Psychoneuroendocrinology 107 (2019) 19–25

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen

Childhood abuse predicts affective symptoms via HPA reactivity during mother-infant stress

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ARTICLE INFO

Keywords:
HPA axis
Cortisol
Childhood maltreatment
Anxiety
Depression
Indirect effect

ABSTRACT

Despite extensive literature positing the hypothalamic-pituitary-adrenal (HPA) axis as a mechanism in the association between early childhood maltreatment and later adult psychopathology, empirical support for this full pathway is lacking. We tested indirect effects of childhood maltreatment on women's later affective symptomatology via HPA axis responding to a stressor involving their own infant. Women (n = 47) in a larger longitudinal study were assessed following the birth of their infant from 3 to 18 months postnatal. They reported childhood maltreatment history at 3 months and participated in a dyadic stress task with their infant at 12 months, at which time four salivary cortisol samples were collected to assess HPA response. Depression and anxiety symptoms at 18 months (controlling for symptom levels reported at 12 months) served as the primary outcome. Multilevel modeling was used to estimate both levels and dynamics of women's cortisol response trajectories. Tests of indirect effects revealed a significant effect of total Childhood Trauma Questionnaire (CTQ) scores on anxiety symptoms and a marginally significant effect on depression symptoms. Follow-up analyses with CTQ subscales revealed significant indirect effects of emotional and physical abuse on women's ongoing anxiety symptoms via more pronounced cortisol reactivity curves during the mother-infant stressor. We discuss methodological choices that may have allowed these effects to be detected in the present study and implications for stress-related risk and intervention.

1. Introduction

Functioning of the hypothalamic-pituitary-adrenal (HPA) axis, a primary branch of the human stress response eventuating in the release of cortisol, is thought to connect stressful or traumatic early life experiences to later well-being. There is evidence for elements of this connection, with research indicating early life stress such as childhood maltreatment relates to HPA functioning (Bunea et al., 2017; Carpenter et al., 2011; Voellmin et al., 2015), and that HPA functioning relates to psychological well-being (Heim and Nemeroff, 2001; Morris et al., 2012a; Steudte-Schmiedgen et al., 2015). However, there is strikingly little research addressing the full pathway from early life stress to later well-being via HPA functioning, especially within the context of interpersonal stress. To understand lasting impacts of maltreatment by a caregiver, it may be important to consider HPA responding to challenging interactions with one's own child, and how this may feed into ongoing psychological symptoms. We aimed to address this gap by testing indirect effects of childhood maltreatment on women's later affective symptomatology via HPA responding to stress involving their infant.

Research linking childhood maltreatment to adult HPA activation during stress has yielded mixed findings. On the one hand, there is evidence for associations between one or more forms of maltreatment and hyporeactivity to psychosocial stressors, as well as to emotional pictures and role-playing situations relevant to interpersonal trauma but not individually tailored to participants (Carnuta et al., 2015; Carpenter et al., 2011; Elzinga et al., 2008; Luecken et al., 2009; Suzuki et al., 2014; Voellmin et al., 2015). On the other hand, research employing a personalized trauma-relevant stressor—describing a personal sexual/physical abuse event—found HPA hyperreactivity in women who had been abused as children and had PTSD as adults, relative to those without PTSD (Elzinga et al., 2003). Another exception comes from a study of women with a history of physical and/or sexual abuse and major depression, who showed heightened HPA reactivity to psychosocial stress compared to their non-depressed counterparts (Heim et al., 2000). Taken together, this literature suggests several dimensions that may be important in distinguishing impacts of childhood maltreatment on later psychopathology-related HPA function, including the nature of maltreatment experienced, the stress context in which HPA activation is observed, and participant sex. Further study of

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https://doi.org/10.1016/j.psyneuen.2019.04.023
Received 29 January 2019; Received in revised form 19 March 2019; Accepted 30 April 2019

reactivity to trauma-relevant cues in samples representing a range of neglect and abuse histories is needed.

