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HORMONES: EMPIRICAL CONTRIBUTION

CORTISOL REACTIVITY AND RECOVERY IN THE CONTEXT OF ADOLESCENT PERSONALITY DISORDER

Jennifer L. Tackett, PhD, Shauna C. Kushner, MA,
Robert A. Josephs, PhD, K. Paige Harden, PhD,
Elizabeth Page-Gould, PhD, and Elliot M. Tucker-Drob, PhD

The present study examined whether the associations between stress responses and psychopathology were moderated by adolescent personality disorder (PD) traits. Participants were a community sample of 106 adolescents (47 male, M_{age} = 16.01) and their parents. Parents reported on adolescents' PD traits and behavioral problems. Changes in salivary cortisol were assessed in response to a laboratory-based stress induction. Moderated regression analyses revealed significant linear and quadratic interactions between cortisol recovery and PD traits in the prediction of behavioral problems. Although typically conceptualized as "adaptive," steeper post-stressor recovery was associated with more behavioral problems when PD traits were high. These findings suggest that, in the presence of maladaptive personality traits, premature recovery from environmental stressors may indicate an inability to respond appropriately to negative environmental stimuli, thus reflecting a core disturbance in PD trait functioning. The results underscore the informative role that personality plays in illuminating the nature of hormone functioning in adolescents and are interpreted in a developmental psychopathology framework.

Personality disorders (PDs) are often conceptualized as rigid and inflexible patterns of thinking, feeling, and behaving, and are often linked to problems in self-awareness, identity, and interpersonal relationships (Skodol et al., 2011). PDs are poorly understood in early life for multiple reasons, including a lack of optimal measurement tools for younger age groups, diagnostic limitations for early PDs, and concerns over early stigmatization (Cicchetti

From University of Houston (J. L. T.); University of Toronto (S. C. K., E. P.-G.); and University of Texas at Austin (R. A. J., K. P. H., E. M. T.-D.).

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Address correspondence to Jennifer L. Tackett, Department of Psychology, University of Houston, Houston, TX, 77204; E-mail: jltackett@uh.edu

& Crick, 2009; Tackett, Balsis, Krueger, & Oltmanns, 2009). Despite these difficulties, empirical research has recently been converging on the understanding that PD characteristics do indeed emerge before adulthood, that youth PD traits share overarching characteristics with adult PD traits, and that youth PD constructs demonstrate reliability of measurement and stability over time that is comparable to what is seen in adult samples (Cicchetti & Crick, 2009; Ferguson, 2010; Tackett et al., 2009). The similarities between PD traits in youth and adults support the validity of PD research in early life. The present study examines the interplay between stress and adolescent PD characteristics.

CORTISOL RESPONSE TO STRESS AND MALADAPTATION

Cortisol (CORT) is a steroid hormone that indexes activation of the hypothalamic-pituitary-adrenocortical (HPA) system, an integral system in the human stress response (Gunnar & Quevedo, 2007). Both state (e.g., acute responses to an immediate stressor) and trait (e.g., average levels of circulating CORT) indices of CORT have been implicated as correlates of internalizing and externalizing psychopathology in youth (Adam, Klimes-Dougan, & Gunnar, 2007; Shirtcliff & Essex, 2008), and of PD characteristics in adults (Walter et al., 2008). Multiple systems (e.g., neurobiological, social, and behavioral) involved in stress regulation mature across childhood and adolescence, resulting in differing expectations for CORT profiles with advancing age (Gunnar & Quevedo, 2007). Research on CORT functioning in adolescents has been sparse relative to other developmental periods. Recent work has indicated that adolescents no longer show the CORT hyporesponsivity that is typical in childhood, but rather they begin to show more adultlike responses to acute stressors (Adam et al., 2007; Gunnar & Quevedo, 2007). In rats, HPA activation after exposure to stressors is prolonged in adolescents relative to adults (McCormick & Mathews, 2007; Romeo, Karatsoreos, & McEwen, 2006). Moreover, adolescents who are using oral contraceptives do not show the salivary cortisol response that is observed in adult women who are using oral contraceptives (Bouma, Riese, Ormel, Verhulst, & Odlehinkel, 2009). Thus, there is a need for developmentally specific empirical investigations of HPA activity that highlight specific age groups, such as adolescence. The current study builds on the nascent body of research investigating CORT responses during adolescence and their relationship to psychopathology.

In response to an acute stressor, the HPA axis activates to produce a characteristic spike in peripheral CORT levels in most individuals, which is measurable in saliva within approximately 20 minutes after the onset of the stressor (Dickerson & Kemeny, 2004). Following removal of the acute stressor, CORT levels eventually return to baseline. This pattern of stress response can be indexed by measuring (a) peak levels of CORT following stressor exposure relative to pre-exposure levels (CORT reactivity), and (b) the rate of decrease in CORT levels following stressor removal (CORT recovery; Ramsay & Lewis, 2003). A "normative" CORT response is characterized by a rapid increase in CORT levels upon exposure to a stressor, with a relatively quick return to baseline levels following stressor removal (Adam et al., 2007; Linden, Earle, Gerin, & Christenfeld, 1997). A single-peaked CORT response to an acute stressor paired with rapid return to a prestressor baseline is the prototype of a well-regulated HPA axis and physiological toughening (Dienstbier, 1989; Epel, McEwen, & Ickovics, 1998).

