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Linking Post-stressor Interpersonal Processes in Adolescent Girls' Close Friendships with Acute HPA Stress Responses

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Abstract

Introduction: For adolescent girls, close friendships may facilitate stress management and mitigate risk for internalizing psychopathology. However, little is known about how friendship processes may buffer (or potentially exacerbate) acute psychobiological responses to interpersonal stressors in ways that affect risk.

Methods: In a sample of 220 girls (ages 12–17 years) with a history of internalizing symptoms, this study investigated friendship dynamics following the Trier Social Stress Test (TSST) to evaluate associations between post-stressor friendship behaviors (expressions of vulnerability by the stressed teen; support offered by their close friend) and hypothalamic-pituitary-adrenal (HPA) axis stress responses.

Results: Multilevel regression modeling revealed that girls who displayed more pronounced cortisol reactivity expressed greater vulnerability to, and received greater support from, their close friend. Expressed vulnerability was associated with more efficient cortisol recovery. Close friend support was not significantly associated with cortisol recovery, nor did it influence the connection between expressed vulnerability and cortisol recovery.

Conclusions: Findings suggest that HPA reactivity may prompt expressions of vulnerability to girls' close friends, and in this context, promote more efficient HPA recovery. Findings highlight the role friendship dynamics may play in HPA-related risk for internalizing symptoms and point

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to expressed vulnerability in adolescent girls' close friendships as a potential consideration for interpersonally-centered therapeutic approaches.

Keywords

HPA axis; cortisol; peer relations; adolescence; stress

Adolescence is marked by a dramatic increase in the prevalence of internalizing symptoms among girls (Hankin & Abramson, 2001). This increase has been linked to the significant rise in interpersonal stress that occurs during the same developmental period (Rudolph & Hammen, 1999). Current etiological models for internalizing psychopathology highlight the role of biological vulnerability to stress, particularly in the context of interpersonal relationships (Beauchaine, Hinshaw, & Bridge, 2019). Consistent with prior work showing that peer relationships have considerable influence on psychological adjustment (Bukowski & Adams, 2005; Masten, 2005), an emerging line of research suggests that interactions with peers contribute to stress-sensitive biological functioning (Doom, Doyle, & Gunnar, 2017). Although adolescent girls are especially affected by peer experiences (Rose & Rudolph, 2006), few studies have illustrated how peer experiences manifest at the psychobiological level of analysis. The current study investigates interpersonal processes occurring in close friendships and their associations with adolescent girls' acute hypothalamic-pituitary-adrenal (HPA) axis responses to interpersonal stress.

Interpersonal Stress, the HPA Axis, and Risk for Internalizing Psychopathology

Adolescence is a unique period of biological vulnerability to interpersonal stress. During this period, youth are exposed to a host of novel interpersonal stressors (Spear, 2009). Simultaneously, major biological stress response systems, such as the HPA axis, undergo substantial changes due to pubertal maturation. This results in greater sensitivity to interpersonal stressors and more pronounced biological responses to these stressors, relative to that observed in childhood (Gunnar, Wewerka, Frenn, Long, & Griggs, 2009). This sensitivity to interpersonal stressors is particularly pronounced for girls (Oldehinkel & Bouma, 2011; Rudolph, 2002).

Interpersonal stressors have the potential to deleteriously impact adolescents' developing brain and bodies in ways that potentiate risk for internalizing psychopathology. When responding to interpersonal stressors, the HPA axis initiates a series of neuroendocrine processes that trigger the release of glucocorticoids (e.g., cortisol) by the adrenal glands (Kaltas & Chrousos, 2007), which prepare adolescents to enact a behavioral response to manage the stressor at hand (i.e., enact coping behaviors) via increases in glucose mobility (i.e., availability of energy), blood circulation (i.e., delivery of energy and oxygen), and enhanced cognition (Sapolsky, Romero, & Munck, 2000). When poorly managed, interpersonal stress exposure can contribute to two dysregulated patterns of adolescent HPA activation with demonstrated links to internalizing difficulties (e.g., depressive symptoms): *hyperreactivity* (Lopez-Duran, Kovacs, & George, 2009) and *protracted recovery* (Shull et al., 2016). Both of these patterns confer risk via cortisol overexposure, which has neurotoxic

effects on higher-order brain regions (e.g., ventromedial prefrontal cortex; Shansky & Lipps, 2013) and contributes to allostatic load-related processes in the body (e.g., heightened inflammation; McEwen, 2000). HPA dysregulation and related neurobiological impairment are thought to restrict children's capacity to enact behavioral responses for managing in vivo stressors (Juster, McEwen, & Lupien, 2009), thereby increasing risk of psychopathology (Cicchetti, Handley, & Rogosch, 2015). As such, identifying psychosocial factors that might exacerbate or mitigate against HPA dysregulation in the context of interpersonal stress is of great importance for understanding psychological risk and resilience.

Girls' Friendships: Risk Buffer or Potentiator?

