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Short Communication

Dispositional mindfulness predicts cortisol, cardiovascular, and psychological stress responses in adolescence

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ABSTRACT

Background: Past studies investigating the link between mindfulness and stress responding (i.e., emotional, psychological, and physiological responses to perceived threat or challenge) have focused on mindfulness training and on adult populations. In addition, research has not directly examined whether high mindfulness is particularly beneficial under conditions of high stress. To fill these gaps, the current study examined whether dispositional mindfulness predicts reduced cortisol, psychological, and cardiovascular stress responding in adolescence, and whether these effects are moderated by perceived life stress.

Methods: Adolescents (N = 150; 14–21yrs) completed measures of dispositional mindfulness, perceived life stress, emotional reactivity, and appraisals of the Trier Social Stress Test (TSST). Cortisol and blood pressure responses were measured.

Results: Higher dispositional mindfulness predicted reduced emotional and cardiovascular responding to the TSST, as well as less-negative task appraisals. In contrast, higher dispositional mindfulness predicted greater cortisol reactivity (or increases in cortisol in response to the TSST), particularly for adolescents experiencing lower perceived life stress.

Conclusion: These findings add to the body of literature indicating that greater mindfulness predicts improved stress responding, but do not suggest that mindfulness buffers the effects of high stress on adolescent stress responding.

1. Introduction

The mindfulness stress buffering account (Creswell and Lindsay, 2014) asserts that mindfulness improves health by buffering the effects of stress (i.e., improving stress resilience), and thus mindfulness is most beneficial for individuals under high stress. Tests of this hypothesis have examined whether mindfulness buffers responses to stressful experiences (i.e., reduces stress responding, or emotional, psychological, and physiological responses to perceived threat or challenge). These studies have focused on individual differences in stress responding following mindfulness training, and they indicate that those who experience mindfulness training display reduced psychological (Creswell et al., 2014) and cardiovascular (Nyklicek et al., 2013) responding relative to controls. The effects of mindfulness training specifically on cortisol reactivity (i.e., increases in cortisol production in response to stress) are mixed, as some research indicates that this training is not related to cortisol reactivity in adults (Rosenkranz et al., 2013), decreases cortisol reactivity in adolescence (Chadi et al., 2016) or actually increases adult cortisol reactivity (Creswell et al., 2014). Together, these studies suggest that mindfulness training may promote healthier stress responding. Fewer studies, however, have focused on the relationship between dispositional mindfulness – a trait-like pattern of present-focused and non-judgmental attention that predicts a variety of health outcomes (Creswell and Lindsay, 2014) – and stress responding, especially during adolescence.

In line with studies focusing on mindfulness training, the few studies documenting links between dispositional mindfulness and stress responding have found that greater dispositional mindfulness predicts diminished psychological (Arch and Craske, 2010; Brown et al., 2012; Weinstein et al., 2009) and cortisol (Brown et al., 2012) stress responding. However, there are several critical gaps in this literature. First, most of this research has focused on adults (although there is evidence for these links in a small sample of college students, Brown et al., 2012). Given the stability of health and well-being from adolescence to adulthood (Fergusson et al., 2005), and the importance of stress responding as a mechanism linking stressful experiences and

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health (Taylor et al., 1997), it is critical to investigate links of dispositional mindfulness earlier in adolescence with psychological, neuroendocrine, and cardiovascular responses to stress. Mindfulness is growing in popularity as an intervention strategy for use with adolescents (ages 10 to 25, Steinberg, 2015), however, there is evidence for developmental differences in how stressors, physiology, and health are related (Lucas-Thompson, 2012). Thus, this study seeks to investigate how dispositional mindfulness is associated with stress responding specifically in adolescence.