Research linking HPA activation to mental health conditions associated with trauma is similarly mixed. While meta-analyses of HPA function in those with depression or PTSD—a syndrome involving both anxious and depressive affective symptoms—reveal either no difference from healthy controls or hyporeactivity to chemical or psychosocial probes (Burke et al., 2005; Klaassens et al., 2012; Morris et al., 2012b), some studies involving individuals exposed to childhood maltreatment and/or responding to a personally relevant interpersonal stressor revealed elevated cortisol reactivity associated with such symptoms (Elzinga et al., 2003, 2010; Laurent et al., 2011a,b; Powers et al., 2016). Further investigation of cortisol-symptom associations across different stress contexts and/or affective symptom clusters is warranted. It is also unclear if HPA dysregulation simply relates to overall symptom levels (due to stable phenotypic associations), or whether HPA responding predicts a progression of symptoms over time. The few studies addressing prospective effects of cortisol reactivity have pointed to both hypo- and hyperreactivity as risk factors for increasing depressive or post-traumatic symptoms (e.g. Morris et al., 2012a; Steudte-Schmiedgen et al., 2015). More longitudinal work is needed to illuminate how HPA responding may perpetuate depressive and/or anxiety symptoms.

It is striking that even as researchers have repeatedly proposed the HPA axis as a mechanism in the association between childhood maltreatment and later psychopathology (Bremner et al., 2003; Ehlert, 2013; Pratchett and Yehuda, 2011; Shea et al., 2005), research investigating this full pathway is lacking. The few studies addressing the mediating role of cortisol in maltreatment-psychopathology paths have not yielded strong support for the proposed model. In youth, familial physical aggression and maltreatment predicted (lower) cortisol reactivity to interpersonal stressors, but cortisol reactivity failed to predict posttraumatic symptoms (Saxbe et al., 2012; Shenk et al., 2014). In adults, one study found an association between cortisol hyperreactivity to affective pictures and depression, but no association between abuse history and cortisol (Suzuki et al., 2014). Another study aimed at testing the indirect effect of maltreatment history on depression found the path through cortisol levels to be nonsignificant (Bockting et al., 2012). To our knowledge, no study has demonstrated a significant indirect effect of childhood maltreatment on later psychological symptoms via HPA function.

One reason for this failure to detect HPA axis-mediated effects of maltreatment on symptoms may be that the stress context does not match the nature of the trauma experienced. That is, most studies examine HPA activation in response to a stressor that does not resemble the traumatic stimulus to which the person has presumably been sensitized. To detect lasting impacts of maltreatment by a caregiver, it may be important to examine HPA responding to challenging interactions with one's child, which could activate memories of harsh or neglectful caregiving interactions that elicit ongoing stress/distress. Indeed, prior studies of women responding to dyadic stressors with their own infant have linked cortisol hyperreactivity during these interactions to depressive symptom elevations (Laurent et al., 2011a,b; Laurent et al., 2018). Although these studies did not address the first part of the proposed path—i.e., from maltreatment history to cortisol—they offer evidence of the second part, and further study involving personalized parent-child stressors is needed to determine whether this context reveals the proposed neuroendocrine link between childhood maltreatment and adult symptoms.

We aimed to address this gap by testing the indirect effect of childhood maltreatment on women's later affective symptomatology via HPA axis responding to a stressor involving their own infant. In a longitudinal study of mother-infant dyads, we tested the proposal that childhood maltreatment would predict ongoing symptom elevations via differences in salivary cortisol—a common index of HPA axis responding—during a mother-infant stressor. We expected that women's reported history of childhood maltreatment at 3 months postnatal would predict greater cortisol reactivity to mother-infant stress at 12 months postnatal, which would predict higher affective symptoms (controlling for 12-month symptoms) at 18 months postnatal. Potential differences based on maltreatment type (physical, sexual, psychological abuse and physical or psychological neglect) and symptom type (depression, anxiety) were approached in an exploratory fashion.

Table 1
Sample Descriptives (time 1).