Though adolescence is a period of increased exposure to peer-related stress, little empirical research has been dedicated to understanding close friendship dynamics that may either improve or impair girls' interpersonal stress-sensitive psychobiological rhythms (Gunnar, 2017). The lack of research in this area is surprising given that girls increasingly come to rely on their close friends to meet self-regulatory, affiliative, and identity development needs during adolescence (Rubin, Bukowski, & Parker, 2006; Spear, 2009). Indeed, most work examining connections between HPA functioning and interpersonal processes has considered peer relationships as a source of stress. Adolescents who have had negative peer experiences, such as peer victimization, show dysregulation in diurnal patterns of HPA activity and dysregulated HPA reactivity to acute social stressors (Calhoun et al., 2014; Ouellet-Morin et al., 2011a, 2011b).

Very little research has considered peer relationships (e.g., close friendships) as sources of support that may promote adaptive HPA stress response functioning (Doom et al., 2017; Hostinar & Gunnar, 2013). Evidence supporting the "tend-and-befriend" hypothesis has emphasized the importance of social connection during times of stress for girls, showing that stress-induced HPA activation triggers affiliation-oriented neurocircuitry (i.e., oxytocin systems), which is protective insofar as it increases social connectedness and support (Taylor, 2000). In this same vein, the "stress-buffering" perspective (Cohen & Wills, 1985) posits that girls' close friendships may promote resilience in the face of interpersonal stress by serving as a context (i.e., a "safe space") for managing stress and receiving support. In support of this perspective, youth with a close friend report less stress and fewer depressive symptoms than youth without a close friend (Nangle, Erdley, Newman, Mason, & Carpenter, 2003). With regards to HPA functioning, children with a friend present after a negative experience have lower cortisol levels than children who do not have a friend present (Adams, Santo, & Bukowski, 2011). In an experimental study, adolescents with higher quality friendships showed greater HPA regulation following an acute stressor, compared to adolescents with low quality friendships (Calhoun et al., 2014). Additional research is needed to clarify how specific, in vivo interactions between stressed adolescents and their close friends either facilitate or disrupt healthy stress response functioning.

Self-Disclosure and Friend Support

An ecologically valid and comprehensive illustration of interpersonal stress regulation dynamics must consider how stressed adolescents actually communicate with their close

friends after encountering a stressor. For instance, self-disclosures (e.g., voluntarily sharing thoughts, feelings, and behaviors) made to friends after encountering a stressor may stem in part from girls' emotional reactivity to the stressor, as well as a perceived need for external support to help manage such reactivity. Certain forms of self-disclosure, however, may impair stress management. In recent investigations, self-disclosure in dyadic relationships has been studied primarily in the context of processes such as conversational self-focus, reassurance-seeking, and co-rumination, all of which have been associated with internalizing symptoms and lower friendship quality (Prinstein, Borelli, Cheah, Simon, & Aikens, 2005; Schwartz-Mette & Rose, 2009; Stone, Hankin, Gibb, & Abela, 2011). At the same time, self-disclosure has the potential to facilitate stress management. Self-disclosure can increase closeness between friends and reduce overall stress (Buhrmester & Prager, 1995) by providing opportunity to engage in self-regulatory processes (e.g., cognitive restructuring, physiological stress management) that prevent stressful experiences from translating into internalizing symptoms (Connor-Smith & Compas, 2004). Taken altogether, self-disclosure has the potential to both impair and aid girls' capacity to manage interpersonal stress; however, research that more closely examines the nuanced nature of self-disclosures in close friendship is needed. Such nuance may be attained by examining connections between adolescent self-disclosure and HPA function.

The few studies that have examined related constructs (e.g., *rumination*; repetitive, unwanted, past-oriented thoughts about negative content) suggest that an excessive focus on personal problems could contribute to protracted HPA recovery following a stressor (Zoccola & Dickerson, 2012). Depressed adolescents high in trait rumination show protracted HPA recovery following socioevaluative stress (Stewart, Mazurka, Bond, Wynne-Edwards, & Harkness, 2013). To date, only one study has demonstrated a potential connection between a variant of self-disclosure specific to the dyadic friendship context and HPA functioning. In an adult sample, co-rumination during the discussion of a personal problem was associated with cortisol hyperresponsivity (Byrd-Craven, Granger, & Auer, 2011). Given that co-rumination is a dyadic manifestation of self-disclosure, it is possible that negatively-oriented self-disclosures and friends' responses to these disclosures could directly contribute to how quickly girls' HPA systems recover following an interpersonal stressor. Continued processing of negatively-oriented thoughts and emotions via disclosure (e.g., "I can't make friends with anyone. Nobody likes me.") could maintain elevated HPA reactivity after a difficult interpersonal encounter. Friend support, however, may facilitate quicker HPA recovery should it be effective in alleviating cognitive or biological factors perpetuating the stress response (e.g., providing reassurances of social worth; engaging in distracting activities/conversations). Naturally, there is reason to believe that both self-disclosure and friend support may make synergistic contributions to HPA recovery. That is, self-disclosure that is met with stress-alleviating friend support may facilitate HPA recovery. However, if paired with friend support that affirms negatively-oriented thoughts and emotions (e.g., "You're so dumb, I can't believe you did that"), self-disclosure could prolong HPA recovery. A careful examination of self-disclosure and friend support in the context of acute stress regulation is needed to understand how each may contribute individually or synergistically to HPA recovery.

