1.3.3. Psychological adjustment

Partners reported current depression symptoms using the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977) and anxiety symptoms using the Beck Anxiety Inventory (BAI; Beck and Steer, 1993). They also reported their global well-being using the World Health Organization well-being scale (WHO—WB; Bech et al., 2003). Internal consistencies for these scales were good (alphas ranged from .78 to .92).

2. Analytic strategy

Dyadic growth curve modeling in HLM was used to test effects on cortisol trajectories (see Raudenbush et al., 1995). This

[1] Relationship variables were examined as controls in the analyses reported below. Although relationship status related to lower women's cortisol, and hours spent together per week to lower men's cortisol, including these variables as controls did not change model results (i.e., the same pattern of significant effects emerged, with all coefficients within the 98% confidence interval of the original).

approach separates variability into within- and between-couple levels while accounting for the dependency of cortisol scores within individuals and individuals within couples. Level 1 modeled individual male and female partner cortisol trajectories, and Level 2 modeled between-couple differences in these trajectories as a function of predictive variables (i.e., mindfulness facets, adjustment measures). Three cortisol parameters were estimated for each partner: (1) an intercept corresponding to the estimated cortisol level at the conflict stress sample, (2) a linear term depicting the recovery slope of the cortisol trajectory at that sample, and (3) a quadratic term describing the steepness of the entire cortisol reactivity–recovery trajectory from samples one through five. Whereas the intercepts reflect each partner's level of physiological stress during the stressor, the linear and quadratic terms reflect the dynamics of his/her response trajectory over time. For illustration, the two-level equation testing effects of mindfulness facets on partners' cortisol is shown below:

Level 1

$$\text{Cortisol} = \text{Male}[\beta_1 + \beta_2(\text{time}) + \beta_3(\text{time}^2)] + \text{Female}[\beta_4 + \beta_5(\text{time}) + \beta_6(\text{time}^2)] + \text{error}$$

Level 2

$$\beta_1 = \gamma_0 + \gamma_1(\text{observing}) + \gamma_2(\text{describing}) + \gamma_3(\text{acting with awareness}) + \gamma_4(\text{nonjudgment}) + \gamma_5(\text{nonreactivity}) + \text{error}$$

similar equations predict $\beta_2 - \beta_6$.

3. Results

3.1. Descriptive analyses

Prior to testing HLM models, correlations between self-reported mindfulness (session 1) and psychological adjustment (session 2) variables were examined. For women, nonreactivity showed the strongest set of associations with adjustment ($r = -.45$, $p < .001$ with CES-D, $-.29$, $p = .003$ with BAI, and .47, $p < .001$ with WB), followed by nonjudgment ($r = -.32$, $p = .001$ with CES-D, $-.22$, $p = .026$ with BAI, and .21, $p = .032$ with WB). Acting with awareness and describing also related to lower depression symptoms ($r = -.30$, $p = .002$ and $-.26$, $p = .008$) and greater well-being ($r = .22$, $p = .030$ and .36, $p < .001$). Men showed fewer associations with adjustment; nonreactivity related positively to well-being ($r = .31$, $p = .002$), acting with awareness related negatively to depression symptoms ($r = -.30$, $p = .003$), and nonjudgment related negatively to symptoms of both depression ($r = -.28$, $p = .004$) and anxiety ($r = -.23$, $p = .022$). Thus, mindfulness facets related in expected ways to adjustment, though the specific pattern of associations differed by sex.

To gain an initial picture of cortisol response to the conflict task, differences between cortisol values at samples 1 (entry) and 3 (conflict stress) were computed. The majority of participants (74%) showed at least a 10% increase, and almost half (44%) showed a 20% increase or greater (see Granger et al., 2012 for task response criteria). Fig. 1 shows mean cortisol values for men and women at each sample. Thus, the task elicited at least moderate cortisol reactivity from most, but not all, participants.