Research has also overlooked cardiovascular responding when investigating links among dispositional mindfulness and stress responding, and we address this limitation. There are often asymmetrical patterns of stress responding across stress response systems, particularly in the context of stressful life experiences (e.g., Gordis et al., 2008). Cortisol production and cardiovascular levels reflect functioning of two different arms of the human stress response (the hypothalamic-pituitary-adrenal axis and the autonomic system, respectively), systems that play distinct roles in the modulation of stress physiology (e.g., the ANS and cardiovascular functioning are "faster" responses relative to the HPA axis). Therefore, it is important to understand how dispositional mindfulness is related to both cortisol and cardiovascular reactivity. Finally, as noted, key to the mindfulness stress buffering hypothesis is the argument that mindfulness is particularly beneficial for individuals experiencing high life stress, but this tenet has not been tested in the context of dispositional mindfulness in adolescence. We examined the mindfulness stress buffering account by testing whether dispositional mindfulness buffers the effects of high life stress on reactivity.

2. Methods

2.1. Participants

Participants were 150 (59% female) adolescents, 14–21 years old (M_{age} = 17.86; SD = 2.14), who were recruited from a university (63.8%, n = 95) and the community (35.3%, n = 55), which was a predominately middle class and Caucasian area of northern Colorado, United States. Adolescents were mostly Caucasian (72%; 7% Hispanic, 3% Asian/Pacific-Islander, 2% African-American, 1% American-Indian; 16% other/multiple ethnicities, 1.3% unreported).

2.2. Procedure

Participants completed computerized questionnaires and the Trier Social Stress Task (TSST) (Kirschbaum et al., 1993) while physiological measurements were taken. After a 10-minute baseline (nature documentary), participants were told that they would give a 5-minute speech in front of an evaluator regarding their strengths and weaknesses, and that this speech would be recorded and evaluated by experts. Participants were given a 5-minute preparation period and then gave the speech in front of a neutral evaluator who gave no feedback. Participants then completed a 4-minute mental arithmetic task in front of the evaluator.

2.3. Measures

2.3.1. Mindfulness

Adolescents completed the 15-item Mindful Attention and Awareness Scale–Adolescent version (Brown et al., 2011) (Cronbach's α = .78).

2.3.2. Perceived stress

Adolescents reported the extent to which their life circumstances are appraised as stressful using the 14-item Perceived Stress Scale (Cohen et al., 1983) (Cronbach's α = .85).

2.3.3. Cortisol

Saliva samples were taken immediately before the TSST (immediately following the baseline period), and immediately as well as 15-minutes after the TSST. Saliva was collected using a 3-min sublingual placement of Salivettes® (Salimetrics, Carlsbad, CA). Saliva samples were stored at -20 degrees Celsius until all samples could be assayed. Samples were centrifuged at 2000 *g for 10 min*, and then assayed in duplicate for cortisol concentrations. The intra- and inter-assays coefficients of variation were 4–6.7% and 7.1–9%.

2.3.4. Blood pressure (BP)

A Dinamap Pro was used to measure systolic and diastolic BP every 3 min, and then average values were calculated for baseline and TSST periods.

2.3.5. Emotions

Immediately before and after the TSST, participants completed the Positive and Negative Affect Schedule (Laurent et al., 1999) which asks participants to rate the extent to which they feel different emotions. Average positive and negative emotions at each period were calculated.

2.3.6. TSST appraisals

Participants reported the extent to which they felt out of control, threatened, and stressed out during the TSST; answers were standardized and averaged to represent threat appraisals. Participants reported wanting to or actually giving up during the TSST; answers were averaged to represent 'giving up.'

3. Results

3.1. Mindfulness main effects

3.1.1. Cortisol

A latent growth curve (LGC) model with a linear slope to estimate cortisol reactivity fit well: χ^2 = 6.50, p = .26, CFI = .99, SRMR = .02. Adding dispositional mindfulness as a predictor to this LGC model (see Fig. 1), indicated that mindfulness was a significant predictor of increased cortisol reactivity (i.e., greater mindfulness was associated with greater increases in **log-t**ransformed salivary cortisol after the stressor). Examination of the raw cortisol reactivity levels based on low and high levels of dispositional mindfulness (based on a median split; see supplementary figure) indicated that adolescents with low levels of reactivity did not display increases in cortisol in response to the TSST, whereas adolescents with high levels did display increases in cortisol production.