A dysregulated CORT response, typically linked to maladjustment, is marked by atypically high or low CORT reactivity (Granger, Weisz, & Kauneckis, 1994; Gunnar, Wewerka, Frenn, Long, & Griggs, 2009; Klimes-Dougan, Hastings, Granger, Usher, & Zahn-Waxler, 2001) or delayed CORT recovery. Failure to habituate to a stressor (i.e., slow CORT recovery) has specifically been implicated in internalizing problems such as anxiety and depression (Adam et al., 2007; Burke, Davis, Otte, & Mohr, 2005). In addition, youth externalizing problems have been associated with a blunted CORT reactivity profile (atypically low CORT response to a stressor), particularly in the absence of comorbid internalizing problems (Adam et al., 2007; van Goozen et al., 1998). No work to date, however, has examined "adaptive" and "maladaptive" CORT response profiles among youth with varying levels of PD traits. This is the goal in the current investigation.

THE PRESENT STUDY

Previous research has highlighted the complexity associated with identifying "risky" CORT response profiles, such that risk profiles for CORT functioning often differ across a variety of moderators, including developmental stages and situational contexts (Del Giudice, Ellis, & Shirtcliff, 2011; Gunnar & Quevedo, 2007), which is resonant with a developmental psychopathology framework. Individual differences have been shown to moderate the relationships between patterns of CORT functioning and maladaptive outcomes (e.g., Gunnar, Kryzer, Van Ryzin, & Phillips, 2011; McEwen, 1998; Phillips, Fox, & Gunnar, 2011; Sapolsky, 2005; Shoal, Giancola, & Kirillova, 2003). Personality researchers similarly have argued for the need to consider PD characteristics as potential diatheses against which to examine psychological functioning (Tyrer, 2007). However, it is important to emphasize that disordered personality domains represent different contexts from normal-range personality functioning and thus may highlight different pathways to adaptation and maladaptation. Specifically, core components of PD (e.g. rigidity, lack of insight) may result in PD traits showing differential moderation of hormone profiles than would normal personality traits. The current article is the first empirical study to examine youth PD traits as a potential moderator of the hormone-psychopathology association.

Hypotheses for the present study were formulated using the higher order factor model of the Dimensional Personality Symptom Item Pool (DIPSI; De Clercq, De Fruyt, Van Leeuwen, & Mervielde, 2006; Tackett & De Clercq, 2009), which is an empirically based measure of personality pathology in youth, producing scores on four differentiable dimensions: disagreeableness, emotional instability, introversion, and compulsivity (each of which is scored in the direction of higher problematic traits). We examine each of these four DIPSI traits as moderators of the association between CORT reactivity, CORT recovery, and psychopathology within a nonclinical adolescent sample. Previously described associations between the DIPSI higher order traits with internalizing (DIPSI emotional instability, introversion, and compulsivity) and externalizing (DIPSI disagreeableness) domains provide a starting point for hypothesis development.

Specific hypotheses were:

Reactivity: A blunted peak CORT response will predict psychopathology among adolescents high in disagreeableness, whereas a heightened peak CORT response will predict psychopathology among adolescent high in emotional instability, introversion, and compulsivity.

Recovery: A steeper CORT recovery will predict psychopathology among adolescents high in disagreeableness, whereas a more shallow CORT recovery will predict psychopathology among adolescents high in emotional instability, introversion, and compulsivity.

METHOD

SAMPLE

Participants were 106 nonclinical adolescents (47 male, 59 female) aged 12 to 18 years old (M = 16.01, SD = 1.29) and their parents (96 mothers, 10 fathers). All participants were solicited using a community-based participant pool database and flyers posted throughout an urban community in southern Ontario, Canada. Inclusion/exclusion criteria were fluency in English and an absence of neurodevelopmental disorders, psychotic disorders, and mental retardation in the child. Informed consent was obtained from all participants and their parents. Participants' Tanner stage, obtained using the self-rated Petersen Development Scale (Petersen, Crockett, Richards, & Boxer, 1988), revealed the following pubertal breakdown: 63.2% advanced pubertal, 23.6% postpubertal, 11.3% midpubertal, and 1.9% unknown. The following ethnicity breakdown was reported by parents: 74.5% European, 6.6% Asian, 2.8% African/Caribbean, 0.9% Pacific Islander, and 15.1% Multiracial/Other. Parents reported an average annual household income in the range of 70,001–80,000 Canadian dollars. Most parents had completed a postsecondary degree or diploma (87.7%), 6.6% had partially completed some postsecondary education, and 5.7% had completed high school.