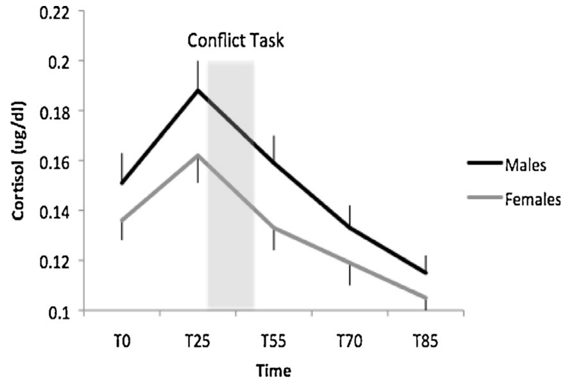

Fig. 1 Men's and women's average cortisol levels across samples (*x*-axis shows time in minutes from sample 1; bars represent standard errors).

4. Cortisol controls

Variables that might need to be controlled in cortisol analyses were examined. These consisted of medication use (including oral contraceptives for women), sleep the night before, exercise habits, BMI, and typical caffeine, alcohol, and nicotine consumption. Women's cortisol related to allergy and asthma medication, and men's cortisol related to allergy medication and typical nicotine consumption. These variables were controlled for in all subsequent models.

5. Model tests: Baseline cortisol model

A baseline HLM model containing no predictors was fit to determine average cortisol response parameters and between-participant variability in these parameters. Significant negative quadratic terms confirmed that both men and women tended to display a reactivity/recovery curve ($\beta = -.88$, $p < .001$ for men; $\beta = -.61$, $p < .001$ for women) across the session. Likewise, significant negative linear terms showed that partners tended to be recovering at the conflict stress sample, having peaked earlier during anticipation ($\beta = -.72$, $p < .001$ for men; $\beta = -.64$, $p < .001$ for women). However, there was significant variability in each of these terms ($\chi^2[102] = 498.36$, $p < .001$ for men's quadratic; $\chi^2[102] = 242.48$, $p < .001$ for women's quadratic; $\chi^2[102] = 514.22$, $p < .001$ for men's linear slope; $\chi^2[102] = 276.23$, $p < .001$ for women's linear slope), as well as in conflict stress cortisol intercepts ($\chi^2[102] = 2448.09$, $p < .001$ for men; $\chi^2[102] = 2088.48$, $p < .001$ for women), confirming individual differences in cortisol responses that could be explained by adding predictors.

6. Model tests: Mindfulness facets related to cortisol

A preliminary model with all five facets predicting men's and women's cortisol trajectories revealed significant associa-

Table 1 Cortisol responses related to mindfulness facets.

	Intercept (conflict stress cortisol level)		Linear term (conflict stress cortisol slope)		Quadratic term (overall reactivity/recovery curve)	
	β	*p*	*β*	*p*	*β*	*p*
Female partner						
Nonreactivity	**.20**	**.01**	.03	.70	−.14	.17
Describing	−.16	.07	−.07	.32	−.001	.99
Male partner						
Nonreactivity	−.02	.81	−.007	.93	.01	.94
Describing	−.15	.12	**.22**	**.02**	**.30**	**.04**

Note. Significant effects highlighted in bold.

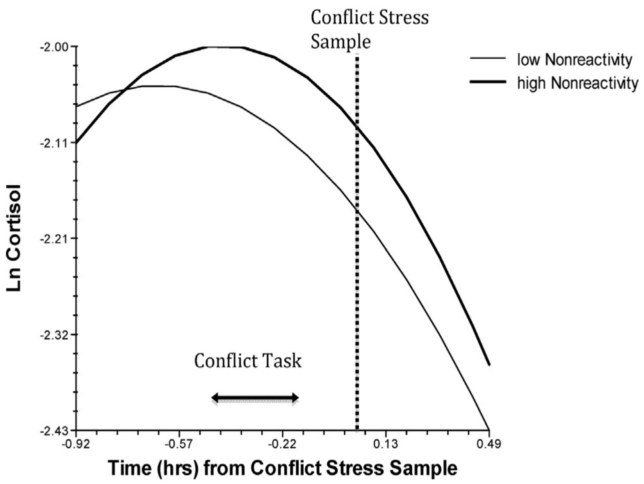

Fig. 2 Women's cortisol trajectories related to FFMQ nonreactivity (plotted at 25th and 75th percentiles).