3.1.2. BP

General estimating equations models were used to examine mindfulness as a predictor of BP change from baseline to reactivity. The dependent variable was BP across periods; 'period' (baseline, reactivity) was dummy-coded, and multiplicative interactions (controlling for lower-order terms) were tested. These analyses indicated that DBP (b = -0.02, SE = .01, p = .03) but not SBP (b = −.001, SE = .01, p = .88) reactivity was predicted by mindfulness: individuals with higher dispositional mindfulness displayed significantly lower DBP reactivity than individuals with lower mindfulness (see Fig. 2A).

3.1.3. Emotions

We examined whether mindfulness predicted post-TSST emotions, controlling for pre-TSST levels. Higher dispositional mindfulness predicted lower levels of negative (b = -.04, SE = .02, p = .03) but not positive (b = −.03, SE = .02, p = .06) emotions after the TSST.

3.1.4. Appraisals

We examined whether mindfulness predicted TSST appraisals. Higher dispositional mindfulness predicted significantly lower reports

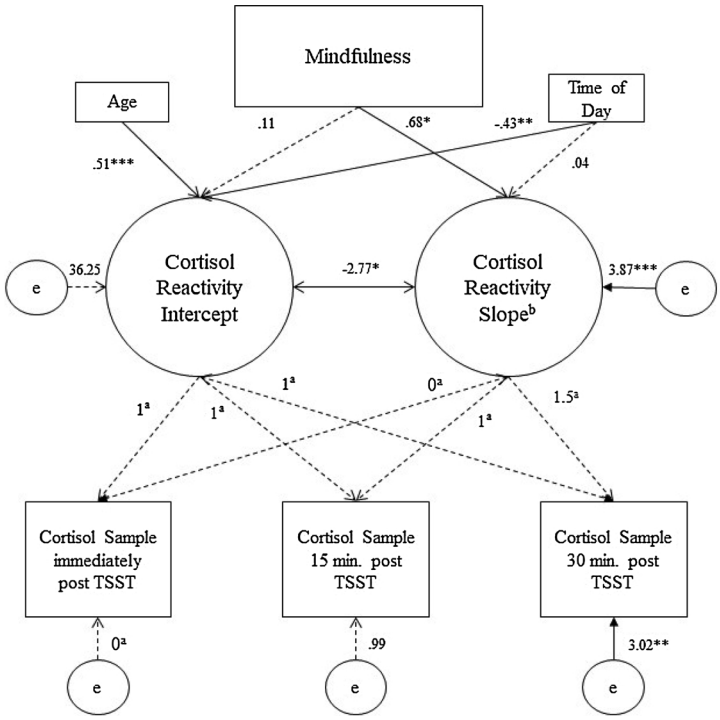

Fig. 1. Growth curve model demonstrating cortisol reactivity predicted by mindfulness. *$p <$ 0.05. ** $p < .01$.*** $p <$ 0.001. [a]Fixed effect estimate. [b]Cortisol reactivity was marginally significant, $M_{slope} = .32$, $SE = 1.21$, $p = .07$. Note: Unstandardized estimates for paths and coefficients for factor loadings and residual variances are unstandardized.Paths with solid arrows were significant, paths with dashed arrows were non-significant. Errors are specified with 'e's'.

of threat ($b = -.36$, $SE = .10$, $p < .001$) and giving up ($b = -.69$, $SE = .19$, $p < .001$).

3.2. Mindfulness as a moderator

Using the LGC cortisol model, there was a significant interaction between dispositional mindfulness and perceived life stress in relation to cortisol reactivity ($b = -.86$, $SE = .38$, $p = .02$): the highest levels of reactivity were evident for adolescents who reported lower life stress but greater dispositional mindfulness; all other adolescents displayed similar levels of reactivity (see Fig. 2B). Of note, there was a moderate sized negative and significant correlation between mindfulness and perceived stress ($r = -.39$, $p < .001$). There were; however, no other significant interactions between dispositional mindfulness and perceived life stress.