Variable	*M, SD*
Age	27.01, 5.39
Number of pregnancies	2.23, 1.53
Variable	% of sample
Race/ethnic identification	76.9
White	9.9
Latina	3.3
African American	2.2
Native American	3.3
Asian American	4.4
Other	
Relationship status	4.4
Single	8.8
Dating	35.2
Living with someone	50.6
Married or legal domestic partnership	1.1
Separated	
Vaginal delivery	58.8
Target child birth order	48.9
First	30.0
Second	12.2
Third	5.6
Fourth	3.3
Fifth	
Education	1.1
Less than high school	25.3
High school	6.6
Vocational/technical school (2-year)	48.4
Some college	9.9
College graduate (4-year)	6.6
Master's degree	2.2
Other	
Employment	5.5
Self-employed	15.4
Part-time paid work	8.8
Full-time paid work	11.0
On leave	18.7
Unemployed	35.2
Full-time homemaker	5.5
Student	
Household income	31.9
< $5,000	5.5
$5,000-$9,999	11.0
$10,000-$19,999	22.0
$20,000-$29,999	12.1
$30,000-$39,999	7.7
$40,000-$49,999	7.7
$50,000-$74,999	2.2
$75,000-$99,999	

2. Method

2.1. Participants

Participants were the 47 women from a larger longitudinal study of mother-infant stress regulation who completed all measures involved in the current study (see Table 1 and Laurent, 2017 for further information about the sample). Women were recruited from the Women Infants Children (WIC) program and other community agencies serving low-income families; thus, they were at elevated risk of stress/distress based on low-income but were not selected for either maltreatment history or psychopathology. As noted previously (Laurent, 2017), the mothers

who completed the study tended to have fewer risk characteristics—i.e., older, in longer-term romantic relationships, higher household income—but they did not differ from non-completers on racial/ethnic minority status, education, or employment. The only mental health variable on which completers differed from non-completers was self-reported depressive symptoms at the first assessment; there were no differences in anxiety symptoms, or in diagnosed mental health conditions.

2.2. Procedure

Women provided informed consent for participation before being assessed at four times: at 3 months, 6 months, 12 months, and 18 months postnatal. All assessments involved completing self-report questionnaires via Qualtrics, and the latter three assessments involved a laboratory stress task with their infant—the Still Face at 6 months, the Strange Situation at 12 months, and the Laboratory Temperament Assessment Battery Maternal Separation and Stranger Approach at 18 months. In order to test a plausible longitudinal model of indirect effects, women's reported childhood maltreatment history (collected at the first assessment) was used to predict their cortisol responsivity at a subsequent (12-month) assessment, which was in turn used to predict their symptoms at the final (18-month) assessment while controlling for previous (12-month) symptoms. Women's stress response at the 12-month, rather than 6-month, assessment was selected as the focus both because the greater length/intensity of the stress episodes and the more elaborated social-emotional relationship with her infant at this time were judged more likely to evoke possible caregiving deficits in the mother's own history. The Strange Situation (SS; Ainsworth and Wittig, 1969) involves seven 3-minute episodes in which the infant is twice separated from the mother—first with an unfamiliar female "stranger" in the room, then with no one in the room—before being reunited; during separations, women were able to watch their infant on a remote computer monitor. This task has been shown to elicit behavioral and physiological stress responses in infants and their mothers (see Gunnar et al., 2009; Laurent et al., 2011a,b).

2.3. Measures

2.3.1. Childhood maltreatment

Was measured through retrospective reporting at the initial (3-month) study time with the Childhood Trauma Questionnaire (CTQ; Bernstein et al., 1994). The CTQ uses 25 items scored on a 5-point Likert scale (from 1 = "never" to 5 = "very often") to assess the occurrence during childhood of five forms of maltreatment: physical abuse, emotional abuse, sexual abuse, physical neglect, and emotional neglect. Consistent with prior evidence that the CTQ is a reliable and valid measure of child maltreatment (e.g., Paivio, 2001), we found high internal consistency across subscales (alphas = .84–.96). Although high internal consistency for the total scale score (alpha = .96) suggested co-occurrence of maltreatment types, correlations among subscale scores varied in size (from r = .33–.81). A substantial proportion of women in the current sample reported experiencing maltreatment according to the cutoff scores recommended by Bernstein and Fink (1998): 43% endorsed at least low-level emotional abuse (24% moderate-severe), 34% at least low physical abuse (25% moderate-severe), 28% at least low sexual abuse (19% moderate-severe), 43% at least low emotional neglect (15% moderate-severe), 37% at least low physical neglect (23% moderate-severe). A minority of participants reported no experiences of maltreatment (9% no maltreatment across subscales; 23% no emotional abuse, 42% no physical abuse, 72% no sexual abuse, 30% no emotional neglect, 42% no physical neglect).