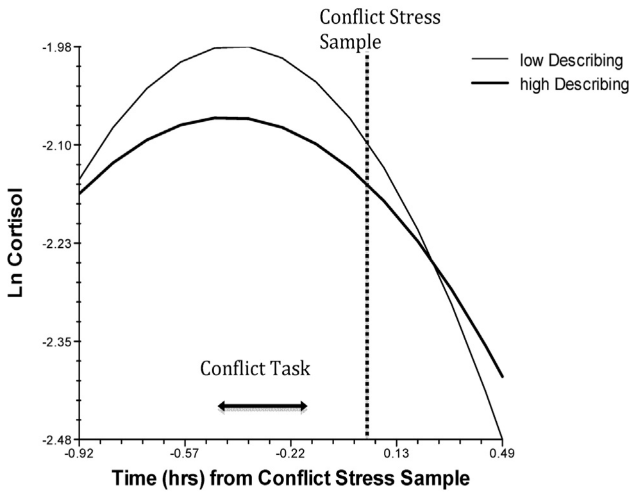

Fig. 3 Men's cortisol trajectories related to FFMQ describing (plotted at 25th and 75th percentiles).

tions for the nonreactivity and describing facets only.[2] Table 1 presents the final model containing just these facets. For women, the nonreactivity facet predicted higher conflict stress cortisol levels (Fig. 2). It should be noted that because women's intercepts were lower than men's overall, this meant that a female partner high in nonreactivity would show cortisol levels similar to that of her male counterpart. To determine whether this effect was specific to cortisol associated with the conflict stressor, or a more generalized effect on cortisol levels, a model centered at the first saliva sample was also tested. This model revealed nonsignificant associations between nonreactivity and women's cortisol, confirming specificity to the conflict stressor.

For men, the describing facet predicted a less pronounced cortisol reactivity/recovery curve and less steep recovery slope during the conflict stressor (Fig. 3). Because men's linear and quadratic slopes were steeper than women's overall, this meant that a male partner high in describing would show a moderate reactivity/recovery curve similar to that of his female counterpart, rather than nonrecovery. This model offered a significant improvement in fit compared to the baseline model, $\chi^2(16) = 41.81$, $p < .001$, and a nonsignificant change in fit compared to the full model with all mindfulness facets, $\chi^2(18) = 23.09$, *ns*.

7. Model tests: Psychological adjustment related to cortisol

As above, a preliminary model tested associations between partners' cortisol trajectories and adjustment variables (depression and anxiety symptoms, well-being). Depression symptoms and well-being showed significant effects and were retained in the final model (see Table 2). Symptoms of depression related to lower women's conflict stress cortisol levels (Fig. 4). Well-being related to lower men's conflict stress cortisol levels and a less pronounced reactivity/recovery curve (Fig. 5). Again, associations with cortisol levels were specific to models centered at the third saliva sample, and were nonsignificant at the first sample. This model

[2] To determine whether mindfulness effects could be better accounted for by perceived stressfulness of the conflict or by depression/anxiety symptoms, models were run controlling for partners' primary and secondary stress appraisals and for CES-D and BAI scores. Effects were unchanged (i.e., yielding the same set of significant predictors, and all coefficients were within the 98% confidence interval of the original), supporting a unique contribution of mindfulness to cortisol responses.

Table 2 Cortisol responses related to psychological adjustment.

	Intercept (conflict stress cortisol level)		Linear term (conflict stress cortisol slope)		Quadratic term (overall reactivity/recovery curve)	
	β	*p*	*β*	*p*	*β*	*p*
Female partner						
Depression Symptoms	**−.26**	**.02**	−.03	.74	.10	.51
Well-being	−.12	.27	−.07	.44	−.05	.76
Male partner						
Depression Symptoms	.09	.48	.17	.15	.15	.42
Well-being	**−.30**	**.02**	.22	.07	**.61**	**.001**

Note. Significant effects highlighted in bold.

yielded a significant fit improvement compared to baseline, $\chi^2(16) = 51.90$, $p < .001$, and a nonsignificant change in fit compared to the full model including anxiety symptoms, $\chi^2(6) = 3.58$, *ns*.

Thus, the cortisol patterns related to mindfulness facets above (i.e., higher women's cortisol, less pronounced men's reactivity/recovery) also related to better adjustment (i.e., lower women's depression symptoms, higher men's well-being).

8. Discussion

The current study demonstrated effects of specific mindfulness facets on young men's and women's cortisol responses to romantic conflict. In turn, these cortisol responses related to partner-specific markers of psychological adjustment. This work offers an objective (neuroendocrine) measure of the benefits of dispositional mindfulness for regulating responses to everyday stressors. At the same time, our findings suggest the nature of mindfulness-stress regulation paths may depend on sex, and that more nuanced investigations of which mindfulness qualities benefit which people are warranted.