To date, a construct has yet to be specified that fully captures self-disclosures specific to stress processing in a way that also allows for simultaneous examination of support offered by a friend. Such a construct could help clarify the nuanced nature of stress processing in friendships. Negative, self-directed thoughts and emotions shared by a stressed individual can provide a context for others to provide effective support (Cohen & Wills, 1985). Of course, self-disclosures such as these must be communicated with a modicum of vulnerability (i.e., willingness to openly disclose that one is in a compromised emotional state) to prompt friend support; otherwise, friends may assume that the stressed individual has already found a way to cope with the stressor. For example, a person is more likely to receive friend support if they were to disclose "it was awful, and I'm still having a hard time with it" than if they disclosed "it was awful, but whatever, I'm over it." Capturing the degree to which stressed individuals express vulnerability to a friend via sharing of negative, self-directed thoughts and emotions is essential for understanding the nature of friend support as well as concurrent changes in HPA stress regulation.

The Current Study: Aims and Hypotheses

In the current study, adolescent girls completed a modified version of the Trier Social Stress Test (TSST-M; for details, see Giletta et al., 2015)) and a subsequent brief discussion with a close friend. Salivary cortisol was collected at four time points over the course of the experiment. Here, we propose two friendship dynamics that may connect with girls' HPA stress responses: 1) a novel variant of self-disclosure referred to herein as "expressed vulnerability," and 2) "close friend support." Expressed vulnerability (EV) is defined as communicating (either in verbal content or affect) negative, self-directed thoughts and emotions in a way that increases risk of negative social evaluation and provides a context for others to provide social support. Note that expressed vulnerability is distinct from co-rumination, in that it is a specific form of self-disclosure carried out by an individual (vs. a dyadic interpersonal process). The construct also attempts to more directly assess thoughts and emotions that may connect with both internalizing symptoms and HPA response function. Close friend support (CFS) is defined as behaviors intended to decrease a stressed friends' self-defeating thoughts/emotions or to increase her positive self-perceptions/emotions. Coding the observed post-stressor friend dynamic into two separate behaviors, one that is carried out by the stressed adolescent (i.e., expressed vulnerability) and one that is carried out by the close friend (i.e., friend support), affords theoretically motivated examination of main and interactive friendship dynamic effects. Motivated by inconsistent findings for self-disclosure and deleterious effects of co-rumination following a stressor (Connor-Smith & Compas, 2004; Schwartz-Mette & Rose, 2009; Stone et al., 2011), we anticipated that the manner in which girls' EV contributes to their HPA recovery may depend on the level of CFS they receive.

Aim 1: Examine the associations of EV and CFS with girls' HPA reactivity patterns. **H₁:** Given that strong emotional reactivity to interpersonal stress may pull for self-disclosure and the provision of support from a close friend, we expected EV and CFS to be associated with more pronounced cortisol reactivity patterns. **Aim 2:** Examine the associations of EV and CFS with girls' HPA recovery patterns. **H₂ₐ:** We expected EV and CFS to be associated with more and less protracted cortisol recovery patterns, respectively. **H₂ᵦ:** We expected to find

a significant EV by CFS interaction, such that EV would be associated with greater cortisol recovery when CFS received was high and more protracted recovery when CFS received was low.

Method

Participants

Participants included 220 adolescent girls between 12 and 17 years old (M=14.7, SD=1.4). Oversampling techniques were used such that the sample included girls with varied levels of internalizing symptoms. Participants were recruited from local psychiatric inpatient and outpatient units as well as through community advertisements (i.e., flyers, emails, and radio/TV commercials). Girls were considered eligible for the study if, in the past two years, they a) had previously received a psychiatric diagnosis (e.g., major depression), b) had received treatment for mental health concerns, or c) met criteria for clinical levels of psychiatric symptoms. Exclusion criteria included active psychosis, intellectual disability, or any pervasive developmental disorder. Girls were required to have a close friend (same-gender, within 2 years of age) who could also take part in the study.

The racial and ethnic breakdown of the sample was 62.7% Caucasian, 24.5% African-American, 1.4% Hispanic or Latina-American, 0.9% Asian-American, and 10.0% reporting multiple-ethnic background or belonging to other ethnic groups. Caregiver educational history was reported as "some high school, but did not graduate" (7.8%), "high school graduate or GED" (29.1%), "AA/Trade degree" (1.6%), "some undergraduate college" (10.2%), "undergraduate degree/bachelor's" (18.9%), "some graduate school" (6.6%), "master's degree (MA) or law degree (JD)" (18.4%), and "doctorate degree (PhD or MD)" (7.4%).

