J Behav Med (2015) 38:28–38
DOI 10.1007/s10865-014-9575-4

Trait mindfulness is associated with blood pressure and interleukin-6: exploring interactions among subscales of the Five Facet Mindfulness Questionnaire to better understand relationships between mindfulness and health

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Received: September 18, 2013 / Accepted: May 22, 2014 / Published online: June 3, 2014

Abstract Mindfulness based interventions have been associated with improvements in physical health; however, the mechanisms underlying these changes are unclear. The current study explored relationships between trait mindfulness, blood pressure (BP) and interleukin-6 (IL-6). Relationships between physical health variables and (1) a composite score of mindfulness, (2) individual facets of mindfulness and (3) interactions between theoretically relevant pairs of mindfulness subscales were investigated. One hundred and thirty healthy, young adults [M (SD) age = 21.7(2.7) years] reported trait levels of mindfulness (Five Facet Mindfulness Questionnaire, subscales include: *observing*, *describing*, *acting with awareness (AWA)*, *nonjudging* and *nonreactivity*), had their resting BP measured and underwent a blood draw to assesses circulating IL-6 levels. Age, gender, body mass index, race/ethnicity, depression and perceived stress were obtained and used as covariates. A composite score of trait mindfulness was associated with lower BP and a trend suggested that it was also associated with lower IL-6. Investigation of individual facets of mindfulness revealed interactions between the subscales *AWA* and *nonjudging*, such that higher endorsement of *AWA* was associated with lower BP only when *nonjudging* was also high. A second interaction was observed between the subscales *observing* and *nonreactivity*, such that higher endorsement of *observing* was associated with lower IL-6 only when levels of *nonreactivity* were also high. Trait mindfulness was associated with both BP and IL-6. Examining interactions between facets of mindfulness variables may be important in understanding how mindfulness based interventions influence physiology.

Keywords Mindfulness · Interleukin-6 · Blood pressure

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Introduction

A mounting body of literature points to the positive benefits of mindfulness based interventions in the promotion of subjective and objective measures of physical health (Baer, 2003; Brown et al., 2007; Epel et al., 2009). Training in mindfulness based interventions has been associated with increased antibody titer response to influenza vaccination (Davidson et al., 2003), buffering of CD4+ lymphocyte declines in HIV-1 infected individuals (Creswell et al., 2009), reduced interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) levels in response to an acute stressor (Pace et al., 2009, 2010) and blood pressure (BP) reductions in individuals with hypertension (Paul-Labrador et al., 2006; Schneider et al., 2005).

Despite research linking mindfulness training to changes in physiological variables, the mechanisms driving the relationship remain unclear. Theoretical models describing associations between meditation and health suggest that they occur through interactions between the development of trait mindfulness, decreases in negative psychological states and subsequent changes in physiology (Brown et al., 2012; Epel et al., 2009; Grossman et al., 2004; Jacobs et al., 2011).

The construct of trait mindfulness is conceptualized as a multifaceted, dispositional characteristic that exists within the general population and is not expected to fluctuate within person unless cultivated through training in meditation (Eisenlohr-Moul et al., 2012). Preliminary investigations of cross-sectional samples have linked trait mindfulness with measures related to the physiological stress response, suggesting that this is one potential pathway linking mindfulness based interventions and health. Brown et al. (2012) found that a unidimensional measure of trait mindfulness was associated with cortisol reactivity in response to a social stressor in a sample of undergraduate students, such that higher trait mindfulness was associated with a smaller cortisol response (Brown et al., 2012). Similarly, in a group of experienced meditators enrolled in a 3-month residential meditation retreat, trait mindfulness, defined as a composite score of three mindfulness subscales, was associated with lower evening cortisol levels (Jacobs et al., 2013).

Self-report assessments of mindfulness

Several self-report scales with good psychometric properties have been developed to measure trait mindfulness, each focusing on a slightly different aspect of the multifaceted construct. The Five Facet Mindfulness Questionnaire (FFMQ) is one of the most widely used self-report scales for assessing mindfulness. The FFMQ was created through factor analysis of five preexisting scales and is intended to measure unique aspects of trait mindfulness (Baer et al., 2006). Subscales on the FFMQ include: *observing*, noticing or attending to internal and external experiences such as sensations, cognitions, emotions, sights, sounds and smells; *describing*, labeling internal experiences with words; *acting with awareness (AWA)*, attending to one's activities of the moment; *nonjudging of inner experience*; taking a nonevaluative stance towards thoughts and feelings; and *nonreactivity to inner experience* or the tendency to allow thoughts and feelings to come and go (Baer et al., 2006, 2008).