Whereas nonreactivity — allowing thoughts and emotions to come and go without getting "stuck" in them — predicted women's cortisol response to the conflict stressor, describing — labeling thoughts and emotions with words — predicted men's cortisol response. These effects may speak to average sex differences in problems with emotion recognition and regulation; while women are more prone to rumination, a form of lingering reactivity (Nolen-Hoeksema, 2011; Nolen-Hoeksema et al., 1999), men are more prone to alexithymia, which entails difficulty identifying and describing emotional states (Levant et al., 2009). Thus, these specific mindfulness facets may offer an antidote to sex-typed mechanisms of stress dysregulation. These effects may further translate into patterns of conflict behavior closely linked to partners' subjective and neuroendocrine regulation (Eldridge and Christensen, 2002; Laurent et al., 2013). Specifically, nonreactivity could help female partners refrain from escalating demands, and describing could help male partners stay engaged in the discussion to express their needs, heading off destructive demand—withdraw cycles. Further research measuring these constructs is needed to determine whether levels of rumination and/or alexithymia, and not sex per se, drive the effects of these particular facets, as well as whether couples' conflict behaviors help to explain their impacts.

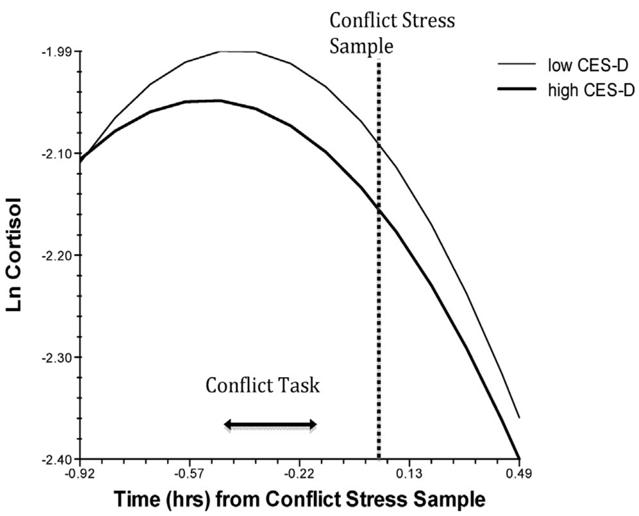

Fig. 4 Women's cortisol trajectories related to CES-D depression symptoms (plotted at 25th and 75th percentiles).

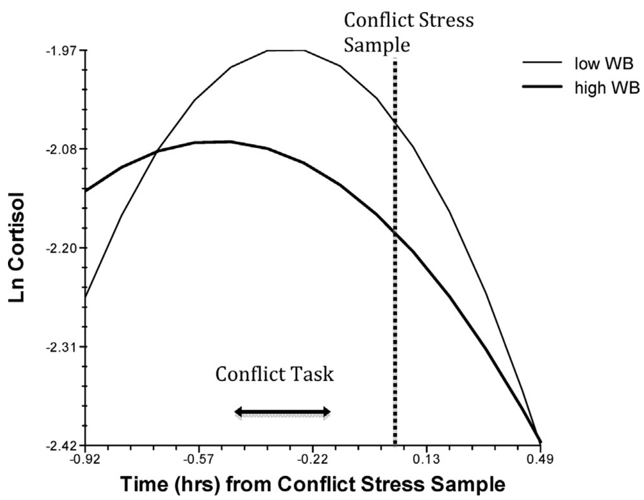

Fig. 5 Men's cortisol trajectories related to WHO well-being (plotted at 25th and 75th percentiles).

