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7 **The role of trait mindfulness in the pain experience of adolescents**

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Abstract

Trait mindfulness appears to mitigate pain among adult clinical populations, and has a unique relationship with pain catastrophizing. However, little is understood about this phenomenon among adolescents. The association between trait mindfulness and pain in both real-world and experimental contexts was examined among a community sample of adolescents. Participants were 198 adolescents who completed measures of trait mindfulness, pain catastrophizing, and pain interference, as well as an interview on daily pain before undergoing an acute experimental pain task. Following the task they provided ratings of pain intensity and state catastrophizing. Results showed that in relation to daily pains, mindfulness was a significant and unique predictor of pain interference and this relationship was partially mediated by pain catastrophizing. Mindfulness also had an indirect relationship with experimental pain intensity and tolerance. These associations were mediated by catastrophizing during the pain task. These findings highlight the association between trait mindfulness and both daily and experimental pain and offer insight into how mindfulness may affect pain among youth. Findings are discussed in the context of current psychological models of pediatric pain and future avenues for research.

Perspective: This article highlights the association between trait mindfulness and pain variables among adolescents in both real world and experimental pain settings. These findings offer further evidence of the unique relationship between trait mindfulness and pain catastrophizing in affecting pain variables across pain contexts and populations.

Keywords: Mindfulness; Adolescents; Pain Interference; Pain Catastrophizing.

The role of trait mindfulness in the pain experience of adolescents

Pain is a common occurrence among adolescents from the general population with approximately a third reporting recurrent pain³¹. A smaller percentage of these adolescents have pain that significantly interferes in their lives, and characteristics of the pain (i.e., intensity, frequency) alone do not adequately explain differences in impairment²⁰. Clinicians and researchers have identified pain catastrophizing as an important variable in predicting adolescents' responses to pain in both acute and chronic contexts^{13,37}. Pain catastrophizing refers to tendency to magnify the threat value of pain, to ruminate about pain, and to feel helpless in the face of pain¹². Recently there has been a call for researchers in the field of pediatric pain to also consider the role that contextual cognitive behavioral variables play in the pain experience of youth^{23,24}. Rather than focusing on the content of thoughts, these variables assess how an individual relates to distressing thoughts and emotions, and the influences they exert on behavior. Mindfulness is one variable within this framework that is associated with a number of pain outcomes among adult clinical populations^{10,29}. Mindfulness refers to a state of consciousness that involves attending to moment-to-moment experience in a nonjudgmental and accepting manner²¹. This nonjudgmental awareness of experience appears to be at odds with the negative evaluations of painful sensations that characterize pain catastrophizing⁶, and some evidence suggests that pain catastrophizing may mediate the relationship between mindfulness and other pain variables¹⁰. The purpose of this study was therefore to examine the relationship between mindfulness and pain variables across real-world and experimental pain settings, while further investigating the nature of its relationship with pain catastrophizing.

Trait mindfulness refers to the tendency to be mindful in daily life. Importantly there are a number of interventions such as mindfulness-based stress reduction (MBSR)²¹, mindfulness-based cognitive therapy (MBCT)³⁰, and acceptance and commitment therapy (ACT)¹⁹, which are designed to improve physical and psychological outcomes (e.g., quality of life, adjustment to illness), with mindfulness being seen as an important mechanism of change to this end.

1 Furthermore, modifications of these interventions have been developed specifically for youth³.
2 Research suggests that trait mindfulness is enhanced through mindfulness-based
3 interventions⁸. These interventions have a growing evidence-base for adult chronic pain
4 populations¹¹ and have been shown to provide benefit for individuals experiencing acute
5 experimental pain^{22,39}. Theoretical definitions of mindfulness which emphasize its non-
6 judgmental focus on present moment experience, also point out that it appears antithetical to
7 variables known to negatively impact the pain experience⁶, such as pain-related catastrophizing,
8 which are secondary negative evaluations of current and past pain experience, as well as
9 concerns regarding future pain⁶. Supporting this hypothesis, several studies have shown that
10 among adults with chronic pain, trait mindfulness is associated with decreased pain-related
11 disability and has a unique relationship with cognitive reactions to pain such as
12 catastrophizing^{10,29}. Furthermore, longitudinal research with adults has found evidence that
13 reductions in catastrophizing may be the active mechanism that mediates the relationship
14 between mindfulness and chronic pain outcomes¹⁰. These findings have potentially important
15 theoretical implications, as pain catastrophizing is a central variable in the fear-avoidance model
16 of pain, which has recently been adapted for pediatric populations¹. Specifically this model
17 predicts that catastrophic interpretations of pain lead to increases in pain-related fear and
18 ultimately to increases in pain-related disability and interference. If increases in mindfulness are
19 associated with decreases in catastrophizing, and ultimately decreases in pain-related
20 interference, mindfulness may also warrant further attention in research examining the pediatric
21 fear-avoidance model of pain.