In spite of evolution in the measurement of trait mindfulness, debate exists about the ability of self-report measures to accurately measure the complex and fluctuating aspects of mindful experience (Grossman, 2011). Interactions between increased attention to present moment experiences and the development of an open, nonreactive, nonjudging attitude are components of the larger construct of mindfulness; at the center of the assessment debate is contention about the ability of unidimensional scales to accurately capture the multidimensional and complex psychological shifts that can occur through meditation (Grossman, 2011). To address this criticism, Eisenlohr-Moul et al. (2012) have proposed examining interactions between unique facets of mindfulness. Specifically, they argue the importance of studying both a person's ability to pay attention to their primary experience (e.g., notice a strong emotion, pay attention to actions) and their secondary reaction (e.g., judge or react to what they have observed; Eisenlohr-Moul et al., 2012). Without the ability to notice present moment experiences in a nonjudgmental/nonreactive way, the authors argue that observation of present moment experiences may lead to distress and maladaptive coping (e.g., avoidance behaviours such as alcohol use). In support of this theory an interaction between the *observing* and *nonreactivity* subscales of the FFMQ has been shown to predict substance abuse in an undergraduate population (Eisenlohr-Moul et al., 2012). At high levels, *observing* was seen to be protective against substance abuse, but only when coupled with high levels of *nonreactivity*. Similarly, Peters et al. (2013) suggest that behavioural activities conducted with attention to the present moment are potentially only beneficial when coupled with a nonjudgmental stance towards what is encountered. In support of this hypothesis, they have reported an interaction between the *AWA* and *nonjudgment* subscales of the FFMQ in the prediction of symptoms associated with borderline personality disorder (e.g., rumination about anger) (Peters et al., 2013). Examination of interactions between various facets of mindfulness appears to be important in clarifying relationships between mindfulness and symptoms of mental health disorders and may also help to clarify relationships between mindfulness and physiological variables.

Objectives of the current study

In the current investigation, we examined cross-sectional associations between a multidimensional scale of mindfulness and two well established health predictors: the inflammatory marker IL-6 and resting BP. Even mild elevations in IL-6 have been shown to predict the development of illnesses such as diabetes and cardiovascular diseases (Harris et al., 1999; Pradhan et al., 2001; Ridker et al., 2000) and elevated BP is associated with increased risk for cardiovascular disease and stroke (Lewington et al., 2002; Stamler et al., 1993). Both IL-6 and BP have been shown to change during mindfulness based interventions; however mechanisms driving the changes are unknown (Pace et al., 2009, 2010; Paul-Labrador et al., 2006; Schneider et al., 2005).

Methods

Participants

Participants were recruited from the University of California, San Diego, via advertisements. Data was collected at the baseline visit as part of a larger study investigating an exercise intervention on vaccination efficacy (Edwards et al., 2012). To qualify for the study, participants had to be English-speaking and over the age of 18. Exclusion criteria included regular smoking (reported current smoking <1 occasion/month), a history of immune or cardiovascular disease, suffering from an acute infection or illness, pregnancy, current psychiatric treatment or diagnosis or history of psychosis, current use of medication (except for birth control). The project was approved by the Institutional Review Board of the University of California, San Diego and all participants provided written informed consent before entering the study.

Procedure

All data were collected between January and June 2010. Participants presented to the laboratory between 12 p.m. and 4 p.m. All participants were instructed to abstain from vigorous exercise for 24 h, alcohol for at least 12 h, caffeine for at least 2 h, and food for at least 1 h prior to testing. Following informed consent, they sat resting for approximately 20 min and completed questionnaires. Participants then met with a study nurse who assessed BP and drew a blood sample from an antecubital vein.

Blood pressure

BP was obtained with a Dinamap 1846 × monitor (Critikon; Tampa, FL) at one time point while participants underwent initial medical screening. When BP measurement is taken only one time, then irrespective of age, the mid BP, average of systolic BP (SBP) and diastolic BP (DBP) has been shown to be more predictive of cardiovascular risk than either SBP or DBP alone, or mean arterial pressure (MAP; Lewington et al., 2002). Thus mid BP (1/2DBP + 1/2SBP) was calculated as a dependent variable in this study.

Blood sampling and assay

Blood was collected into a tube containing ethylenediaminetetraacetic acid (EDTA K3E Becton–Dickinson, UK), stored on ice until centrifuged (3,000 rpm at −7 °C for 10 min) and the plasma was aliquotted and stored at −80 °C until analysis. IL-6 was determined by commercial ELISA (Quantikine, R&D Systems, Minneapolis, MN). Sensitivity was <.8 pg/ml; intraassay and interassay coefficients of variation were <5 %. Due to the skewed distribution of IL-6, analyses were performed using $\log_{10}$ transformed values.