We also found differences in men's vs. women's cortisol profiles related to adjustment, as measured by depression symptoms and global well-being. Replicating prior findings in a similar sample (Powers et al., unpublished observations), higher conflict stress cortisol levels were actually advantageous for women — associated with lower depression symptoms — whereas lower cortisol and less reactive curves were advantageous for men—associated with greater well-being. This adds weight to the contention that no one type of cortisol response profile should be considered "good," and that both cortisol levels and dynamics of response may be important for adjustment. Typically, quicker reactivity/recovery is considered healthy (see Burke et al., 2005), but young men may need to slow down to respond more to the conflict itself (rather than the anticipation of conflict) and remain more in tune with their partners. Similarly, lower cortisol reactivity is often considered healthy, but young women may need higher levels to feel fully engaged in the discussion and the relationship more broadly (Laurent et al., 2013). Closer examination of these effects revealed that partners higher in a given mindfulness facet had cortisol profiles similar to what was normative in their opposite-sex counterparts, suggesting a normalization of function consistent with previous findings for diurnal cortisol (e.g., Bränström et al., 2013; Carlson et al., 2004; Matousek et al., 2011). A healthy response may best be represented by a balance of engagement with the stressor and disengagement once it is over, with mindfulness helping individuals to calibrate upward or downward toward that balance. Importantly, these analyses support the proposal that mindfulness shapes the physiological stress response in ways that benefit each partner.

Relations in the expected direction between mindfulness and adjustment measures replicated previous findings for the robust benefits of nonreactivity and nonjudgment facets in non-meditating samples (Baer et al., 2008). More widespread mindfulness-adjustment associations among female partners may speak to a greater benefit of mindfulness cultivation for women, though further research in diverse samples (including clinical populations with varying levels of mindfulness experience) is needed to confirm or disconfirm this idea. Further, the fact that the same mindfulness facet related to both cortisol and adjustment outcomes for women, but not men, suggests differing paths by which mindfulness impacts mental health. It may be that mindfulness qualities improve stress appraisals and emotion-focused coping strategies more commonly employed by women, but do less to enhance the problem-focused coping more commonly used by men (Ptacek et al., 1994; Tamres et al., 2002). It is also possible that the stressor type matters, with women showing greater mindfulness benefits in situations of interpersonal stress, and men exhibiting greater benefits in other stress contexts (i.e., performance stress). If the latter is true, we might expect that sex differences in mindfulness effects emerge during adolescence when differential sensitivities to interpersonal vs. performance stress arise (Stroud et al., 2009). Future longitudinal studies assessing different coping styles and stress contexts should clarify how and why mindfulness supports males' vs. females' adjustment at different points in development.

Conclusions to be drawn from this study should be tempered by an acknowledgment of limitations. We examined self-reported mindfulness in a normative community sample; given acknowledged limitations in self-report measures of mindfulness (see Grossman and Van Dam, 2011), we cannot necessarily assume these effects would apply similarly to meditators, nor to clinical samples suffering from more severe difficulties with stress and emotion regulation. We expect that a greater range of mindfulness and/or stress regulation found in an intervention study would actually strengthen effects, but this remains to be tested. Additional noise in cortisol response measures may have been introduced by variations in menstrual cycle phase among female participants, which was not measured in the current study. Like many self-report measures, the FFMQ is vulnerable to social desirability confounds, and future studies might fruitfully incorporate alternative behavioral measures, such as mind wandering, to tap individual differences in mindfulness.

Although the paths tested here are consistent with the idea that HPA responses serve as a mechanism for mindfulness effects on adjustment, the cross-sectional design of this study was not optimized to test mediation. Tests of mediated effects should be pursued in longitudinal intervention research. Reported effects did not appear to be driven by perceived stressfulness of the conflict, but it is possible that the type of conflict topic chosen varies as a function of mindfulness and helps to explain effects on stress physiology; this and other intervening mechanisms should be explored. Finally, this study was limited to cortisol measures during an interpersonal stressor; other aspects of stress physiology and/or response in other stress contexts may relate differently to mindfulness facets. Now that a basis for expecting dispositional mindfulness effects on acute stress response is established, further research investigating moderators — both individual difference variables and contextual factors — should follow.