2.3.2. HPA Axis response

Was measured via women's salivary cortisol during the 12-month laboratory session. All sessions took place in the afternoon to minimize the influence of diurnal variation in HPA output. Before proceeding with the session, other factors that could interfere with salivary cortisol were checked (i.e., recent intake of food/drink or nicotine, tooth brushing, or vigorous exercise; current illness). If none of these conditions had been violated, each woman contributed four saliva samples via passive drool: the first soon after arrival, the second immediately following the completion of the SS procedure, the third 20 min after the start of the second separation from the mother, and the fourth 30 min after the preceding sample. These sample times were selected to represent mothers' HPA activation prior to engaging in study procedures (sample 1), during the anticipatory phase/early portion of the stress task (sample 2), during the portion of the stress task meant to elicit maximum infant distress (sample 3), and during the post-task recovery phase (sample 4), while accounting for the roughly 20-minute lag for these influences on the HPA axis to appear in salivary cortisol.

All samples were assayed in duplicate with the commercially available Salivary Cortisol Enzyme Immunoassay (Salimetrics, Carlsbad, CA) without modification to the manufacturer's recommended protocol. The test uses 25 µl saliva, has a lower limit of sensitivity of 0.007 µg/dl, standard curve range .012–3.0 µg/dl. The intra-assay and inter-assay coefficients of variation were on average < 10% and 15%, respectively. Cortisol scores were natural log-transformed prior to analysis to correct positive skew. A number of potential control variables were examined for influence, including medication and substance use: the most commonly reported were hormonal contraceptives (30%) and nicotine (22%), with smaller proportions endorsing asthma (8%), psychotropic (antidepressant and/or antianxiety, 6%), pain (6%), allergy (5%), or thyroid (3%) medication, and 5% reporting marijuana use. Neither these nor other variables examined—i.e., session start time, sleep/wake times, body mass index—were found to influence cortisol levels in this sample and so were not included in further analysis.

2.3.3. Affective symptoms

Were assessed with two self-report instruments tapping depression and anxiety. The Center for Epidemiologic Studies Depression Scale (CESD; Radloff, 1977) is a 20-item measure of depression symptoms experienced in the past week rated from 0 ("rarely or none of the time") to 3 ("most or all of the time"), alpha = .87. The Beck Anxiety Inventory (BAI; Beck et al., 1988) is a 21-item measure of anxiety symptoms in the past month rated from 0 ("not at all") to 3 ("it bothered me a lot"), alpha = .92. Based on the scales with clinical cutoffs, a substantial minority of the sample experienced elevated symptoms (21% above cutoff for likely depression; 24% above cutoff for at least mild anxiety, 13% for moderate-severe anxiety). Total CESD and BAI scores were used in analyses.

2.4. Analytic strategy

Study hypotheses were tested in a series of steps: First, childhood maltreatment reported at 3 months postnatal—the total score and, if a significant overall effect was detected, individual subtypes—was used to predict women's cortisol response trajectories during the mother-infant stress task at 12 months postnatal using multilevel modeling in HLM. This approach separates within-person from between-person variability in a repeated-measures outcome. Level 1 modeled variation in each woman's cortisol scores across the four samples with an intercept (representing cortisol level during peak stress—SS second separation), linear slope (representing instantaneous rate of ongoing reactivity or recovery during peak stress), and quadratic slope (representing overall steepness of the reactivity/recovery curve); Level 2 modeled differences in these cortisol response components across women. Next, women's cortisol responses—intercepts, linear and quadratic slopes extracted from the HLM residual file—were used to predict their depression and anxiety symptoms at 18 months postnatal using multiple regression. These analyses controlled for women's 12-month symptoms

Table 2
Means, Standard Deviations, and Correlations.