Questionnaires

The Five Facet Mindfulness Questionnaire (FFMQ)

Participants completed the 39-item FFMQ, which assesses five distinct aspects of mindfulness (Baer et al., 2006). The five subscales of the FFMQ (followed by α coefficients from our sample) include: *observing* (α = .90), *describing* (α = .90), *acting with awareness* (α = .84), *nonjudging of inner experience* (α = .89) and *nonreactivity to inner experience* (α = .77; Baer et al., 2006, 2008). Participants rated the degree to which each item applied to them using a 5-point Likert-type scale (1 = never or very rarely true, 5 = almost always or always true). The FFMQ has demonstrated good internal consistency in samples of undergraduate students, with α coefficients ranging from .75 to .91 in the original sample, and it demonstrated similar consistency in our sample (Baer et al., 2006). Construct validity has been demonstrated by the FFMQ's ability to discriminate between meditation naïve and experienced mediators (Baer et al., 2008). The FFMQ has demonstrated sensitivity to change, increasing as individuals learn and practice mindfulness (Carmody & Baer, 2008; Carmody et al., 2009).

With the exception of the *observing* subscale, FFMQ subscale scores correlate in the expected directions with variables assessing psychological symptoms, well-being, experiential avoidance and thought suppression (Baer et al., 2006, 2008; Carmody & Baer, 2008). The *observing* subscale has demonstrated unexpected associations with psychological variables in meditation naïve participants; for example, higher *observing* scores are associated in the expected direction with openness, emotional intelligence and self-compassion, but are also positively correlated with dissociation, absent-mindedness, and thought suppression (Baer et al., 2006). After instruction in meditation, scores on the *observing* subscale have been shown to correlate with psychological variables in the expected direction (Baer et al., 2006).

Perceived Stress Scale (PSS)

Participants completed the 10-item PSS, which was used to assess psychological stress over the previous month (α = .73) (Cohen et al., 1983).

Center for Epidemiological Studies-Depression Scale (CESD)

The 20-item CESD was used to assess depressive symptoms over the previous month ($\alpha = .89$; Radloff, 1977). Due to the skewed distribution of CESD scores, analyses were performed using $\log_{10}$ transformed values.

Physiological covariates

Racial/ethnic group membership, gender and age were collected through self-report. BMI was computed as the ratio of body weight in kilograms divided by square height in meters (kg/m^2), with weight and height measurements (to the nearest .1 kg and .1 cm) taken on a calibrated scale.

Statistical analyses

Relationships between mindfulness, demographic and psychological covariates were explored using correlational analyses. Ethnicity was dichotomously coded as Asian = 1 versus "other" = 0 for the purposes of the analyses. Gender was coded as female = 0 and male = 1. Hierarchical regression analysis was used to investigate relationships between mindfulness, BP and IL-6. Considering available statistical power, in Step 1 of all analyses, we included between person covariates that are of theoretical importance in a study of BP and inflammation, including: age, BMI, gender, and race.

To make our findings more comparable to the existing literature, we examined our data in multiple ways. First, relationships between a composite score of trait mindfulness, BP and IL-6 were investigated. The trait mindfulness composite score was created by taking the average all 39-items from the FFMQ—from here on referred to as FFMQ mean—and was added on Step 2 of the regression. In line with a suggestion from the developers of the FFMQ we next examined individual facets of mindfulness and their relationship with outcomes (Baer et al., 2006). This second analysis was conducted by adding each of the five FFMQ variables (*observing*, *describing*, *acting with awareness*, *nonreactivity* and *nonjudging*) simultaneously on Step 2 of the regression. Finally, we investigated potential interactions between the *observing* and *nonreactivity subscales* and *AWA* and *nonjudging subscales* (Eisenlohr-Moul et al., 2012; Peters et al., 2013). We included the five FFMQ variables on Step 2 of the regression and on Step 3 we added the products of *observing* with *nonreactivity* and *AWA* with *nonjudging*. All continuous predictors were mean-centered prior to entry into the regression model.

Next, covariates that were not investigated in the primary analysis were considered in exploratory analyses, these included the PSS and CESD. We also explored interactions between ethnicity and FFMQ subscale scores in the prediction of our outcome variables.