MEASURES

Dimensional Personality Symptom Item Pool (DIPSI). The DIPSI (De Clercq et al., 2006; Tackett & De Clercq, 2009) is a 172-item parent-report questionnaire measuring personality pathology, which was originally developed with 5- to 15-year-old Belgian youth (De Clercq et al., 2006). Validation data for the English translation suggest excellent psychometric properties (Tackett & De Clercq, 2009). DIPSI items are scored to generate scales for four higher order maladaptive personality dimensions—Disagreeableness, Emotional Instability, Introversion, and Compulsivity—and 27 lower order facets. Scale reliabilities (Cronbach's alpha) for the higher order DIPSI dimension scores ranged from .91 (Introversion) to .98 (Disagreeableness) in the present sample.

Child Behavior Checklist (CBCL–6–18). The CBCL (Achenbach, 2001) is a 118-item parent-report questionnaire measuring psychopathology among 6- to 18-year-old youth. The presence of problems in the past 6 months is rated 0–2, ranging from *not true (as far as you know)* to *very true or often true*. Items from the CBCL are scored to generate dimensional scores for Internalizing Problems, Externalizing Problems, and Total Problems, as well as specific syndrome scales, which have demonstrated good psychometric properties (Achenbach & Rescorla, 2001). In the current investigation, we examined the CBCL Total Problem scale, which provides a global measure of internalizing, externalizing, social, attention, and thought problems. Cronbach's alpha for this scale was .94 in the present sample.

Trier Social Stress Test (TSST). The TSST (Kirschbaum, Pirke, & Hellhammer, 1993) is a laboratory protocol that was designed to be a "strong situation" that elicits a stress response to a psychosocial stressor (Kirschbaum et al., 1993). This protocol involved a 3-minute anticipatory period during which participants were asked to prepare a brief speech describing why they would be an ideal candidate for their dream job. Next, participants were asked to give this speech to two unacquainted judges for 4 minutes, who prompted participants to continue if they paused for longer than 10 seconds. Participants were then asked to complete a 5-minute math task (i.e., "Count backwards out loud, starting at the number 996 in steps of 7."). If participants made any errors, they were asked to start over. After three errors or six successful responses, the judges provided new starting and count numbers.

CORT Assays. CORT samples were collected through passive-drool between noon and sundown to limit the potential influence of diurnal variation in CORT levels (Kirschbaum & Hellhammer, 1994). Samples from female participants were obtained during the self-reported follicular phase (first 10 days) of the menstrual cycle—the hormonal nadir of the menstrual cycle—to allow for the greatest sensitivity of hormonal responses to psychological events (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). Participants were requested to abstain from eating, drinking, and smoking for 2 to 4 hours prior to their testing session to prevent contamination of the saliva samples. Upon providing informed consent, participants rinsed their mouths and drank a small cup of water. After 30 minutes of sedentary activity (e.g., completing questionnaires), participants were requested to drool into a 2-mL IBL vial using a sanitary straw. Samples were transferred to a –20°C freezer and shipped on dry ice to be assayed at Clemens Kirschbaum's laboratory (Technical University of Dresden) where they were immunoassayed (IBL International, Hamburg, Germany). The intraassay and interassay coefficients for cortisol were below 8%.

PROCEDURE

Data for this investigation were drawn from a larger longitudinal study examining the role of personality traits in predicting behavioral outcomes. In total, 185 youth aged 11–17 years at intake were invited for a follow-up assessment. Of those eligible, 144 completed this second assessment 1–3 years following their initial participation.[1] Ethics approval was obtained from the research ethics board. Packages including informed consent documentation and questionnaires were mailed to participants to be completed and returned at an in-lab visit, during which they completed an extended assessment battery and provided saliva samples; however, 38 participants were unable to attend and therefore returned completed questionnaires by mail.[2] The present investigation included only those participants who attended the in-lab testing session, so the final sample comprised 106 youth and their parents. During the lab visit, baseline CORT samples (T1) were collected immediately prior to the administration of the TSST. Subsequently, two samples were collected at 20 minutes (T2) and 35 minutes (T3) following the start of the TSST speech task. Participating families received $50 Canadian plus a $25 gift card for completing the protocol. Missing data were minimal (<1% for any measure) and were imputed using the expectation-maximization (EM) algorithm in SPSS 20.