		M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1.	CTQ Total	42.44	18.57	1													
2.	CTQ Emotional Neglect	9.83	5.01	.87**	1												
3.	CTQ Physical Neglect	7.93	3.95	.87**	.77**	1											
4.	CTQ Physical Abuse	7.7	3.6	.83**	.67**	.64**	1										
5.	CTQ Sexual Abuse	7.03	4.36	.64**	.36**	.51**	.33**	1									
6.	CTQ Emotional Abuse	9.94	5.52	.91**	.74**	.68**	.81**	.46**	1								
7.	T3 Cortisol Sample 1	−2.02	.72	.31*	.21	.28*	.28*	.21	.29*	1							
8.	T3 Cortisol Sample 2	−2.19	.68	.26*	.21	.27*	0.22	.15	.22	.86**	1						
9.	T3 Cortisol Sample 3	−2.36	.71	.21	.16	.22	.16	.11	.18	.81**	.93**	1					
10.	T3 Cortisol Sample 4	−2.49	.77	.19	.21	.24	.14	.05	.17	.72**	.82**	.89**	1				
11.	T3 Anxiety Symptoms	0.95	8.44	.19	.12	.18	.32*	.05	.22	.19	.14	.13	.02	1			
12.	T3 Depression Symptoms	10.93	7.64	.08	.03	-.06	.23	-.03	.17	.15	.15	.19	.13	.51**	1		
13.	T4 Anxiety Symptoms	7.55	7.71	.05	-.16	.1	.22	.07	.08	.04	-.04	-.12	-.27	.72**	.49**	1	
14.	T4 Depression Symptoms	11	8.25	-.05	-.19	-.13	.14	-.11	.13	.13	.07	.06	-.01	.33*	.65**	.58**	1

Note: Childhood Maltreatment variables are total CTQ and subscale scores; Cortisol scores are natural log-transformed values of μg/dl; Depression Symptoms are total CESD scores, Anxiety Symptoms are total BAI scores; * indicates $p < .05$, ** indicates $p < .01$.

in order to address ongoing symptom progression during this period. Finally, we examined indirect effects of maltreatment on women's symptom progression via cortisol response components with the Hayes PROCESS macro (see Hayes and Rockwood, 2017), which uses bootstrapping to estimate direct and indirect effects and generate confidence intervals.

3. Results

Descriptive statistics and zero-order correlations among study measures are given in Table 2. Results of primary study models are reported below:

3.1. Step 1: path from childhood maltreatment to cortisol

CTQ scores were entered as predictors of women's cortisol response trajectories to test the first part of the proposed path. Higher total maltreatment predicted a significantly more negative linear slope (γ = -.0034, p = .027) and a marginally more negative quadratic slope (γ = -.0020, p = .067), suggesting that women who had experienced more childhood maltreatment showed earlier/more sharply peaking cortisol reactivity during the task. Fig. 1, displays predicted cortisol trajectories for women reporting varying levels of total childhood maltreatment. In order to interpret the source of the total maltreatment effects, separate subscale-specific analyses were conducted; physical abuse predicted significantly more negative linear (γ = -.019, p = .016) and quadratic (γ = -.014, p = .016) cortisol slopes, and emotional abuse showed similar but somewhat weaker effects (linear γ = -.0097, p = .052; quadratic γ = -.0080, p = .049). None of the other CTQ subscales (i.e., sexual abuse, physical and emotional neglect) predicted women's cortisol response trajectories.