Results

Demographic characteristics

Characteristics of the sample are presented in Table 1. The final sample consisted of 130 young men and women. The majority of participants (49.2 %) endorsed being of Asian ethnicity, 35.2 % endorsed being Caucasian, the remaining participants identified as Latino, African American, Native Hawaiian or other Pacific Islander, or multiracial. Approximately 20 % of the sample had a CESD score above 16, indicating that they were experiencing symptoms of depression (Radloff, 1977). The mean of the PSS score in our sample was 13.7, slightly lower than age matched subjects from the eNation Survey (Cohen & Janicki-Deverts, 2012).

Table 2 shows simple correlations among study variables. Of note, IL-6 was negatively associated with the *observing* subscale, such that higher endorsement of observation of present moment experiences was associated with lower levels of IL-6. No other facets of mindfulness, or the FFMQ mean were significantly associated with mean BP or IL-6. With the exception of the *observing* subscale, mindfulness subscales and the FFMQ mean were significantly positively associated with each other and negatively with depression and perceived stress. Individuals classified as "Asian" had lower FFMQ Mean scores and lower *AWA* scores than those in the "other" category.

Trait mindfulness, BP and IL-6[1]

Hierarchical regression equations were constructed in which mean BP and IL-6 values were predicted from age, BMI, sex, and ethnicity, followed on the next step by the FFMQ Mean. There was a significant inverse relationship between the FFMQ Mean ($\beta = -4.25$, SE = 2.11, $t = -2.02$, $p = .05$, $\Delta R^2 = .02$) and mean BP such that higher FFMQ mean scores were associated with lower mean BP. There was also a trend suggesting that higher FFMQ mean scores were associated with lower IL-6 values, ($\beta = -.15$, SE = .08, $t = -1.84$, $p = .07$, $\Delta R^2 = .03$).

Facets of mindfulness, BP and IL-6

Next, hierarchical regression equations were constructed in which mean BP and IL-6 values were predicted from age,

[1] Tests for multicollinearity indicated that a very low level of multicollinearity was present (*VIF* < 1.1 for all predictors across analyses).

Table 1 Sample characteristics

	M ± SD (56 % women)
Age (years)	21.7 ± 2.7
BMI (kg/m^2)	23.7 ± 3.86
Mean Mid-BP (mmHg)	84.7 ± 9.98
IL-6 (pg/ml)[a]	0.84 ± 1.13
Five Facets of Mindfulness Subscales	
Mean FFMQ	3.42 ± .40
Observing	3.39 ± .69
Describing	3.53 ± .70
Act with Awareness	3.44 ± .60
Nonjudgment	3.54 ± .73
Nonreactivity	3.24 ± .57
Perceived Stress Scale	13.7 ± 5.7
Center for Epidemiological Studies Depression Scale[a]	11.2 ± 7.7

BMI body mass index, *BP* blood pressure, *IL-6* interleukin-6, *FFMQ* Five Facet Mindfulness Questionnaire

[a] Untransformed value

BMI, sex, and ethnicity followed on the next step by the five FFMQ subscales. In the second analysis, there was a trend linking addition of the five FFMQ subscales and mean BP, ($\Delta R^2 = .06$, $\Delta F(9, 117) = 2.03$, $p = .08$). As shown in Table 3, there were no significant relationships between any individual FFMQ subscales and mean BP, although the subscale *AWA* approached significance ($p = .07$). Addition of the five FFMQ subscales was associated with a significant change in the model predicting IL-6 ($\Delta R^2 = .11$, $\Delta F(9, 120) = 3.20$, $p = .01$). As shown in Table 4, when the five FFMQ subscales were entered into a regression simultaneously the *observing* subscale was significantly associated with IL-6 ($p < .001$).

Interactions between the subscales observing and nonreactivity, and AWA and nonjudging, BP and IL-6

Finally, we explored potential interactions between theoretically paired FFMQ subscales. Interaction terms between the *observing* and *nonreactivity* subscales and *AWA* and *nonjudgment* subscales were added onto Step 3. As seen in Table 3, after controlling for covariates, *observing* and *nonreactivity* subscales did not interact in the prediction of mean BP ($p > .80$). However, there was a significant interaction between the *AWA* and *nonjudgment* subscales ($\beta = -3.36$, SE = 1.69, $t = -1.98$, $p = .05$, $\Delta R^2 = .02$). Low and high levels of both AWA and nonjudgment were quantified as 1 SD above and below each mean, and simple slopes were graphed at 1 SD from the mean of BP (see Fig. 1).