RESULTS

All variables were screened for nonnormality prior to analysis. To approximate a normal distribution, the following transformations were applied: One extreme value was obtained for CORT at T3 (it was 3.91 *SD* above the mean) and was Winsorized; time of waking was standardized; and CORT data from T1, T2, and T3 were log-transformed (Mehta & Josephs, 2006). Descriptive statistics and correlation coefficients are displayed in Table 1. Mean comparisons of CORT data suggest that the TSST provocation successfully elicited an endocrine stress response: T1 vs. T2: $t(105) = -8.55$, $p < .001$; T2 vs. T3: $t(105) = 3.58$, $p = .001$. Following transformation, CORT reactivity was computed by subtracting T2 scores from T1 scores, whereas CORT recovery was computed by subtracting T3 scores from T2 scores. Although area-under-the-curve analyses are also sometimes used to examine CORT reactivity, this statistic does not allow differentiation between reactivity and recovery indices (Lobo, Jiménez-Valverde, & Real, 2008); thus, we relied on change scores in the present study. Four hierarchical moderated regression models were conducted to examine the interaction between either

1. We conducted *t* tests on DIPSI data collected during the intake phase to determine if the 144 participating in the current study evidenced significant differences from those eligible but who did not participate ($n = 41$). The results of these analyses revealed no significant differences, all ts(183) < 1.14, all ps < .255.

2. We conducted *t* tests on DIPSI data to determine if the 106 participating in the current study evidenced significant differences from those who participated by mail only ($n = 38$). The results of these analyses revealed no significant differences, all ts(142) < 0.70, all ps < .487.

TABLE 1. Bivariate Correlation Coefficients and Descriptive Statistics

	1	2	3	4	5	6	7
1. DIPSI Disagreeableness	1.00						
2. DIPSI Emotional Instability	0.83***	1.00					
3. DIPSI Introversion	0.62***	0.73***	1.00				
4. DIPSI Compulsivity	0.38***	0.48***	0.57***	1.00			
5. CORT Reactivity	0.01	-0.07	-0.10	-0.01	1.00		
6. CORT Recovery	0.03	0.03	0.03	0.02	0.00	1.00	
7. CBCL Total Problems	0.81***	0.74***	0.57***	0.30**	0.03	0.10	1.00
M	1.68	1.52	1.39	1.84	-0.20	0.04	22.96
SD	0.59	0.56	0.46	0.77	0.24	0.13	20.40

Note. DIPSI = Dimensional Personality Symptom Item Pool. CORT = Cortisol. CBCL = Child Behavior Checklist. *$p < .05$. **$p < .01$. ***$p < .001$.

CORT reactivity or CORT recovery and the higher order DIPSI traits (i.e., 1: Disagreeableness; 2: Emotional Instability; 3: Introversion; 4: Compulsivity). All independent and moderator variables were centered prior to analysis. For each model, we first entered the effect of youth sex and time of waking (Step 1), followed by main effects for either CORT reactivity or recovery and one higher order DIPSI trait (Step 2). Next, we entered the interaction terms for linear moderators (Step 3), followed by the quadratic main effect for CORT reactivity or recovery (terms were derived as the square of each variable) and the product of this term with the DIPSI trait (Step 4). In all models, neither sex nor time of waking significantly predicted CBCL Total Problems ($\beta = -.173$, $p > .05$ and $\beta = .015$, $p > .05$, respectively) and were therefore omitted from Tables 1 and 2. Simple effects were tested using the Hayes and Matthes (2009) MODPROBE modeling approach and used moderator values +/–1 *SD* from the mean.

CORT REACTIVITY

Results from moderated regression analyses for CORT reactivity are displayed in Table 2. In all four models, the main effects for the higher order DIPSI traits positively predicted CBCL Total Problems,[3] whereas all main effects for CORT reactivity were nonsignificant. In addition, none of the linear moderator effects were significant. Remaining significant effects were scattered across analyses, with no clear patterns of significance emerging. The

3. Given the lack of previous research jointly examining the focal constructs of the present study, specific hypotheses were not formulated for the prediction of internalizing versus externalizing problems. However, exploratory analyses predicting CBCL Internalizing and Externalizing problems revealed few differences in the pattern of linear moderation effects. None of the specific moderator effects for CORT reactivity were significant in predicting either internalizing or externalizing problems, whereas CORT recovery interacted with three of four DIPSI traits. Specifically, CORT recovery was negatively associated with internalizing and externalizing problems when Emotional Instability, Introversion, and Compulsivity were low, whereas CORT recovery was positively associated with internalizing and externalizing problems when these traits were high. A notable exception was for Disagreeableness, which showed a significant interaction with CORT recovery in predicting internalizing problems ($\beta = .240$, $p = .003$), but not externalizing problems ($\beta = -.096$, $p = .128$). High CORT reactivity was associated with higher internalizing problems among highly disagreeable youth, $t(100) = 2.28$, $p = .024$.