These limitations notwithstanding, the current investigation adds in important ways to existing research. This study is the first to our knowledge to show mindfulness effects on neuroendocrine response to interpersonal stress, and only the second to demonstrate effects on response to psychosocial stress more broadly. Notably, the 1-week separation of mindfulness measurement from the stress session strengthens our interpretation that dispositional mindfulness impacts stress response, rather than vice versa. We also established that mindfulness effects were specific to cortisol levels and dynamics associated with the conflict stressor, and not an artifact of more generalized effects on resting cortisol. Finally, by examining individual facets of mindfulness in men and women separately, we highlighted sex-specific paths by which mindfulness may operate to improve stress regulation. These findings support the value of interventions to increase mindfulness in young couples while suggesting further refinements in treatment targets (i.e., which mindfulness facets and stress response parameters to focus on for male and female partners). At a broader level, this work supports the notion that the stress response is driven less by the objective features of events people encounter, and more by their subjective experience of these events. Mindfulness, which has often been likened to shining a light or clarifying the mirror through which experience is reflected, transforms the subjective ground on which stress responses are based. By seeing stressors and one's own part in them more clearly, mindfulness allows us to respond more skillfully with what is needed — higher or lower, faster or slower stress activation — and move forward with greater equanimity.

Conflict of interest

In the interest of full disclosure, DAG is founder and Chief Strategy and Scientific Advisor at Salimetrics LLC (State College, PA) and Salivabio LLC (Baltimore, MD). DAG's relationships with these entities are managed by the policies of the Conflict of Interest Committee at the Johns Hopkins University School of Medicine and the Office of Research Integrity and Assurance at Arizona State University. HL, SL, RH, and DE have no conflicts of interest to report.

Contributors

Authors HL and SL designed and carried out the study with the assistance of RH and DE. DG oversaw the salivary assay measures and advised on the use of these data. HL conducted analyses and wrote the manuscript. All authors reviewed it and offered feedback prior to submission.

Role of the funding source

The sources of funding for this research did not play a role in the analysis or interpretation of the data. The funders do not have any particular archiving or other requirements.

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References

Baer, R.A., Smith, G.T., Hopkins, J., Krietemeyer, J., Toney, L., 2006. Using self-report assessment methods to explore facets of mindfulness. Assessment 13, 27—45.

Baer, R.A., Smith, G.T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., Walsh, E., Duggan, D., Williams, J.M., 2008. Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. Assessment 15, 329—342.

Barnes, S., Brown, K.W., Krusemark, E., Campbell, W.K., Rogge, R.D., 2007. The role of mindfulness in romantic relationship satisfaction and responses to relationship stress. J. Mar. Fam. Ther. 33, 482—500.

Bech, P., Olsen, L., Raabaek Kjoller, M., Rasmussen, N.K., 2003. Measuring well-being rather than the absence of distress symptoms: a comparison of the SF-36 mental health subscale and the WHO-five well-being scale. J. Meth. Psychiatry Res. 12, 85—91.

Beck, A.T., Steer, R.A., 1993. Beck Anxiety Inventory Manual. Harcourt Brace, San Antonio, TX.

Brand, S., Holsboer-Trachsler, E., Naranjo, J.R., Schmidt, S., 2012. Influence of mindfulness practice on cortisol and sleep in long-term and short-term meditators. Neuropsychobiology 65, 109—118.

Bränström, R., Kvillemo, P., Åkerstedt, T., 2013. Effects of mindfulness training on levels of cortisol in cancer patients. Psychosomatics 54, 158—164.

Brown, K.W., Weinstein, N., Creswell, J.D., 2012. Trait mindfulness modulates neuroendocrine and affective responses to social evaluative threat. Psychoneuroendocrinology 37, 2037—2041.

Burke, H.M., Davis, M.C., Otte, C., Mohr, D.C., 2005. Depression and cortisol responses to psychological stress. A meta-analysis. Psychoneuroendocrinology 30, 846—856.

Carlson, L.E., Speca, M., Faris, P., Patel, K.D., 2007. One year pre—post intervention follow-up of psychological, immune, endocrine and blood pressure outcomes of mindfulness-based stress reduction (MBSR) in breast and prostate cancer outpatients. Brain Behav. Immun. 21, 1038—1049.

Carlson, L.E., Speca, M., Patel, K.D., Goodey, E., 2004. Mindfulness-based stress reduction in relation to quality of life, mood, symptoms of stress and levels of cortisol, dehydroepiandrosterone sulfate (DHEAS) and melatonin in breast and prostate cancer outpatients. Psychoneuroendocrinology 29, 448—474.

Creswell, J.D., Way, B.M., Eisenberger, N.I., Lieberman, M.D., 2007. Neural correlates of dispositional mindfulness during affect labeling. Psychosom. Med. 69, 560—565.