To gain a better understanding of the interaction, we conducted simple slopes analyses using the software Interaction! 1.7.2211 by Soper (2013). The simple slopes test revealed that among people who were 1 SD above the mean on the *nonjudgment* subscale, there was a significant relationship between *AWA* and BP ($\beta = -4.74$, SE = 1.38, $t = -3.43$, $p < .0001$), such that as *AWA*

Table 2 Correlations of study variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Observing	–	.16†	.04	−.15†	.11	.41**	−.29**	−.11	−.04	.01	−.09	.01	−.04	.05
2. Describing		–	.19*	.26**	.30**	.67**	−.17†	−.10	.17†	−.08	−.13	.08	−.38**	−.36**
3. AWA			–	.43**	.14	.62**	−.02	−.05	.13	−.08	−.24**	.08	−.41**	−.35**
4. Nonjudgment				–	.10	.58**	−.06	−.06	.19*	−.07	−.14	−.13	−.44**	−.35**
5. Nonreactivity					–	.53**	.04	.05	.13	−.05	.15†	.21*	−.31**	−.32**
6. FFMQ Total						–	−.15†	−.12	.19*	−.07	−.27*	−.03	−.53**	−.50**
7. IL-6†							–	.10	−.004	.17†	−.09	−.01	−.08	.03
8. Mean BP								–	.03	.45**	−.12	.50**	−.12	−.08
9. Age									–	.06	−.31*	−.08	−.32**	.01
10. BMI										–	−.12	−.07	−.04	−.005
11. Race											–	−.07	.21*	.23*
12. Gender												–	−.03	−.067
13. CESD†													–	.70**
14. PSS														–

AWA act with awareness, *FFMQ* Five Facet Mindfulness Questionnaire, *IL-6* interleukin-6, *BP* blood pressure, *BMI* body mass index, *CESD* Center for Epidemiologic Studies-Depression Scale, *PSS* Perceived Stress Scale

* $p < .05$; ** $p < .01$; † $p < .10$ (two-tailed)

† Transformed value

Table 3 Hierarchical regression of facets of mindfulness predicting blood pressure

Step	Predictor	*B*	SE	*t*	*p*	R^2	ΔR^2
1	Age	.15	.31	.50	.62	.31	
	BMI	.80	.21	3.86	<.001		
	Gender	7.28	1.60	4.56	<.001		
	Race	−1.41	1.58	−.89	.38		
2	Age	.15	.31	.48	.63	.37	.06
	BMI	.74	.21	3.61	<.001		
	Gender	7.98	1.65	4.83	<.001		
	Race	−2.22	1.60	−1.39	.17		
	Observing	−1.55	1.11	−1.40	.16		
	Describing	−1.78	1.17	−1.53	.13		
	AWA	−2.49	1.37	−1.82	.07		
	Nonjudgment	1.40	1.22	1.15	.25		
	Nonreactivity	.38	1.40	.27	.79		
3	Age	.22	.306	.72	.47	.39	.02
	BMI	.75	.208	3.58	<.001		
	Gender	7.74	1.66	4.67	<.001		
	Race	−2.10	1.61	−1.30	.20		
	Observing	−1.63	1.10	−1.48	.14		
	Describing	−1.95	1.17	−1.66	.10		
	AWA	−2.37	1.36	−1.74	.09		
	Nonjudgment	.83	1.24	.67	.51		
	Nonreactivity	.45	1.39	.32	.75		
	AWA × nonjudgment	−3.36	1.69	−1.98	.05		
	Observing × nonreactivity	−.35	1.62	−.21	.83		

SE standard error, *BMI* body mass index, *AWA* acting with awareness

increased, BP decreased. However, when participants were 1 SD below the mean on *nonjudgment*, there was no relationship between *AWA* and BP (β = −.004, SE = 1.38, $t = -.003$, $p = .99$).

As seen in Table 4, after controlling for covariates, *AWA* and *nonjudgment* subscales did not interact in the prediction of IL-6 ($p > .40$); however, there was a significant interaction between the *observing* and *nonreactivity* subscales (β = −.13, SE = .06, $t = -2.04$, $p < .05$, $\Delta R^2 = .03$). Low and high levels of both *observing* and *nonreactivity* were quantified as 1 SD above and below each mean, and simple slopes were graphed at 1 SD from the mean of IL-6 (see Fig. 2).

Simple slopes analyses showed that among people who were 1 SD above the mean on the *nonreactivity* subscale, there was a significant relationship between *observing* and IL-6 (β = −.23, SE = .04, $t = -5.35$, $p < .0001$). When participants were 1 SD below the mean on *nonreactivity*, the relationship between *observing* and IL-6 was attenuated, but remained significant (β = −.08, SE = .04, $t = -2.07$, $p = .04$). At 2 SD below the mean on *nonreactivity*, *observing* was no longer associated with IL-6 (β = −.02, SE = .04, $t = -.35$, $p = .72$).