4. Discussion

Our goal was to examine links of dispositional mindfulness in adolescence with psychological, neuroendocrine, and cardiovascular responses to stress, and test whether mindfulness reduces the effects of high perceived life stress on stress responding. Results indicate that higher levels of dispositional mindfulness predicted less-negative appraisals of the TSST as well as attenuated negative emotional and cardiovascular responses to the stressor, but also greater cortisol reactivity (i.e., greater increases in cortisol production in response to the stressor),

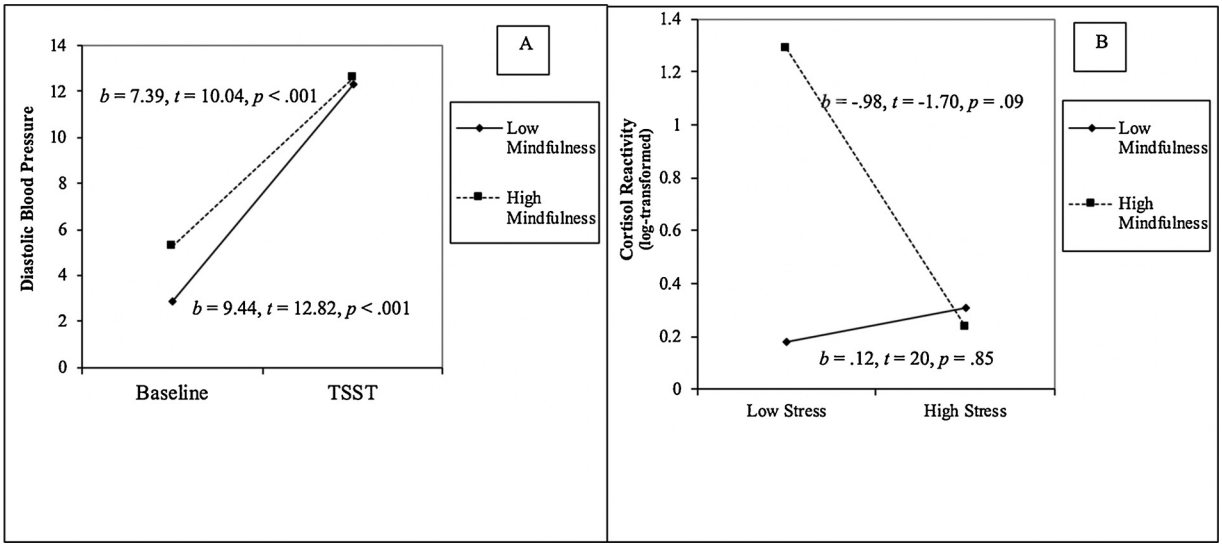

Fig. 2. (a) Associations between baseline and TSST and diastolic blood pressure are moderated by mindfulness, $b = -1.60$, $SE = .81$, $p = .048$. *bs*, *ts*, and *ps* represent the simple slope of the association between the variables on the X and Y axes for high and low levels of mindfulness (1 SD +/- the mean). (b) Associations between baseline and TSST and cortisol reactivity are moderated by mindfulness, $b = -.86$, $SE = .38$, $p = .02$. *bs*, *ts*, and *ps* represent the simple slope of the association between the variables on the X and Y axes for high and low levels of mindfulness (1 SD +/- the mean).

particularly for those experiencing low life stress. These results support the mindfulness stress buffering account (Creswell and Lindsay, 2014) that mindfulness may benefit health in adolescence through reduced emotional and cardiovascular reactivity to stress, as well as increases in positive appraisals of acute stressful experiences. However, results do not support the proposition that mindfulness is particularly beneficial for adolescents with high life stress.