22 While there is increasing interest in the use of mindfulness-based interventions with
23 pediatric populations³³, research examining the association between mindfulness and pain
24 variables in adolescents is lacking. Research that has been conducted in pediatric community
25 samples has found that trait mindfulness is associated with decreases in somatic complaints¹⁷
26 and that mindfulness-based interventions result in decreased somatic symptoms among teens

1 mindfulness and self-reported daily and experimental pain variables. The primary purpose of
2 other manuscript from this larger study was to examine the effect of a novel mindful-attention
3 manipulation on experimental pain variables, although the manuscript also examined the
4 relationship between state mindfulness and pain variables [Petter, McGrath, & Chambers,
5 2013]. Methods presented below therefore contain details relevant to the present study only.
6 Ethical approval for this study was obtained from the health centre research ethics board and all
7 participants provided informed consent.

8 ***Participants***

9 Participants were adolescents recruited from the general community through
10 advertisements in local schools, hospitals, doctors' offices, sports clubs, recreation centers,
11 science camps, and other community services targeting adolescents, as well as advertisements
12 in local online, print, radio, and television media. Additional efforts were made to recruit
13 adolescents with meditation experience. With this goal in mind, a number of advertisements
14 were placed at local Buddhist meditation centers, yoga studios, and through mailing lists to local
15 Buddhist and non-secular meditation groups. Furthermore, a local private school, which
16 incorporates regular meditation practice as part of its curriculum allowed its students to take part
17 through the school.

18 Participants were excluded if they met any of the following criteria: (1) inability to follow
19 instructions in English or read and write fluently in English; (2) significant uncorrected hearing or
20 vision impairment; (3) diagnosis of attention-deficit/hyperactivity disorder; (4) health-related
21 medical condition that could be made worse by placing the hand in cold water (e.g., circulation
22 disorders, heart problems, injuries to the arms or hands); or (5) having previously taken part in a
23 study involving a cold pressor task. Participants with health conditions that are not made worse
24 by placing the hand in cold water (e.g., asthma, chronic pain conditions) were allowed to take
25 part in the study.

1 Before being enrolled in the study, exclusionary criteria were assessed by a screening
2 interview. No adolescents withdrew following enrolment in the study. One minor adverse event
3 was reported with a participant feeling light-headed following participation in the experimental
4 pain task. However, these symptoms were transient and subsided quickly after the participant
5 lay down and was offered a snack and drink. Due to deviation from protocol this participant was
6 removed from the final analysis. One more participant was also excluded due to a perceived
7 inability to adequately understand the content of questionnaires and answer questions
8 appropriately as noted by the researcher who was present during their participation.

9 Final analysis included 198 adolescents (132 females, 66 males) aged 13 to 18 years
10 ($M_{\text{age}} = 15.99$ years, $SD = 1.89$), who were recruited from the community ($n = 175$) or a local
11 school ($n = 23$). The majority of participants identified themselves as White ($n = 172$), and
12 reported that their parents were married ($n = 131$).

13 **Measures**

14 *Trait Mindfulness*

15 The Child and Adolescent Mindfulness Measure (CAMM)¹⁷ is a 10-item questionnaire
16 designed to measure mindfulness skills among children and adolescents. The CAMM contains
17 items that reflect acting with present-moment awareness (e.g., “At school, I walk from class to
18 class without noticing what I’m doing”) with an attitude of acceptance and non-judgment (e.g., I
19 think that some of my feelings are bad and I shouldn’t have them”). Items are answered on a 5-
20 point Likert scale with anchors of 0 – “Never True” and 4 – “Always True”, which are then
21 reverse scored. Scores range from 0-40 with higher scores indicating higher levels of trait
22 mindfulness. This scale has been shown to be a valid measure of trait mindfulness in children
23 and adolescents¹⁵. In this sample the scale showed good internal consistency with $\alpha = .846$.

24 *Pain Catastrophizing*

25 The Pain Catastrophizing Scale (PCS)³² was used to measure trait levels of pain
26 catastrophizing. This 13-item scale assesses the tendency to catastrophize about pain (e.g.,

1 “When I have pain I feel I can’t stand it anymore”). Items are answered on a 5-point Likert scale.
2 Simplified anchors were used on the scale (e.g., “not at all” = 0, to “extremely” = 4), and the
3 stem “When I have pain” was placed in front of each item. The PCS is a widely used measure in
4 pain research and in this sample showed excellent internal consistency with $\alpha = .904$.

5 *Daily Pain*

6 In order to assess daily pain, a structured interview was created for the purposes of this
7 study. The interview focused on the most common pain the adolescent experienced over the
8 previous three months. Initially, the interviewer briefly discussed any major life events (e.g.,
9 school activities, sports, holidays) that may have occurred three months prior to the interview in
10 order to anchor the timeline for the participant. The interviewer then asked the participant to
11 indicate any aches or pains they had over that time, providing relevant examples (e.g.,
12 headache, stomachache, tooth pain, muscle pain, back pain). The participant was asked to
13 continue listing pains they had until they had indicated all the pain they had experienced during
14 that time. They were then asked to indicate which of these pains they had the most often over
15 the previous three months, and what the cause of that pain was. The rest of the interview then
16 focused on this most common pain. Based on PedIMMPACT recommendations²⁶ participants
17 were asked to provide details on the length (i.e., how long they had been experiencing this type
18 of pain), frequency (i.e., over the last three months how often they experienced this type of pain)
19 and the typical intensity of their most common pain. Typical pain intensity scores were given on
20 an 11-point numerical rating scale with anchors of 0 – “no pain” and 10 – “the worst possible
21 pain”. Numerical rating scales are well validated in pediatric populations³⁸. In addition,
22 participants were asked whether they had taken any medication or missed any days of school
23 because of their most common pain.