Exploratory analyses

In order to better understand the relationship between trait mindfulness, IL-6 and BP, we also controlled for depression and perceived stress, which have been linked with IL-6 and BP (Howren et al., 2009; Kiecolt-Glaser et al., 2003; Matthews et al., 2004). A set of hierarchical regression analyses were conducted (analyses not shown) in which the final models for IL-6 and BP were altered to include the original set of covariates (age, race, gender, BMI) plus one of the potential covariates. The addition of each of these, covariates had virtually no impact on the interactions between *AWA* and *nonjudging* in the prediction of BP or *observing* and *nonreactivity* in the prediction of IL-6 (*p*'s = ns).

Acknowledging that our sample was primarily composed of students identifying as "Asian" we also investigated if there were interactions between race and mindfulness in the prediction of our outcome variables. Using hierarchical regression analysis, we investigated (1) if there were significant interactions between race and individual mindfulness subscales and (2) three way interactions between race and the significant interactions

Table 4 Hierarchical regression of facets of mindfulness predicting IL-6

Step	Predictor	*B*	SE	*t*	*p*	R^2	ΔR^2
1	Age	−.01	.01	−.66	.51	.05	
	BMI	.02	.01	2.11	.04		
	Gender	−.07	.06	−1.09	.28		
	Race	−.08	.06	−1.22	.22		
2	Age	−.01	.01	−.85	.40	.16	.11
	BMI	.02	.09	2.26	.03		
	Gender	−.10	.06	−1.51	.13		
	Race	−.09	.06	−1.49	.14		
	Observing	−.15	.04	−3.60	<.001		
	Describing	−.04	.04	−.86	.39		
	AWA	.03	.05	.58	.56		
	Nonjudgment	−.05	.05	−1.08	.28		
	Nonreactivity	.07	.05	1.24	.22		
3	Age	−.01	.01	−.99	.33	.19	.03
	BMI	.02	.09	2.66	.01		
	Gender	−.11	.06	−1.77	.08		
	Race	−.07	.06	−1.07	.29		
	Observing	−.16	.04	−3.77	<.001		
	Describe	−.02	.04	−.48	.64		
	AWA	.04	.05	.77	.45		
	Nonjudgment	−.05	.05	−.97	.33		
	Nonreactivity	.06	.05	1.18	.24		
	AWA × nonjudgment	.05	.07	.71	.48		
	Observing × nonreactivity	−.13	.06	−2.04	.04		

SE standard error, *BMI* body mass index, *AWA* acting with awareness

reported above in the prediction of mean BP and IL-6. We included the original set of covariates in the model as well as FFMQ subscale scale scores and interaction terms. Our results showed no significant interactions between ethnicity and FFMQ subscales and mean BP or IL-6 (p's = ns).

Discussion

A growing body of evidence points to the beneficial effects of mindfulness practice in the promotion of subjective and objective measures of physical health (Baer, 2003; Brown et al., 2007; Epel et al., 2009). In the present study, relationships between trait mindfulness, and two clinically relevant physiological variables were investigated. A composite score of trait mindfulness was associated with BP, such that higher trait mindfulness was associated with lower BP. There was also an indication that higher trait mindfulness was associated with lower levels of IL-6. Investigation into interactions between mindfulness subscales revealed two significant results. First, *AWA* interacted with *nonjudgment* in the prediction of BP. At high levels of *nonjudgment*, *AWA* was associated with significantly lower levels of BP; however, at low levels of *nonjudgment*, there was no association between *AWA* and BP. Second, *observing* and *nonreactivity* subscales interacted in the prediction of IL-6. Results suggested that participants who endorsed higher levels of *observing* had lower levels of IL-6, but only if they also endorsed high levels of *nonreactivity*.

Measurement tools differ on the emphasis placed on specific aspects of mindfulness. Assessment scales range from one-factor models developed to assess attention and awareness in daily life to multi-factor models thought to encompass unique, but related aspects of mindfulness (Baer et al., 2004, 2008; Brown & Ryan, 2003; Brown et al., 2007; Jacobs et al., 2011). Findings from our study revealed an interesting association between a composite score of mindfulness, BP and IL-6; however, investigation into specific facets of mindfulness and interactions between theoretically relevant pairs revealed a more nuanced picture. Examining interactions between facets of mindfulness aligns with more traditional perspectives in Buddhism and theory underlying contemporary psychotherapy models (Strosahl et al., 2012; Weissman & Weissman, 1999).