3.2. Step 2: path from cortisol to symptoms

Women's cortisol responses—i.e., intercept, linear slope, and quadratic slope estimates based on the unconditional HLM model—were entered as simultaneous predictors of their CESD and BAI symptom scores at the final assessment. Each model controlled for previous (12-month) symptom levels on the same measure. A more negative quadratic slope predicted higher levels of symptoms on both scales: CESD β = -.27, p = .028; BAI β = -.27, p = .015 none of the other cortisol response components significantly predicted symptoms

3.3. Step 3: indirect path from childhood maltreatment to symptoms via cortisol

Finally, we tested indirect effects of CTQ scores on final CESD and BAI scores via cortisol response components (intercept, linear and quadratic slopes). All models included the previous symptom score as a covariate and employed 10,000 bootstrap samples to arrive at estimates. As expected, based on the above steps, only the cortisol quadratic slope proved a significant mediator of maltreatment effects on symptoms. The indirect effect of total CTQ scores on anxiety symptoms was significant (b = .031, SE = .024, 95% CI .0011-.112 for BAI), and the indirect effect on depression symptoms was marginally significant (b = .034, SE = .029, 90% CI .0018-.103 for CESD). As above, follow-up analyses were conducted with individual subscales to determine the source of effects. These revealed significant indirect effects of emotional

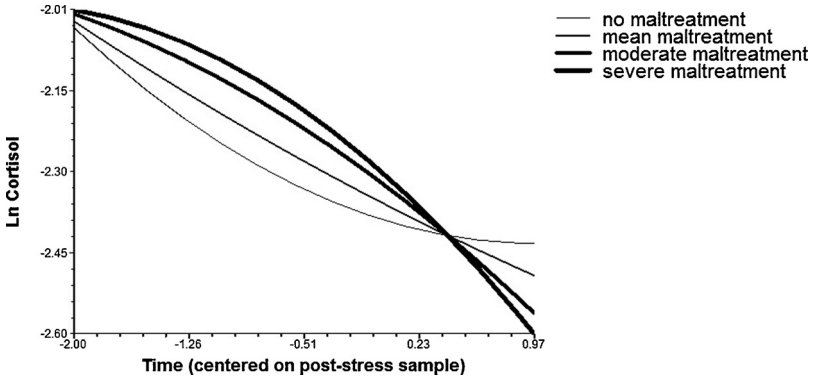

Fig. 1. Predicted cortisol trajectories for women reporting no childhood maltreatment (total CTQ = 25), average level of maltreatment for the sample (total CTQ = 42), moderate maltreatment (total CTQ = 62), and severe maltreatment (total CTQ = 73).

abuse (b = .136, SE = .107, 95% CI .0042-.519) and physical abuse (b = .186, SE = .133, 95% CI .021-.670), as well as a marginally significant indirect effect of sexual abuse (b = .104, SE = .098, 90% CI .0127-.378) on anxiety symptoms. Indirect effects of the neglect subscales were nonsignificant, suggesting childhood abuse drove the overall effect.

4. Discussion

The primary goal of the current study was to test indirect effects of childhood maltreatment on women's later affective symptomatology via HPA axis stress responding. As predicted, early life adversity appeared to contribute to ongoing symptom elevations via heightened HPA reactivity to stress. In particular, a history of emotional and/or physical abuse predicted more marked cortisol reactivity trajectories during a mother-infant stress task at 12 months postnatal, which in turn predicted increased anxiety symptoms at 18 months postnatal. These findings not only help to explain how early maltreatment continues to exert harmful effects on mental health later in life, but they also point to possible targets for intervention to protect high-risk women and their infants during a vulnerable period of development.