Procedure

On the day of the study, girls attended the laboratory-based assessment with a caregiver and a close friend. Girls were instructed to refrain from taking medications on the day of the assessment to avoid potential effects on HPA functioning. Girls and caregivers independently completed questionnaires assessing girls' current medication usage and pubertal development. Girls also reported current symptoms and social functioning. Upon completing questionnaires, girls completed a modified version of the Trier Social Stress Test (TSST) and a subsequent discussion task with their close friend that took place immediately thereafter.

Trier Social Stressor Test (TSST).—Girls completed a developmentally adapted version of the Trier Social Stressor Test (TSST; for details, see Giletta et al., 2015). Girls were asked to prepare (1 min) and record (3 min) an audition speech with the goal of trying to convince an audience of their peers that they should be selected to star in a fictional television show about teens' ability to form and maintain friendships. While preparing and recording the speech, girls stood facing a camera and a closed-circuit television screen displaying their own live image. A male research assistant also sat in the room ostensibly to evaluate girls' performance.

Post-stressor discussion with a close friend.—Immediately following the TSST, girls participated in a discussion with their friend (4 min). Girls were instructed to discuss the TSST and their performance with their friend. Girls were provided questions to encourage discussion of self-evaluative thoughts and emotions ("How do you think you did on your speech," "What do you think your chances are for being selected for the reality show," "What were the best and worst parts of your speech," "How do you feel about yourself after giving your speech?"). Girls' close friends were given the instructions "Your friend has the instructions for this activity" to allow girls to share as much or as little as they wanted about the speech task without added pressure from the friend.

Measures

cute HPA functioning.—Baseline saliva samples were collected with oral swab (N=160) or via passive drool (N=56)[1]. All samples following the TSST were collected using oral swabs. Baseline samples (pre-TSST start + 0 min) were collected following a 20-minute relaxation period, during which girls watched a video intended to promote relaxation. Because cortisol reaches peak levels in saliva approximately 20 min after the onset of a stressor (Gunnar, Talge, & Herrera, 2009), a sample was collected 20 min after the conclusion of the TSST to index peak HPA reactivity in response to the TSST (post-TSST start + 25 min). Third and fourth samples were collected at 20 min intervals after the post-TSST discussion to index HPA recovery that may have been attributable to the post-TSST discussion (post-TSST start + 45 min, post-TSST start + 65 min). Samples were frozen for storage at −25°C and then shipped on dry ice to Pennsylvania State University's Behavioral Endocrinology Laboratory for assay (Salimetrics, PA). Samples were assayed for cortisol using a 510-k cleared high-sensitive enzyme immunoassay, which uses 25 µl of saliva (for singlet determinations), has a lower limit sensitivity of .007 µg/dl and a range of sensitivity from .007 to 1.2 µg/dl.

To correct for positive skew, log-transformation was applied to raw pre-TSST start + 0 min (M=0.13, SD=0.07), post-TSST start + 25 min (M=0.17, SD=0.10), post-TSST start + 45 min (M=0.15, SD=0.08), and post-TSST start + 65 min (M=0.13, SD=0.06) cortisol values prior to analyses. Outlier values were winsorized to 3 SD from the sample average value. Cortisol values were z-scored relative to baseline for all analyses.

Expressed vulnerability (EV).—Expressed vulnerability was defined as behaviors that communicated (either verbally or affectively) negative, self-directed thoughts and emotions in a way that both increased risk of negative social evaluations and provided a context for others to provide social support. Negative, self-directed thoughts included any self-deprecating remarks (e.g., "My speech was horrible," "I sounded so stupid"), whereas negative, self-directed emotions could include affective or verbal expressions of anxiety, fear, embarrassment, guilt, sadness, or self-directed anger. An expression of negative, self-directed thoughts and emotions did not count as expressed vulnerability if the adolescent immediately dismissed or nullified the expression (e.g., "My speech was horrible, but I don't care because I wouldn't want to be on the reality show anyway"). The coding

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[1]Raw cortisol values did not differ by sampling method (t(108)=0.71, p=.48).

scheme for expressed vulnerability used a 7-point rating scale, with lower ratings indicating few negative, self-directed thoughts or emotions and higher ratings indicating greater communication of negative, self-directed thoughts and emotions (1 = Teen did not express any negative self-evaluations or negative self-directed emotions, 7 = Teen expressed a high degree of negative, self-directed emotional state on multiple, independent occasions AND maintained a negative, self-directed emotional state or shared negative self-perceptions throughout the majority of the discussion).