TABLE 2. Moderated Hierarchical Regression Analyses Predicting Child Behavior Checklist (CBCL) Total Problems From Cortisol Reactivity (CORT REA), and Dimensional Personality Symptom Item Pool (DIPSI) Traits

Step	Variable	*B*	SE_B	95% CI	R^2	*F*
			Model 1: DIPSI Disagreeableness (DIS)			
2	CORT REA	3.11	5.02	[-6.85, 13.08]	0.66	49.78***
	DIPSI DIS	27.95***	2.03	[23.92, 31.99]		
3	CORT REA × DIS	-7.47	7.26	[-21.88, 6.94]	0.67	40.06***
4	CORT REA^2	-50.99*	20.99	[-92.65, -9.33]	0.69	30.64***
	CORT REA^2 × DIS	-3.19	31.74	[-66.17, 59.79]		
			Model 2: DIPSI Emotional Instability (EI)			
2	CORT REA	8.71	5.61	[-2.42, 19.85]	0.58	35.05***
	DIPSI EI	27.12***	2.36	[22.44, 31.80]		
3	CORT REA × EI	-1.92	7.88	[-17.55, 13.71]	0.58	27.79***
4	CORT REA^2	-36.48	23.55	[-83.23, 10.26]	0.62	22.53***
	CORT REA^2 × EI	-94.79*	37.78	[-169.75, -19.82]		
			Model 3: DIPSI Introversion (ITR)			
2	CORT REA	8.84	7.03	[-5.11, 22.79]	0.35	13.30***
	DIPSI ITR	25.00***	3.61	[17.85, 32.15]		
3	CORT REA × ITR	-21.68	11.54	[-44.57, 1.21]	0.37	11.62***
4	CORT REA^2	-5.62	28.83	[-62.84, 51.61]	0.37	8.21***
	CORT REA^2 × ITR	-26.39	50.99	[-127.57, 74.80]		
			Model 4: DIPSI Compulsivity (COMP)			
2	CORT REA	5.70	8.02	[-10.20, 21.61]	0.14	4.24**
	DIPSI COMP	8.94***	2.48	[4.02, 13.85]		
3	CORT REA × COMP	-17.92	9.14	[-36.05, 0.22]	0.18	4.26**
4	CORT REA^2	26.96	31.15	[-34.85, 88.76]	0.22	3.91**
	CORT REA^2 × COMP	70.72	37.12	[-2.95, 144.40]		

Note. Separate moderated hierarchical regression analyses were conducted for each higher-order DIPSI trait to examine the linear, quadratic, and interaction terms between adolescent PD traits and CORT reactivity. For all models, sex and time of waking were entered in Step 1, but neither significantly predicted CBCL Total Problems ($\beta = -.173$, $p > .05$ and $\beta = .015$, $p > .05$, respectively) and were therefore omitted. Model estimates are displayed for new variables added at each subsequent step (omitted estimates available upon request). Reported R^2 coefficients denote the proportion of variance explained by all predictor variables for each forced block entry. *F* denotes statistical significance of the regression model at each step. *B* = unstandardized regression coefficient. *SE* = standard error. Values in square brackets denote 95% confidence intervals.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

only significant moderation was evident for CORT reactivity^2 × Emotional Instability ($\beta = -.344$, $p = .014$). The simple effects analysis for the quadratic interaction suggests that the association between CBCL Total problems and Emotional Instability was highest when CORT reactivity was high, $t(98) = -2.89$, $p = .005$).[4]

4. All moderated regression analyses were repeated after excluding seven female participants who reported using hormonal contraceptives to examine their potential influence on the current results. The same pattern of results emerged. These results are available from the first author on request.

TABLE 3. Moderated Hierarchical Regression Analyses Predicting Child Behavior Checklist (CBCL), Total Problems From Cortisol Recovery (CORT REC), and Dimensional Personality Symptom Item Pool (DIPSI) Traits

Step	Variable	*B*	SE_B	95% CI	R^2	*F*
	Model 1: DIPSI Disagreeableness (DIS)					
2	CORT REC	12.76	9.21	[-5.50, 31.03]	0.67	50.92***
	DIPSI DIS	27.91***	2.02	[23.91, 31.92]		
3	CORT REC × DIS	66.96***	17.68	[31.89, 102.02]	0.71	48.99***
4	CORT REC^2	99.10*	43.08	[13.62, 184.59]	0.73	38.86***
	CORT REC^2 × DIS	252.83*	97.62	[59.11, 446.55]		
	Model 2: DIPSI Emotional Instability (EI)					
2	CORT REC	12.77	10.39	[-7.85, 33.38]	0.58	34.52***
	DIPSI EI	26.81 ***	2.37	[22.12, 31.50]		
3	CORT REC × EI	94.75 ***	23.58	[47.96, 131.54]	0.64	34.99***
4	CORT REC^2	95.80	49.52	[-2.47, 194.08]	0.67	28.98 ***
	CORT REC^2 × EI	425.26 **	128.71	[169.83, 680.69]		
	Model 3: DIPSI Introversion (ITR)					
2	CORT REC	13.82	12.97	[-11.91, 39.55]	0.34	13.14***
	DIPSI ITR	24.52 ***	3.60	[17.37, 31.66]		
3	CORT REC × ITR	130.58 ***	30.15	[70.76, 190.40]	0.45	16.11***
4	CORT REC^2	5.76	61.88	[-117.03, 128.56]	0.45	11.68***
	CORT REC^2 × ITR	267.69	218.16	[165.24, 700.61]		
	Model 4: DIPSI Compulsivity (COMP)					
2	CORT REC	14.56	14.76	[-14.72, 43.85]	0.15	4.38**
	DIPSI COMP	8.81 **	2.47	[3.91, 13.71]		
3	CORT REC × COMP	70.17 **	22.75	[25.04, 115.30]	0.22	5.70***
4	CORT REC^2	10.51	74.66	[-137.65, 158.68]	0.24	4.44***
	CORT REC^2 × COMP	217.38	142.82	[-66.05, 500.80]		