Danese, A., McEwen, B.S., 2012. Adverse childhood experiences, allostasis, allostatic load, and age-related disease. Physiol. Behav. 106, 29—39.

Eldridge, K.A., Christensen, A., 2002. Demand-withdraw communication during couple conflict: a review and analysis. In: Noller, P., Feeney, J.A. (Eds.), Understanding Marriage: Developments in the Study of Couple Interaction. Cambridge University Press, New York.

Farb, N.A., Anderson, A.K., Segal, Z.V., 2012. The mindful brain and emotion regulation in mood disorders. Can. J. Psychiatry 57, 70—77.

Gex-Fabry, M., Jermann, F., Kosel, M., Rossier, M.F., Van der Linden, M., Bertschy, G., Bondolfi, G., Aubry, J.M., 2012. Salivary cortisol profiles in patients remitted from recurrent major depression: one year follow-up of a mindfulness-based cognitive therapy trial. J. Psychiatry Res. 46, 80—86.

Golden, S.H., 2007. A review of the evidence for a neuroendocrine link between stress, depression and diabetes mellitus. Curr. Diabetes Rev. 3, 252—259.

Granger, D.A., Fortunato, C.K., Beltzer, E.K., Virag, M., Bright, M.A., Out, D., 2012. Focus on methodology: salivary bioscience and research on adolescence: an integrated perspective. J. Adolesc. 35, 1081—1095.

Grossman, P., Van Dam, N.T., 2011. Mindfulness, by any other name: trials and tribulations of *sati* in western psychology and science. Contemp. Buddhism 12, 219—239.

Graeff, F.G., 2007. Anxiety, panic and the hypothaamic—pituitary—adrenal axis. Rev. Bras. Psiquiatr. 29, S3—S6.

Heffner, K.L., Kiecolt-Glaser, J.K., Loving, T.J., Glaser, R., Malarkey, W.B., 2004. Spousal support satisfaction as a modifier of physiological responses to marital conflict in younger and older couples. J. Behav. Med. 27, 233—254.

Hölzel, B.K., Lazar, S.W., Gard, T., Schuman-Olivier, Z., Vago, D.R., Ott, U., 2011. How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. Perspect. Psychol. Sci. 6, 537—559.

Jacobs, T.L., Shaver, P.R., Epel, E.S., Zanesco, A.P., Aichele, S.R., Bridwell, D.A., Rosenberg, E.L., King, B.G., Maclean, K.A., Sahdra, B.K., Kemeny, M.E., Ferrer, E., Wallace, B.A., Saron, C.D., 2013. Self-reported mindfulness and cortisol during a shamatha meditation retreat. Health Psychol. Advance online publication.

Jensen, C.G., Vangkilde, S., Frokjaer, V., Hasselbalch, S.G., 2012. Mindfulness training affects attention—or is it attentional effort? J. Exp. Psychol. 141, 106—123.

Kabat-Zinn, J., 1990. Full Catastrophe Living: Using the Wisdom of Your Body and Mind to Face Stress, Pain, and Illness. Delacourt, New York.

Keng, S., Smoski, M.J., Robins, C.J., 2011. Effects of mindfulness on psychological health: a review of empirical studies. Clin. Psychol. Rev. 31, 1041—1056.

Kiecolt-Glaser, J.K., Glaser, R., Cacioppo, J.T., MacCallum, R.C., Snydersmith, M., Kim, C., Malarkey, W.B., 1997. Marital conflict in older adults: endocrinological and immunological correlates. Psychosom. Med. 59, 339–349.

Laurent, H.K., Powers, S.I., 2007. Emotion regulation in emerging adult couples: temperament, attachment, and HPA response to conflict. Biol. Psychol. 76, 61–71.

Laurent, H.K., Powers, S.I., Laws, H., Gunlicks-Stoessel, M., Bent, E., Balaban, S., 2013. HPA regulation and dating couples' behaviors during conflict: gender-specific effects and cross-partner interactions. Phys. Behav. 118, 218–226.

Lengacher, C.A., Kip, K.E., Barta, M., Post-White, J., Jacobsen, P.B., Groer, M., Lehman, B., Moscoso, M.S., Kadel, R., Le, N., Loftus, L., Stevens, C.A., Malafa, M.P., Shelton, M.M., 2012. A pilot study evaluating the effect of mindfulness-based stress reduction on psychological status, physical status, salivary cortisol, and interleukin-6 among advanced-stage cancer patients and their caregivers. J. Holist. Nurs. 30, 170–185.