To the best of our knowledge, our study is the first to demonstrate that childhood maltreatment contributes to ongoing symptom elevations via altered HPA axis activation. This fills a critical gap between empirical evidence and theoretical models positing that the HPA axis acts as a link in the chain from early adversity to later mental health. The current findings extend existing evidence supporting individual links between early life stress and HPA functioning, and between HPA functioning and psychological well-being, while offering further insight into the conditions under which hyper- vs. hyporeactivity may emerge as a risk marker. Like the previous study examining maltreatment effects on cortisol during a personalized trauma-relevant stressor (Elzinga et al., 2003) and in contrast to the bulk of prior research relating trauma to blunted cortisol, we found women's maltreatment history predicted more marked cortisol reactivity to the mother-infant stressor. Similarly, the association we found between more marked cortisol reactivity and ongoing affective symptoms fits with previous studies examining cortisol during interpersonal stress (e.g., Laurent et al., 2011a,b), but not with the general body of literature on cortisol and trauma-related psychopathology. It may be that stress-sensitizing sequelae of trauma are most notable within a stress context reminiscent of the individual's traumatic experience—here, a challenging parent-child interaction that may activate memories of abusive parenting—and that conflicting or null findings in other studies are due to the choice of chemical or psychosocial stress probes. The fact that more naturalistic interpersonal stressors such as the one in this study tend to elicit less of a uniformly strong cortisol response than standard tasks such as the Trier Social Stress Test may further allow for the detection of individual differences in responding based on characteristics like caregiving history. Further research systematically investigating early trauma and acute stressor characteristics in relation to cortisol will be necessary to test these ideas.

Other characteristics of this study that may have made a difference in the detection of proposed trauma-cortisol-symptom paths include the longitudinal modeling of cortisol and symptoms. Unlike the majority of prior studies focusing on cortisol levels or AUC (which tends to conflate cortisol levels with stress-related reactivity/recovery dynamics), we considered both cortisol levels and dynamics of response across a stress session. The effects we found involved the latter only, highlighting the importance of separating HPA activation levels from response dynamics to avoid diluting effects and potentially reaching false conclusions regarding null associations. Specifically, women reporting greater childhood maltreatment and later anxiety symptoms showed a more sharply peaking cortisol reactivity trajectory during the session, as opposed to the gradual decline in cortisol evidenced by women reporting no maltreatment. This suggests that problematic HPA response profiles are characterized not by the degree of activation, but rather by the relation between activation and events unfolding over time. Here, it may be that lower-risk (non-maltreated) women did not find the repeated separations and reunions with their infant stressful, whereas their higher-risk counterparts found the task to be more threatening. Interestingly, this same pattern of exaggerated cortisol reactivity dynamics—but not levels—during mother-infant stress has been associated with blunted activation to infant distress cues in brain regions implicated in optimal parenting (Laurent et al., 2011a,b). It will be important to determine whether maltreatment makes parenting interactions more stressful, at least in part, because mothers find it difficult to process their child's emotions in a way that allows them to effectively regulate their own and their child's distress.

It is worthy of note that the relation we found between cortisol and symptoms was not simply a cross-sectional association, but rather a prediction of future symptoms while controlling for earlier symptom levels. Although the non-experimental study design does not allow for causal conclusions, this adds weight to the idea that childhood maltreatment does not result in a stable psychophysiological risk phenotype, but instead may sensitize women to later stressful experiences that in turn fuel ongoing symptomatology. Prospective longitudinal research investigating links between women's mental health and stress responding across multiple times both within and outside the perinatal period could shed further light on the nature of these paths.

Follow-up analyses to disentangle the source of overall CTQ effects suggest it may be important to separately consider different forms of childhood maltreatment in order to gauge long-term impacts. We found significant indirect effects of both emotional and physical abuse, but not of neglect, on later anxiety. This builds on previous evidence for a link between childhood physical abuse specifically and cortisol responding to psychosocial stress (Carpenter et al., 2011). It is possible that abuse—which involves a higher degree of immediate threat to the physical and/or emotional self than neglect—activates the HPA axis more potently in subsequent stress situations. It is also possible that the consequences of neglect are more evident in the context of different types of stress that map more closely onto neglect experiences, and/or in different aspects of stress physiology such as autonomic arousal or inflammation. Another potentially relevant characteristic is participant sex; many of the prior studies detecting maltreatment-related effects have involved women, and meta-analytic evidence supports sex as a moderator of early adversity-cortisol associations in the direction of stronger effects for women (Bunea et al., 2017; though see also Elzinga et al., 2008 for an example in which men showed stronger effects of adversity history on cortisol responding). Further work will be needed to disentangle whether and under what conditions women are especially likely to display these patterns of stress-related risk and how this may help to understand disparities in mental health.