Note. Separate moderated hierarchical regression analyses were conducted for each higher-order DIPSI trait to examine the linear, quadratic, and interaction terms between adolescent PD traits and CORT recovery. For all models, sex and time of waking were entered in Step 1, but neither significantly predicted CBCL Total Problems (β = -.173, $p > .05$ and β = .015, $p > .05$, respectively) and were therefore omitted. Model estimates are displayed for new variables added at each subsequent step (omitted estimates available upon request). Reported R^2 coefficients denote the proportion of variance explained by all predictor variables for each forced block entry. *F* denotes statistical significance of the regression model at each step. *B* = unstandardized regression coefficient. *SE* = standard error of unstandardized regression coefficient. Values in square brackets denote 95% confidence intervals.
*$p < .05$. **$p < .01$. ***$p < .001$.

CORT RECOVERY

Results from moderated regression analyses for CORT recovery are displayed in Table 3. In all four models, the main effects for the higher order DIPSI traits positively predicted CBCL Total Problems (see footnote 3), whereas all main effects for CORT recovery were nonsignificant. Linear interactions are displayed in Figure 1. Significant quadratic interactions are displayed in Figure 2. In Model 1, there were linear and quadratic interactions with Disagreeableness (β = .213, $p < .001$, and β = .173, $p = .011$,

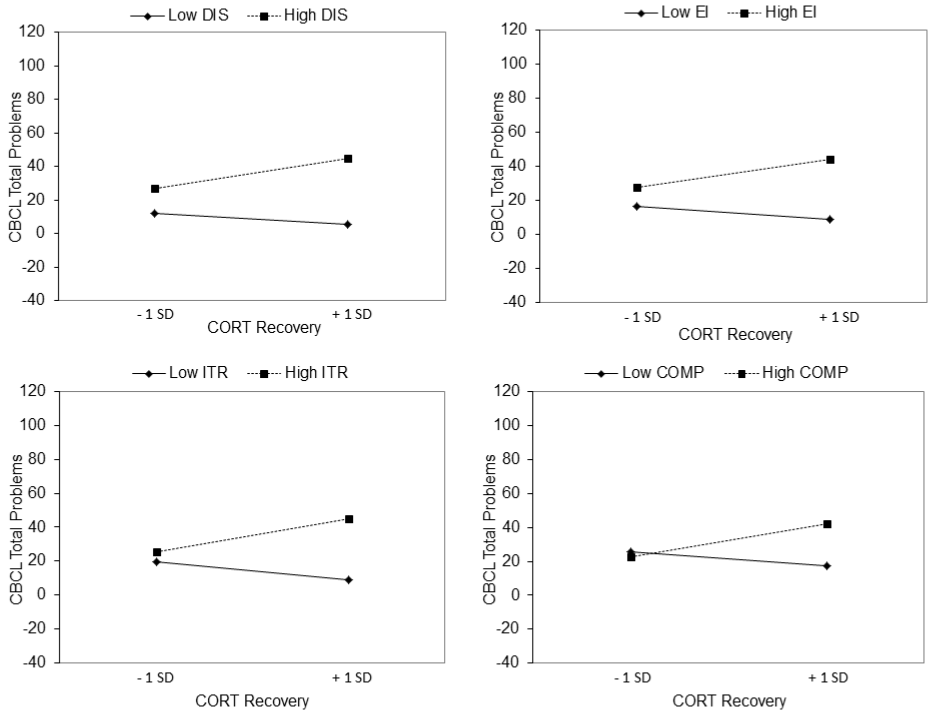

FIGURE 1. Linear interactions between CORT recovery and DIPSI traits in predicting CBCL Total Problems. DIS = DIPSI Disagreeableness; EI = DIPSI Emotional Instability; ITR = DIPSI Introversion; COMP = DIPSI Compulsivity. Higher values on CORT recovery indicate faster poststressor recovery.

respectively). The simple effects analysis for the linear interaction revealed that the relationship between CORT recovery and Total Problems was not significant among individuals low in Disagreeableness; among individuals high in Disagreeableness, however, steeper CORT recovery predicted higher Total Problems, $t(100) = 3.94$, $p < .001$. That is, the CORT reactivity profile typically considered “adaptive” was associated with increased behavioral problems among youth high on the PD trait of Disagreeableness. The simple effects analysis for the quadratic interaction suggests that the association with CBCL Total problems and Disagreeableness was strongest when CORT recovery was fastest, $t(98) = 3.04$, $p = .003$, with potentially accelerated fanning at steeper levels of CORT recovery.