Close friend support (CFS).—The friend support coding scheme incorporated elements (e.g., responsiveness) from the Peer Dyadic Mutuality Rating System (Piehler & Dishion, 2004) and novel elements to allow for a more comprehensive evaluation of friend support. Ratings of friend support were determined based on the frequency and intensity/salience of both supportive and non-supportive friend behaviors (i.e., the degree to which the behavior had the potential to negatively or positively influence girls' emotional state). A seven-point scale (1–7) was used to assess friend support. A "7" indicated friend behaviors that seemed intended to decrease the participant's self-defeating thoughts/emotions or to increase her positive self-perceptions (e.g., normalizing the experience, providing reassurance or discounting girls' self-critical negative remarks, positively reframing the experience, noting positive aspects of girls' performance, reaffirming their friendship). A rating of "1" indicated that the friend demonstrated primarily non-supportive behaviors such as: substantially and inappropriately re-directing the topic of the conversation (i.e., "hijacking" the conversation), showing affective responses that do not complement or reciprocate girls' affective expressions, active avoidance of engaging in a discussion with girls, or behaving in a way that clearly communicated criticism or a negative opinion (e.g., put-downs, teasing, providing elaboration/examples of girls' weaknesses or insufficiencies). A rating of "4" indicated equivocal or unclear support (e.g., primarily asked questions about stressor task but not about the girls' internal experience of the stressor task, responded with some reciprocal affect but did not offer supportive or non-supportive comments).

Inter-rater reliability.—Reliability for the two friendship coding schemes was established using ratings generated by the first author and a postdoctoral fellow. Coders were unaware of participants' scores on primary measures, and they independently coded 23% (*n*=60) of all videotaped and transcribed post-stressor discussion segments. Reliability estimates were computed using percent agreement and intraclass correlations. As in other observational work using 7-point scales (Piehler & Dishion, 2007), percent agreement was computed allowing for 1-point disagreements between coders' ratings. To account for chance agreement between raters, single measures intraclass correlations were calculated using a mixed effects model in which the coders were considered random effects and the codes were considered fixed effects (Shrout & Fleiss, 1979). Reliability estimates for EV and CFS were in the "excellent" range per established guidelines (Cicchetti & Sparrow, 1981), with 93 and 97 percent agreement and intraclass correlations of .84 and .90, respectively.

Covariates

Depressive symptoms were considered as a covariate, given their established connections with HPA functioning (Guerry & Hastings, 2011). Medication usage variables also were

created, given prior work indicating that corticosteroids, birth control, antidepressants, and anxiolytics may influence acute HPA stress responses (Bouma, Riese, Ormel, Verhulst, & Oldehinkel, 2009; Fries, Hellhammer, & Hellhammer, 2006; Hastings, Fortier, Utendale, Simard, & Robaey, 2009; Manthey et al., 2011). Lastly, a variable for cortisol timing (i.e., timing of cortisol collection in relation to beginning of diurnal cycle) was computed to adjust for the effects of diurnal cortisol cycles on acute HPA stress responses (Calhoun et al., 2012, 2014).

Depressive symptoms.—Girls reported depressive symptoms using the Mood and Feelings Questionnaire (MFQ; Costello & Angold, 1988). The MFQ was designed specifically for assessing depressive symptoms in youth ages 8 to 18 years. It has demonstrated good reliability and validity in clinical adolescent samples (Davis et al., 2006) and excellent convergent validity with diagnostic interviews for Major Depressive Disorder (Wood, Kroll, Moore, & Harrington, 1995). The MFQ demonstrated excellent internal consistency in the current sample (α=.94)

Medication usage.—Girls and caregivers reported all medications that girls currently or recently (i.e., in the past two weeks) used. Three dichotomous variables were created (1=use, 0=do not use) for medications with known links to HPA function, including birth control (N=37, 1 missing), corticosteroids (N=21), and antidepressants/anxiolytics (N=101).

Cortisol timing.—Baseline cortisol was collected for most adolescents (88.5%) between the hours of noon and 5:00 p.m. The cortisol timing variable was computed by subtracting the time an adolescent awoke from the time that the first cortisol sample was collected.

Data Preparation and Analytic Plan

Descriptive statistics, correlations, and t values (for medication variables) were computed for study variables. Depression, antidepressant/anxiolytic medication, birth control, corticosteroid, and cortisol timing variables were included as covariates in all analyses. A series of multilevel regression models with cortisol timepoints (i.e. +25, +45, + 65 min post-TSST start) nested within persons were used to assess friendship dynamic (EV, CFS) associations with cortisol reactivity (random intercept) and recovery (random slope). In the base model, correlates included baseline cortisol and covariates. In the second and third models, EV and CFS were each added, respectively. An EV by CFS interaction was included in the fourth and final model. Multilevel regression analyses were completed in R version 3.6.1 using the *lme4* package, with listwise deletion to handle missing data.

Results

Descriptive statistics and correlations among study variables are presented in Table 1. EV was positively correlated with cortisol at TSST start +25 min. CFS was not correlated with any study variable. All cortisol time points were strongly correlated. Independent samples t-test analyses were used to examine medication group differences on study variables. Girls taking antidepressant/anxiolytic medication had higher cortisol at baseline (t=−3.08, p<.01), +45 min (t=−2.04, p<.05), and +65 min (t=−2.35, p<.05), were older (t=−3.21, p<.01), and reported greater depressive symptoms (t=−3.82, p<.001). Girls taking birth control had

lower cortisol at +25 min (t=2.81, p<.01), expressed less vulnerability (t=2.04, p<.05), were older (t=−8.06, p<.001), and reported greater depressive symptoms (t=−3.07, p<.01). No corticosteroid usage group differences emerged.