Levant, R.F., Hall, R.J., Williams, C.M., Hasan, N.T., 2009. Gender differences in alexithymia. Psychol. Men Masc. 10, 190–203.

Lipschitz, D.L., Kuhn, R., Kinney, A.Y., Donaldson, G.W., Nakamura, Y., 2013. Reduction in salivary α-amylase levels following a mind-body intervention in cancer survivors—an exploratory study. Psychoneuroendocrinology Advance online publication.

Matousek, R.H., Dobkin, P.L., Pruessner, J., 2010. Cortisol as a marker for improvement in mindfulness-based stress reduction. Complement. Ther. Clin. Pract. 16, 13–19.

Matousek, R.H., Pruessner, J.C., Dobkin, P.L., 2011. Changes in the cortisol awakening response (CAR) following participation in mindfulness-based stress reduction in women who completed treatment for breast cancer. Complement. Ther. Clin. Pract. 17, 65–70.

Morris, M.C., Rao, U., Garber, J., 2012. Cortisol responses to psychosocial stress predict depression trajectories: Social-evaluative threat and prior depressive episodes as moderators. J. Affect. Disord. 143, 223–230.

Nolen-Hoeksema, S., 2011. Emotion regulation and psychopathology: the role of gender. Ann. Rev. Clin. Psychol. 8, 161–187.

Nolen-Hoeksema, S., Larson, J., Grayson, C., 1999. Explaining the gender difference in depressive symptoms. J. Pers. Soc. Psychol. 77, 1061–1072.

Nyklíček, I., Mommersteeg, P.M.C., Van Beugen, S., Ramakers, C., Van Boxtel, G.J., 2013. Mindfulness-based stress reduction and physiological activity during acute stress: a randomized controlled trial. Health Psychol. Advance online publication.

Palazidou, E., 2012. The neurobiology of depression. Br. Med. Bull. 101, 127–145.

Powers, S.I., Gunlicks, M., Laurent, H., Balaban, S., Bent, E., Sayer, A., 2006a. Differential effects of subtypes of trauma symptoms on couples' hypothalamus–pituitary–adrenal (HPA) axis reactivity and recovery in response to interpersonal stress. Ann. N.Y. Acad. Sci. 1071, 430–433.

Powers, S.I., Pietromonaco, P.R., Gunlicks, M., Sayer, A., 2006b. Dating couples' attachment styles and patterns of cortisol reactivity and recovery in response to a relationship conflict. J. Pers. Soc. Psychol. 90, 613–628.

Ptacek, J.T., Smith, R.E., Dodge, K.L., 1994. Gender differences in coping with stress: when stressor and appraisals do not differ. Pers. Soc. Psychol. Bull. 20, 421–430.

Radloff, L.S., 1977. The CES-D scale: a self-report depression scale for research in the general population. Appl. Psychol. Meas. 1, 385–401.

Raudenbush, S.W., Brennan, R.T., Barnett, R.C., 1995. A multivariate hierarchical model for studying psychological change within married couples. J. Fam. Psychol. 9, 161–174.

Schlotz, Kumsta, W., Layes, R., Entringer, I., Jones, S., Wüst, A., 2008. Covariance between psychological and endocrine responses to pharmacological challenge and psychosocial stress: a question of timing. Psychosom. Med. 70, 787–796.

Stroud, L.R., Foster, E., Papandonatos, G.D., Handwerger, K., Granger, D.A., Kivlighan, K.T., et al., 2009. Stress response and the adolescent transition: performance versus peer rejection stressors. Dev. Psychopathol. 21, 47–68.

Stroud, L.R., Salovey, P., Epel, E.S., 2002. Sex differences in stress responses: social rejection versus achievement stress. Biol. Psychiatry 52, 318–327.

Tamres, L.K., Janicki, D., Helgeson, V.S., 2002. Sex differences in coping behavior: a meta-analytic review and an examination of relative coping. Pers. Soc. Psychol. Rev. 6, 2–30.

Tang, Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M.K., Fan, M., Posner, M.I., 2007. Short-term meditation training improves attention and self-regulation. Proc. Nat. Acad. Sci. 104, 17152–17156.