There were also significant linear and quadratic interactions with Emotional Instability in Model 2 ($\beta = .256$, $p < .001$, and $\beta = .238$, $p = .001$, respectively). Similar to the pattern seen for Disagreeableness, the simple effects analysis for the linear interaction revealed that faster CORT recovery was associated with fewer Total Problems among individuals with low Emotional Instability, $t(100) = -2.19$, $p = .031$. In contrast, faster CORT recovery was associated with a higher level of Total Problems among individuals with high levels of Emotional Instability, $t(100) = 4.09$, $p < .001$. The simple effects analysis for the quadratic interaction suggests that the association with CBCL Total problems and Emotional Instability was strongest when CORT

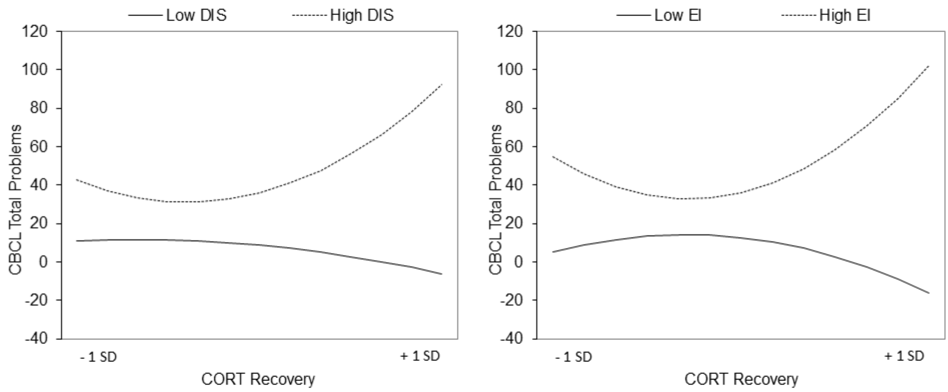

FIGURE 2. Quadratic interactions between CORT recovery time and DIPSI traits in predicting CBCL Total Problems. DIS = DIPSI Disagreeableness; EI = DIPSI Emotional Instability. Higher values on CORT recovery indicate faster poststressor recovery.

recovery was fastest, $t(98) = 3.28$, $p = .002$, with potentially accelerated fanning at steeper levels of CORT recovery.

The same pattern was found for Introversion and Compulsivity traits and moderation of CORT recovery effects. In Model 3, there was a significant linear interaction between CORT recovery and Introversion ($\beta = .327$, $p < .001$). The simple effects analysis for the linear interaction revealed that faster CORT recovery was associated with fewer Total Problems among individuals with low Introversion, $t(100) = -2.42$, $p = .017$. In contrast, faster CORT recovery was associated with a higher level of Total Problems among individuals with high levels of Introversion, $t(100) = 4.08$, $p < .001$. Finally, in Model 4, there was a significant linear interaction between CORT recovery and Compulsivity ($\beta = .282$, $p < .001$). The simple effects analysis for the linear interaction revealed that CORT recovery was not associated with Total Problems among individuals with low Compulsivity. In contrast, faster CORT recovery was associated with a higher level of Total Problems among individuals with high levels of Compulsivity, $t(100) = 3.10$, $p = .002$ (see footnote 4).

Overall, across the four PD traits examined in this study, a consistent pattern emerged, in which faster CORT recovery—typically considered an adaptive CORT response profile—was associated with lower levels of psychopathology only among youth without elevated PD traits. Among youth with higher levels of PD traits, faster CORT recovery instead appeared to reflect a maladaptive profile, predicting higher levels of internalizing and externalizing psychopathology.

DISCUSSION

These results indicate that personality pathology consistently moderates the link between CORT recovery and broadly defined behavioral problems.

CORT recovery interacted with all four domains of higher order youth PD traits in predicting overall behavioral problems. Specifically, the linear effects essentially replicated across all PD traits, such that in the context of higher levels of youth PD traits, faster levels of CORT recovery—which indicate a quicker return to baseline following stressor exposure—predicted a greater number of behavioral problems. In contrast, for youth with low levels of PD, faster CORT recovery predicted fewer behavioral problems. Contrary to our hypotheses, we did not see directional specificity for internalizing and externalizing DIPSI traits; rather, all PD traits interacted with the stress response in the same direction. Our results indicate that the classic conceptualization of faster CORT recovery reflecting an adaptive profile (e.g., Burke et al., 2005; Epel et al., 1998; Linden et al., 1997) may be reversed for those youth possessing high levels of PD traits. The context of higher levels of youth PD traits also moderated quadratic effects for CORT recovery for two traits—disagreeableness and emotional instability. At pathological ends of these spectra, faster CORT recovery showed an accelerated association with total behavioral problems.