Parameter estimates for our multilevel regression models examining cortisol reactivity and recovery patterns are displayed in Table 2. Effects of EV and CFS on cortisol reactivity and recovery patterns are depicted in Figure 1. Across models, baseline cortisol was associated with more pronounced cortisol reactivity and steeper cortisol recovery slopes.[2] Birth control was associated with less pronounced reactivity and less steep cortisol recovery slopes.

Aim 1. As expected (**H₁**), EV was positively associated with cortisol reactivity. CFS was also positively associated with cortisol reactivity. **Aim 2.** Contrary to expectation (**H₂ₐ**), EV was associated with less protracted (i.e., more efficient) cortisol recovery. Notably, this effect held when accounting for the level of CFS girls' received, which was unexpectedly not associated with girls' cortisol recovery efficiency. Also, contrary to expectation (**H₂ᵦ**), no significant EV by CFS interaction effects predicting cortisol recovery emerged.

Discussion

This study examined the connections of post-stressor dyadic friendship processes (expressed vulnerability, close friend support) with HPA stress responses to a laboratory-based interpersonal stressor in a sample of adolescent girls with varied levels of internalizing symptoms. Given that adolescents are more likely to discuss stressors with friends than parents (Furman & Buhrmester, 1992), findings from this study offer a rare glimpse into how girls may utilize friendships to help manage interpersonal stress in their daily lives. Findings from this study suggest that close friendships hold the potential to facilitate girls' management of acute biological responses to difficult interpersonal encounters, responses known to potentiate risk for the development of internalizing psychopathology (Lopez-Duran et al., 2009; Shull et al., 2016). By illustrating the benefits of specific close friendship dynamics for girls' HPA functioning, this study unpacks how friendships could positively impact adolescent girls' management of allostatic load (McEwen, 2002) and, consequently, their risk of future internalizing symptoms.

Adolescent girls who exhibited more exaggerated cortisol reactivity to interpersonal stress were more likely to express vulnerability to a close friend during an intimate discussion that followed. Poorly managed interpersonal stressors, particularly those that are beyond their sphere of influence, are known to exert deleterious impacts on adolescents' stress-sensitive biological systems (Gunnar et al., 2009). Difficulty managing interpersonal stressors may lead girls to call into question their ability to form and maintain friendships and doubt their overall likeability, which may be accompanied by dramatic HPA reactivity in the face of such stressors. Our findings suggest that this reactivity may, in turn, translate into a need to lean on close friends for external support and manifest behaviorally in self-disclosure to close friends about experienced negative self-directed thoughts and emotions. Although expressed vulnerability was not associated with greater close friend support, girls exhibiting

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[2]This effect fell short of significance in the base model (B=−.04, SE=.02, p=.08).

more dramatic HPA reactivity were more likely to receive support from their close friend during their discussions, suggesting that perhaps friends offered greater support to girls who appeared more visibly distressed (e.g., stress physiology–expression concordance; Lerner et al., 2007), regardless of the degree to which girls openly expressed vulnerability.

Girls who expressed greater vulnerability to their close friend during the post-stressor discussion also exhibited less protracted (i.e., more efficient) HPA recovery patterns, pointing to the benefits afforded to girls by this specific dynamic. Notably, this effect did not depend on close friend support. Our findings are unique from prior work that has demonstrated rumination and co-rumination effects on psychological maladjustment and protracted HPA recovery (Byrd-Craven et al., 2011; Schwartz-Mette & Rose, 2009; Stewart et al., 2013; Stone et al., 2011), those upon which our original hypotheses were formed. Our results suggest that while expressing vulnerability may provide a context for others to provide social support, the manner in which expressed vulnerability gets "underneath the skin" and downregulates girls' HPA hyperreactivity is independent of the amount of support given in the acute post-stressor context. Rather, our findings are consonant with the claim that expressing vulnerability with a close friend may provide girls' an opportunity to engage in intrapersonal (e.g., cognitive reframing) and unidirectional interpersonal (e.g., emotional expression) coping processes that may facilitate HPA recovery, thereby preventing potential increases in allostatic load and related risk for internalizing symptoms (Zimmer-Gembeck & Skinner, 2011). Although not examined in this study, it is also possible that discussing a stressor with a close friend facilitates regulation of affiliation-oriented neurobiological systems (i.e., oxytocin), which in turn attenuates HPA stress reactions (Taylor, 2000).