A final distinction that merits further investigation is between types of affective symptom outcomes that may follow trauma. Even though effects were similar across the two symptom measures included in this study, the indirect effect of maltreatment via cortisol was significant for anxiety but not for depression symptoms. One possible reason for the discrepancy has to do with the symptom measures themselves; the anxiety (BAI) scale taps symptoms in the past month, whereas the depression (CESD) scale taps the past week only. Perhaps a longer timeframe is required to appreciate the cumulative impact of stress-related difficulties in women with a maltreatment history. It is also possible that there are other psychological or physiological mechanisms beyond the HPA axis that better explain depression outcomes in this population. Future research should explore both immediate and longer-term effects of childhood trauma on different dimensions of stress regulation and psychological symptomatology to clarify this.

Implications of the present findings highlight the need for intervention programs that help at-risk women with a history of maltreatment better cope with stressful situations that arise in parenting. For such women, parent training could help mitigate the stressfulness of

parenting interactions with their own infant, in turn protecting them from an escalation of affective symptoms. There is meta-analytic support for the power of parent training programs to positively change parenting behavior and child behavioral regulation (Kaminski et al., 2008). Learning to engage in more positive interactions and emotional communication with their child—skills maltreated women may not have learned from their own parents—could better equip women to parent with a sense of competence, improving their own mental health and potentially interrupting intergenerational transmission of stress vulnerability.

The results of the current study should be evaluated with respect to the following limitations. First, because of the observational (rather than experimental) study design, we are unable to make strong conclusions about specific causal paths. There are potentially other aspects of adversity/risk associated with childhood maltreatment that are important for HPA regulation and mental health outcomes. Alternative intervening mechanisms, such as other stress response systems or cognitive mediators, might provide further insight into the relationship between early maltreatment and later psychological health. Second, although the pathway tested follows the dominant theoretical paradigm in which HPA dysregulation drives psychopathology, it is also possible that there are bidirectional links between affective symptoms and HPA function over time, with symptoms both driving and being driven by HPA reactivity. More extensive longitudinal studies involving multiple assessments of HPA responsivity and symptoms would help to clarify this. Limitations in the time frame of assessment also constrain conclusions about when this pattern of HPA dysregulation first manifested and how durable its effects may be. Further research might investigate whether the HPA reactivity profile identified here is evident earlier in development (i.e., during childhood/adolescence) and if there is a critical time window for maltreatment exposure that determines whether a mother will show ongoing dysregulation with her infant. Relatedly, it remains to be seen whether this dysregulation is only evident during parent-child stress, or whether it might arise during other trauma-relevant stressors prior to becoming a parent. Finally, it should be noted that participants were part of a small community sample and not recruited for high levels of maltreatment or trauma, limiting our power to detect mediated effects (as suggested by Fritz & MacKinnon's 2007 analysis), particularly at the more severe end of the spectrum. Given the likelihood that tests of smaller-sized effects were underpowered, it should not necessarily be concluded that nonsignificant paths in this study represent true null associations between neglect and cortisol, and between cortisol and depressive symptoms. Future studies with larger clinical samples might yield further insight into more subtle effects of maltreatment and associated adversity.

These limitations notwithstanding, the present study fills an important gap by demonstrating empirically the proposed indirect path from early trauma to later mental health via functioning of the HPA axis during stress. Our results support the idea that women with childhood maltreatment histories are sensitized to later stressful experiences that feed into ongoing symptomatology. This provides a critical foundation for further efforts to understand and intervene on cascading paths of familial risk for stress-related disorders.

Conflict of interest

The authors have no conflicts of interest to report.

Role of the funding source

This work was supported by the Society for Research in Child Development Victoria Levin Award to H. Laurent and by the University of Oregon College of Arts and Sciences. The funders did not play a role in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

Author contributions

HL conceived the larger longitudinal study from which the current study data are drawn. SK and HL conceived the current study, analyzed the data, and contributed to the interpretation of the manuscript. Both authors contributed to literature searches and the writing and revision of the manuscript. Both authors approved the final submitted version.

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