It is clear that individual differences in PD traits offer increased nuance and complexity when investigating the adaptive and maladaptive correlates of different CORT profiles. In particular, the idea that quicker CORT recovery following a stressor is associated with adaptation (Dienstbier, 1989) may not hold in the context of PD traits. Although this is the first study, to the best of our knowledge, to investigate empirical associations in the context of youth PD, our broader knowledge about PD traits helps us understand the emergent picture in the present study. Specifically, PD traits are typically conceptualized as highly rigid characteristics (such that individuals with PDs are unable to adapt to situations when necessary) marked by a lack of insight and self-awareness. In this theoretical framework, the present results become clearer: It was those youth with high PD traits who, following a stressor exposure, returned to baseline perhaps too quickly. This finding may reflect a lack of impact of the stressful environment on those youth high in PD traits, and it may further demonstrate the general rigidity and inflexibility thought to mark the disorder. Parents' perceptions of mal/adaptivity may also be influenced by the perceived appropriateness of poststressor recovery (e.g., quick recovery from parental discipline may be viewed negatively, whereas slower recovery may be perceived favorably). These findings are particularly notable in that they showed robust replication across all four higher order traits, suggesting that the extent to which the quick CORT recovery profile is maladaptive may reflect core, underlying features of general PD. Our results also supported the importance of quadratic effects of CORT functioning within a youth PD context. These findings are again consistent with general theory and research in this area, but highlight them within the moderating context of youth PD traits and emphasize the importance of examining hormonal functioning across many situations, features, and potential moderators in the search for prediction of adaptation and maladaptation (Del Giudice et al., 2011).

PD traits did not robustly differentiate findings for CORT reactivity. Few significant findings emerged for CORT reactivity in the context of youth PD, with one exception. The presence of emotional instability in adolescence did moderate a quadratic effect for CORT reactivity, such that both extremely high and extremely low levels of CORT reactivity predicted greater overall problems, but only when emotional instability is high. This finding is largely consistent with previous theories regarding mal/adaptive CORT reactivity profiles (Adam et al., 2007) and suggests that differential PD contexts—particularly that of high emotional instability—may be particularly useful in elucidating a maladaptive CORT reactivity profile. Alternatively, it may be possible that youths with faster recovery times had low CORT reactivity to begin with; however, it is notable that CORT reactivity and recovery were not significantly correlated in this sample. Furthermore, when we repeated our regression analyses for CORT recovery including CORT reactivity as a covariate, the same general pattern of results emerged (additional results are available upon request).

Several limitations of the study should be noted, as well as important directions for future research. As the first empirical investigation of CORT reactivity/recovery profiles in a PD context, the findings presented here should be presented as preliminary evidence and replicated in future studies. Developmental considerations are certainly an important direction for future research. A previous investigation in this sample indicated potential differences in joint testosterone-CORT functioning between early and later adolescence (Tackett, Herzhoff, Harden, Page-Gould, & Josephs, 2013); however, conducting the analyses in the present sample across split-halves based on age produced no change in the findings. Thus, it will be important to examine whether these findings replicate in other ages, including adult samples, or whether they reflect an adolescent phenomenon. It is also notable that the follicular phase for female participants was determined from self-reports of menstruation cycles, because adolescent females often do not experience regular, 28-day cycles. In addition, the robustness of effects should ideally be demonstrated in larger samples and across different measures of personality pathology. This is particularly true in aiming to determine the potential specificity of what may be trait-specific findings (e.g., the interaction between quadratic effects for both CORT reactivity and recovery with trait emotional instability). Finally, empirical investigations of CORT recovery continue to be understudied relative to CORT reactivity (Dickerson & Kemeny, 2004; Linden et al., 1997; Ramsay & Lewis, 2003), despite growing evidence that associations with CORT recovery may offer different insights than those established in research on CORT reactivity, a point that is underscored by the results of the present study. Thus, these findings further support differentiating reactivity and recovery aspects of the stress response, identifying contextual moderators when identifying mal/adaptivity (e.g., Albers, Riksen-Walraven, Sweep, & Weerth, 2007; Tarullo, Mliner, & Gunnar, 2011) and expanding our theories and empirical investigations to more fully capture the stress recovery process.

In sum, this study presents the first empirical investigation of youth PD interactions with CORT reactivity/recovery profiles in the prediction of general psychopathology. We find consistent evidence that quicker CORT recovery may not always reflect adaptive functioning, because it relates to more problems in youth with high levels of PD. Taken together, this work highlights the relevance of youth PD traits for examining links between hormone functioning and broader behavioral problems, and it suggests that hormone functioning exerts fundamental interplay with individual differences in PD traits in predicting mal/adaptive outcomes.

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