Findings emphasize the importance of considering the behaviors of both a stressed adolescent and her friend in determining how friendships can influence biological stress regulation. While support from a close friend appears to be responsive to stressed girls' biological reactions, it may not be as essential to helping girls recover from a stressor, at least not immediately following a stressor. Rather, it is possible that talking with a close friend serves the primary function of helping girls process negative thoughts and feelings. Moreover, the results also highlight the importance of considering HPA response phase specificity in better understanding how these dynamics confer or mitigate risk. There is debate about the utility of modeling the reactivity and recovery phases of the stress response separately (Ji, Negriff, Kim, & Susman, 2016). Here, we show that doing so provides more nuanced detail about how close friendship dynamics unfold at the biological level, with HPA reactivity to interpersonal stress connecting with greater expressed vulnerability and close friend support, and only expressed vulnerability contributing to HPA recovery.

Strengths and Implications

This study was among the first to consider the role of adolescent girls' close friendships in acute stress regulation. By using a sample of girls that were recruited from the community and via clinical-referrals, findings reflect associations that may be relevant for girls with a wide range of stress response patterns and varied levels of internalizing symptoms. Also, the incorporation of an experimental paradigm allowed for more objective evaluations of interpersonal and biological processes occurring after a stressor. The novel observational

coding system developed to examine interpersonal processes showed strong reliability and acceptable validity. Even more, the use of codes that independently considered adolescent and friend behaviors allowed for an in-depth look at friendship processes that could not be obtained with dyadic codes (i.e., codes that collectively consider the behaviors of both conversational partners, such as co-rumination). Codes used in this study revealed novel nuances about adolescent girls' friendship interactions, showing how post-stressor friendship behaviors can connect with HPA reactivity and regulation in meaningful ways.

Our findings also present clinical implications for interpersonal approaches to working with adolescent girls at risk for internalizing problems (Mufson et al., 1993). Such approaches often teach girls how to discriminate friendships that are harsh or critical from those that are supportive, the interpersonal skills needed to shape friendships for the better, as well as strategies to safely end harmful relationships and seek healthier ones. Our findings extend to this literature the consideration that close friendships, irrespective of level of supportiveness, may in and of themselves provide a context necessary for girls to sort through difficult thoughts and feelings that arise from day-to-day interpersonal stressors. Friendships that facilitate a higher level of expressed vulnerability may be important for fostering increased use and refinement of intrapersonal coping strategies that alleviate stress in the short-term. This parallels tenets of most empirically-supported therapeutic approaches for stress- and anxiety-based disorders, which center predominantly on helping individuals learn and practice coping skills that promote self-sufficiency.

Limitations and Future Directions

This study has limitations that point to future directions for research. First, although the use of standardized stressor (i.e., TSST) allows for more direct comparisons of biological processes across adolescent studies, it also limits the generalizability of findings. The TSST is a contrived scenario that may provoke different biological and interpersonal responses than social stressors adolescent girls more commonly encounter in their daily lives. Second, given the current study's focus on girls' dyadic friendships, findings cannot be generalized to boys. Similarly, this study did not consider differences based on gender identity, and as such, findings could only be interpreted based on assumptions of homogenous, cisgender identity within our female sample. Some evidence suggests that girls are more likely than boys to expect that problem-oriented self-disclosures within friendships will lead to feelings of being cared for or understood by a friend, whereas boys are more likely to expect that talking about problems will be a "waste of time" (Rose et al., 2012); these findings highlight differences that could be rooted in binary gender norms (e.g., culturally-informed notions of masculinity and femininity), biological sex (e.g., differences in activation of affiliative neurobiological systems), or both. Future work should clarify how friendship dynamics affect stress regulation differently based on youths' biological sex and gender identity. Third, additional biomarkers (e.g., salivary or serum oxytocin) are needed to clarify whether the connection between the observed friendship behaviors and HPA regulation is mediated or moderated by changes in neurobiological systems associated with affiliative behaviors, as the tend-and-befriend hypothesis suggests. Fourth, in addition to observed friendship behaviors, future work should consider preexisting indices of friendship quality as plausible moderators of HPA recovery. It is possible that preestablished friendship

schema contribute to perceptions of support in ways that were not captured in this study. For instance, participants with higher quality friendships may have experienced greater stress regulation simply from having their friend in the room (Calhoun et al., 2014) and/or been more receptive to support offered by the friend (Uno, Uchino, & Smith, 2002). Fifth, future work may consider how HPA attunement between girls and their close friends could help to explain connections between observed friendship behaviors and HPA regulation; research on this topic in adult samples suggests that physiological linkages in close relationships may confer both benefits and risk, depending on the nature of the relationship (Timmons, Margolin, & Saxbe, 2015). Lastly, while the study suggests that certain post-stressor friendship dynamics promote greater acute stress regulation than others, longitudinal work is needed to determine if the observed patterns influence the trajectory of internalizing symptoms over time. Further, conclusions based on our examination of friendship dynamics immediately following a stressor cannot be extended to more delayed stress processing in close friendships. The role of close friend support in HPA stress recovery may be different when a girl expresses vulnerability and actively seeks support days or weeks after experiencing a stressor; in situations such as these, when girls may have exhausted intrapersonal coping efforts, close friend support may be more relevant to stress management.