Results that higher levels of dispositional mindfulness were related to greater cortisol reactivity are in keeping with past evidence that mindfulness training increases cortisol reactivity, particularly for those entering training with low dispositional mindfulness (Creswell et al., 2014). Although speculative, it may be that adolescents with greater dispositional mindfulness are more actively engaged in coping with the TSST. This speculation is based on several lines of evidence, taken together with our findings that mindfulness predicts attenuated emotional reactivity as well as less-negative TSST appraisals, and that adolescents with low levels of mindfulness appeared not to increase cortisol production in response to the stressor. Cortisol acts on neural networks involved in emotion regulation (Het and Wolf, 2007); thus, greater cortisol responses to stress may be indicative of greater coping, and have been associated with reduced psychological stress following a stressor (Het and Wolf, 2007; Oldehinkel et al., 2011). Similarly, greater cortisol reactivity during the TSST is associated with lower levels of negative mood and anxiety following the stressor, suggesting that greater cortisol reactivity may indicate the use of active coping methods (Schlotz et al., 2008). Indeed, greater emotion regulation predicts elevated cortisol reactivity (Lam et al., 2009). Therefore, links between greater mindfulness and higher levels of cortisol reactivity may be a result of greater engagement in processes such as active reappraisal.

In addition, comparing our findings to past research raises the possibility of developmental differences in the links between mindfulness and stress responding. Evidence in adults links higher dispositional mindfulness to attenuations in *both* psychological and cortisol responses to stress (Brown et al., 2012). This contrast between past research with adults and our study with adolescents is in keeping with previous work indicating that adolescence is a period during which dysregulation across stress response systems is likely to occur, especially in the face of chronic stress (e.g., Gordis et al., 2008; Lucas-Thompson, 2012). In addition, in line with evidence that there are age-related differences in coping among adolescents and adults (Leipold et al., 2019), it is possible that this reappraisal/coping process is more effortful in adolescence than in adulthood. As a result, reappraisal/coping may be more likely to elevate neuroendocrine production during a stressor for adolescents than adults. This argument is also consistent with positions that increased cortisol reactivity may be evident for individuals with low dispositional mindfulness who participate in mindfulness training because active coping efforts are initially very effortful, but that with longer periods of mindfulness training, active coping may become more automatic (Creswell et al., 2014). Cardiovascular functioning, as an indicator of the faster responding ANS, may be less strongly related to cognitive processes like reappraisal than is HPA axis modulation (Lucas-Thompson et al., 2018).

Our results also did not provide support for mindfulness as particularly beneficial for individuals experiencing high perceived life stress. Instead, only adolescents who had both low life stress and high dispositional mindfulness showed the greatest reactivity. This pattern of results suggests these adolescents may be most likely to be more engaged in processes like reappraisal and coping during the TSST, and as a result, show the greatest cortisol reactivity. Given developmental improvements in executive functioning and emotion regulation from adolescence to adulthood, it is possible that adolescents may struggle more than adults to effectively use mindfulness under conditions of high acute stress. It also may be that benefits of mindfulness under high-stress conditions are more likely to be evident in terms of physical health outcomes. Interestingly, the predicted difference in cortisol reactivity (of approximately 1.10 log-transformed nmol/l units, or 2.72 raw nmol/l units) is comparable in size to differences in reactivity based on depression, anxiety, and maltreatment (Fiksdal et al., 2019; Harkness et al., 2011), suggesting a clinically relevant difference in reactivity based on interactions between mindfulness and life stress.

A limitation of this study is our inability to examine how mindfulness predicts dynamic recovery from stress. Future research should examine mindfulness in relation to cortisol recovery, and also whether support for the mindfulness stress buffering account in adolescence is evident as a result of mindfulness training. As our study design was cross-sectional, precluding causal conclusions about directional pathways, future research should investigate these links longitudinally.

The results of this study provide the first evidence that mindfulness in adolescence may promote resilience to acute stress, but under conditions of low rather than high general life stress. These results are supportive of some but not all tenets of the mindfulness stress buffering account (Creswell and Lindsay, 2014) in adolescence, but suggest that mindfulness may benefit adolescent health, in part, because of improved resilience to acute stressful experiences.

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Declaration of Competing Interest

None.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.psyneuen.2019.104405.

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