The *observe* subscale of the FFMQ assesses the act of noticing, or paying attention to internal (e.g., bodily sensations) and external (e.g., smell) stimuli. In populations of

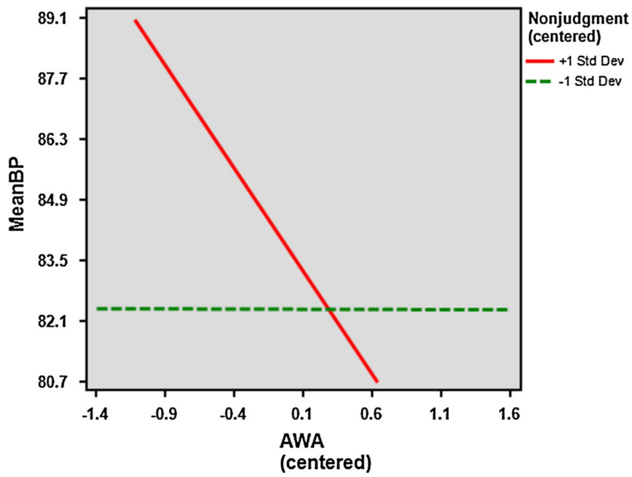

Fig. 1 Mean BP and interaction between the acting with awareness and nonjudgment subscales from the FFMQ

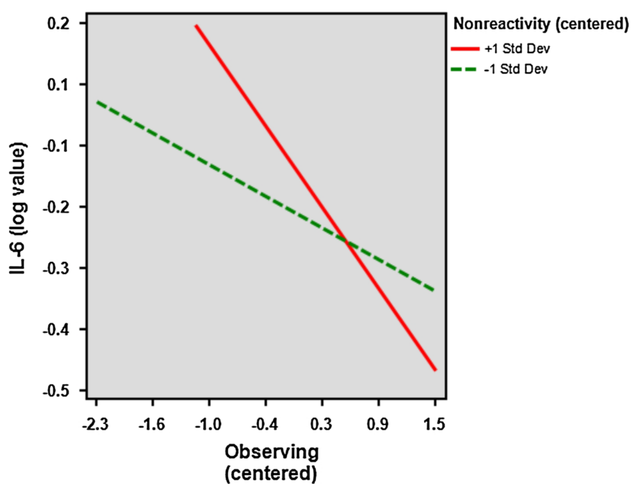

Fig. 2 IL-6 and interaction between the observing and nonreactivity subscales from the FFMQ

experienced meditators, all five facets of mindfulness from the FFMQ are highly correlated; however, in meditation-naïve samples, the *observing* subscale has not correlated with other facets of mindfulness, a finding replicated in our study. Without training in mindfulness meditation, observation of present moment experiences may be biased or reactive and higher levels of observation of the present moment may only confer benefit when paired with an accepting or nonreactive lens (Eisenlohr-Moul et al., 2012). The *nonreactivity* subscale of the FFMQ appears to capture nonreacitvity to inner experiences (e.g., feelings, thoughts) and is strongly correlated with self-compassion (Baer et al., 2006).

AWA was associated with lower BP, only when coupled with high levels of *nonjudgment*. At low levels, the *AWA* subscale of the FFMQ captures the experience of acting on autopilot or dissociation; at high levels it measures the tendency to engage in conscious and deliberate action. When coupled with higher levels of nonjudgment, increased awareness of actions if theorized to decrease reactivity to emotional distress (Peters et al., 2013). Conceptually, this is the difference between critiquing and judging one's experiences versus accepting and remaining open to them. The nonjudgment subscale has a strong, negative correlation with neuroticism and thought suppression (Baer et al., 2006). Findings from our sample lend support to the hypothesis that higher levels of observation and/or awareness of the present moment may have a salubrious relationship with physiological outcomes only when paired with a nonreactive and/or nonjudgmental attitude.

Mechanisms linking mindfulness and health

Potentially, increases in levels of trait mindfulness impact BP and inflammation by reducing physiological responsivity to stressors. In support of this hypothesis, trait mindfulness has been associated with lower activation of the amygdala in response to social threat (Creswell et al., 2007). Further, two studies have now linked trait mindfulness to the stress hormone cortisol. Brown et al. (2012) reported that cortisol responses, after exposure to a social evaluative threat paradigm, were moderated by levels of dispositional mindfulness as assessed by a unidimensional scale that is highly correlated with the *AWA* subscale from the FFMQ. Similarly, Jacobs et al. (2013) reported that mindfulness (defined as the summary of three subscales from the FFMQ, *observing*, *nonreactivity* and *AWA*) was associated with baseline levels of evening cortisol among attendees of a 3-month meditation retreat; changes in mindfulness over the course of the retreat were also associated with changes in cortisol (Eisenlohr-Moul et al., 2012). Further investigation of potential interactions between facets of mindfulness may help us to better understand how training in meditation works to modulate the stress response.