Summary

This study extends a burgeoning line of research examining the role of friendships in biological stress regulation. Findings were among the first to reveal post-stressor interpersonal processes that connect with HPA regulation for adolescent girls. Though more work is needed, our results offer critical information that shed light on how stress management within friendships may affect girls' HPA-related risk for internalizing psychopathology.

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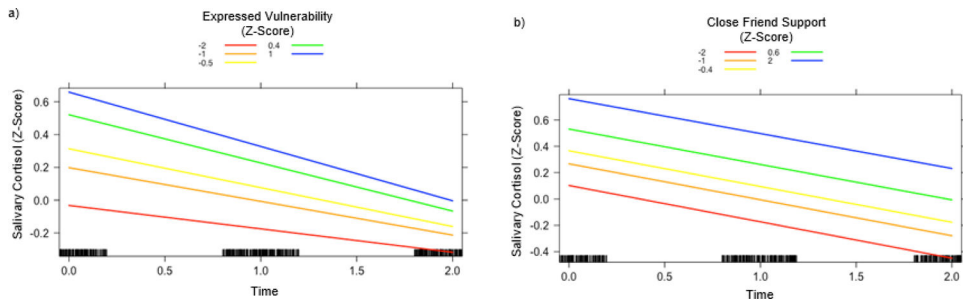
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Figure 1.
Plots showing the main effects of a) expressed vulnerability and b) close friend support predicting cortisol reactivity (intercept) and recovery (slope). Continuous variables are z-scored and depicted in standardized units. Cortisol +25 min after the start of the TSST is reflected at time 0.0. Cortisol at +45 min and +65 min after the start of the TSST is reflected at time 1.0 and 2.0, respectively.

Table 1

Descriptive statistics and correlations among primary study variables

Variable	M (SD)	% Missing (N)	1.	2.	3.	4.	5.	6.	7.
1. Cortisol +0 min s_TSST	−0.93 (0.20)	3.2% (7)	--						
2. Cortisol +25 min s_TSST	−0.84 (0.24)	5% (11)	.50***	--					
3. Cortisol +45 min s_TSST	−0.89 (0.22)	5% (11)	.50***	.90***	--				
4. Cortisol +65 min s_TSST	−0.94 (0.20)	4.5% (10)	.55***	.87***	.92***	--			
5. Expressed vulnerability	4.83 (1.70)	3.6% (8)	−.05	.18**	.13	.08	--		
6. Friend support	4.62 (1.49)	3.6% (8)	−.06	.08	.07	.11	−.02	--	
7. Depressive symptoms	0.52 (0.42)	0.5% (1)	.01	−.02	−.03	.01	.12	.04	--

Note. s_TSST = start of the Trier Social Stress Test. Cortisol values reported above after log-transformation and winsorizing.

*
$p < .05$

**
$p < .01$

***
$p < .001$

Table 2

Estimates of multilevel regression models predicting cortisol response

	Base	EV	CFS	EV x CFS
Intercept (Reactivity peak)				
Intercept	.70 (.25) **	.70 (.25) **	.65 (.25) *	
Baseline cortisol	.59 (.07) ***	.62 (.07) ***	.62 (.07) ***	
Birth control	−.66 (.20) ***	−.54 (.20) **	−.65 (.20) **	
Corticosteroid	.24 (.24)	.28 (.24)	.30 (.25)	
Cortisol timing	−.04 (.04)	−.03 (.04)	−.02 (.04)	
Depressive symptoms	.02 (.07)	−.01 (.07)	.01 (.07)	
Depression medication	.06 (.15)	.01 (.15)	.02 (.15)	
Expressed vulnerability (EV)		.22 (.07) **		
Close friendship support (CFS)			.14 (.07) *	
Time (Recovery slope)				
Intercept	−.33 (.07) ***	−.30 (.07) ***	−.30 (.07) ***	−.30 (.07) ***
Baseline cortisol	−.04 (.02)	−.05 (.02) *	−.05 (.02) *	−.05 (.02) **
Birth control	.22 (.06) ***	.15 (.05) **	.18 (.05) **	.16 (.05) **
Corticosteroid	−.01 (.07)	−.04 (.07)	−.06 (.07)	−.04 (.07)
Cortisol timing	.01 (.01)	−.01 (.01)	.01 (.01)	.01 (.01)
Depressive symptoms	−.01 (.02)	.01 (.02)	−.01 (.02)	.01 (.02)
Depression medication	.03 (.04)	.05 (.04)	.04 (.04)	.04 (.04)
Expressed vulnerability (EV)		−.06 (.02) ***		−.06 (.02) **
Close friendship support (CFS)			−.01 (.02)	.01 (.02)
EV x CFS				−.03 (.02)

Note. Cortisol timepoints nested within persons; Cortisol reactivity = random intercept; Cortisol recovery = random slope; all variables standardized prior to modeling.

*
$p < .05$

**
$p < .01$

***
$p < .001$