Interestingly, different facets of mindfulness interacted in the prediction of BP and IL-6. While BP and IL-6 are both influenced by sympathetic and parasympathetic input, BP is more dynamically regulated in the short term. Potentially, the effects of response to acute stress (e.g., laboratory assessment) were associated with less emotional distress in individuals higher on both *AWA* and *nonjudgment*, which translated into lower BP in the assessment period (Peters et al., 2013). IL-6 does not change as quickly in response to stress, possibly obscuring relationships between *AWA* and *nonjudgment* in the prediction of IL-6. Alternatively, relationships between *observing* and *nonjudgment* may exert their influence on IL-6 through different mechanisms, such as health behaviours (e.g., alcohol use), which may exert a greater impact on inflammatory markers than BP (Eisenlohr-Moul et al., 2012).

Variation in meditation traditions

Meditation traditions differ and the importance of developing specific skills (e.g., focus on the present moment or compassionate lovingkindness) varies by tradition. For example, transcendental meditation (TM) focuses on training the mind to stay attentive to a specific point, or mantra, increasing attentional control and awareness. Interestingly, BP decreases have been consistently shown after practice in TM (Anderson et al., 2008), and in our sample increased awareness of present moment experience was linked to BP. This preliminary evidence leads to the suggestion that the development of this psychological skill may be particularly important in reducing BP. In studies training undergraduates in compassionate lovingkindness meditation, decreases in IL-6 in response to a social stressor were noted as a result of the intervention (Pace et al., 2009, 2010). Similarly, our findings suggested that nonreactivity, a concept linked closely to self-compassion, (Baer et al., 2006) was associated with reductions in IL-6 when paired with high levels of observation of present moment experiences.

These observations are offered cautiously, acknowledging that meditation traditions are by nature multi-faceted and participants in TM and compassionate lovingkindness meditation are likely exposed to instructions that fall outside the realm and main focus of the training; however, the associations raise interesting questions about whether varying focus of instruction in specific facets of mindfulness find their expression in different physiological aspects. Given the increasing popularity of mindfulness and acceptance based techniques in the treatment of chronic mental and physical illness, continued detailed study of how mindfulness may influence physiology and careful examination of how mindfulness facets change across various mindfulness based practices, is warranted.

Study limitations

Results from this study are preliminary and are limited by their cross-sectional nature. We are unable to draw conclusions about whether mindfulness influences physiology, or if better health may be associated with an increased willingness to pay attention to present moment experiences. Additionally, we were limited in our assessment of factors that may better account for the mindfulness/physiology association. Although our analyses suggested that relationships were not working through differences in perceived stress or depression, they may have been influenced by other psychological variables or health behaviours (e.g. alcohol consumption, which has been linked to facets of mindfulness and IL-6; Eisenlohr-Moul et al., 2012). Also, IL-6, which displays diurnal variation was assessed at a single time point. However, we sampled blood within a relatively small window of time from 12:30 p.m. to 4:30 p.m. from each subject in order to lessen this potential source of variation. Finally, participants in our sample were generally young and healthy. Blood pressure in the sample was well within normal limits for the majority of participants, none were suffering from clinically significant disease and most reported low levels psychological distress. Replicating these findings in samples of participants who are older and experiencing more physical and psychological comorbidities is a necessary next step in this line of research.

Future directions

Continued research in the mental and physical health literature is necessary to better understand interactions between mindfulness and health; manipulation of facets of mindfulness (e.g., through meditation training) and examining changes in physiological variables is needed before firm conclusions can be drawn. Future studies should examine older populations and those in less optimal health then our sample. Additionally, these findings should be extended in a longitudinal design to determine whether baseline levels of mindfulness are associated with changes in health status over time, and ultimately which facets of mindfulness are modifiable with treatment and whether such changes can predict future health status.

Acknowledgments This work was supported by the Bill and Melinda Gates Foundation (K.E.), Inamori Fellowship, Canadian Institute of Health Research, and by the generous donors of the Alberta Children's Hospital Foundation (L.T.), and RR 00827 (University of California San Diego General Clinical Research Center Grant). We would like to thank Dr. Joshua Madsen for his helpful comments on the revision of this manuscript.

Conflict of interest Drs. Tomfohr, Pung, Mills and Edwards declare that they have no conflict of interest.

Human and animal rights and Informed Consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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