24 *Pain Interference*

25 The National Institute of Health PROMIS Pediatric Pain Interference Scale Short Form
26 8a (PPPIS-8a)^{27,35} was used to assess pain interference. The PPPIS is an 8-item measure of

1 how much pain interferes with day-to-day functioning (e.g., “I had trouble doing schoolwork
2 when I had pain”) over a 7-day recall period. Items are answered on a 5-point Likert scale with
3 anchors of 0 – “Never” and 4 – “Almost Always”, raw scores are then converted to T-scores with
4 a population mean of 50 and a standard deviation of 10 using a standardized scoring template.
5 T-scores range from 34 – 78 with higher scores reflecting higher levels of pain interference. The
6 PPPIS has been normed in community populations using item-response theory³⁵. In this sample
7 the scale showed good internal consistency with $\alpha = .870$.

8 *Meditation Experience*

9 In order to assess meditation experience, as part of the pain interview, participants were
10 also asked to indicate whether they currently meditated, if so, how long they had been
11 meditating for, and how frequently they meditated. Specifically, participants were asked whether
12 they had ever meditated before, and clarification was provided if they were unsure whether
13 previous experiences would be considered meditation.

14 *Experimental Pain Task*

15 The cold pressor is an ethically acceptable pain task for use with pediatric populations⁵.
16 The cold pressor involves having participants place their non-dominant hand up to the wrist in 5
17 °C water up to a maximum of four minutes. Based on recent recommendations for use of the
18 cold pressor where tolerance is an outcome of interest⁴, participants were not informed about
19 the 4-minute ceiling. Prior to beginning the task, participants were instructed to leave their hand
20 in the water for as long as they could, even if it was uncomfortable, but to remove it when it
21 became too uncomfortable or hurt too much. The cold-pressor device used was a commercially
22 available RU-200 Techne Dip Cooler controlled by a Techne TE-10D Liquid Temperature Bath
23 Thermoregulator [Bibby Scientific Limited, Staffordshire, UK]. The device maintains a steady
24 temperature and circulates water to prevent local warming around the participants’ hand. Pain
25 tolerance was recorded by the experimenter as the time between when the participant first

1 placed their hand in the water, until it was voluntarily withdrawn up to a maximum time of 4
2 minutes.

3 *Situational Pain Catastrophizing*

4 In order to assess catastrophizing during the experimental pain task the Situational
5 Catastrophizing Questionnaire (SCQ)⁸ was used. The 6-item SCQ asks participants to indicate
6 the types of thoughts and feelings they had during a pain procedure (e.g., “I thought that the
7 pain might overwhelm me). Items are answered on a 5-point Likert scale with anchors of 0 –
8 “Not at All” and 4 “All the Time”. Scores range from 0-24 with higher scores representing higher
9 levels of catastrophizing. The SCQ has been shown to be more strongly associated with acute
10 pain responses than trait measures of pain catastrophizing⁸. In this sample the scale had good
11 internal consistency with $\alpha = .880$.

12 *Experimental Pain Intensity*

13 A verbally administered 11-point numerical rating scale was used as the measure of pain
14 intensity following the cold pressor. Participants were asked to rate their pain on a scale from 0
15 – 10 where “0” represents no pain, and “10” represents the worst pain possible. These types of
16 numerical ratings scales are well validated for use with pediatric populations³⁸.

17 **Procedure**

18 After completing the initial screening interview and providing informed consent
19 participants took part in the study either at a research centre at a tertiary care hospital, or at
20 their school. As part of the study protocol, adolescents initially completed the measures of trait
21 mindfulness (CAMM) and pain catastrophizing (PCS). Following completion of these measures
22 participants completed the day-to-day pain interview and the measure of pain interference
23 (PPPIS-8a). Next, participants completed the brief interview related to their meditation
24 experience and then went to a separate room to complete the cold pressor task. During the cold
25 pressor participants were accompanied by an experimenter who remained in the room, but
26 seated behind the participant out of their sight to record pain tolerance times. Immediately after

1 withdrawal of the limb from the water during the cold pressor task, or after reaching the 4-minute
2 ceiling, participants reported their average pain intensity and completed the measure of
3 situational catastrophizing (SCQ). They then received a \$20 honorarium if they took part at the
4 research centre or had \$20 donated on their behalf to a fundraising event if they took part
5 through their school.

6 **Results**

7 ***Data Analysis***

8 Questionnaire data were initially checked for missing item responses. Overall,
9 .001% of items were missing from the questionnaire data. A single imputation using the
10 expectation maximization algorithm was therefore utilized to replace these missing items¹⁴.
11 Missing data were imputed using Missing Values Analysis within SPSS 20. To correct for the
12 inclusion of multiple analyses in this study alpha was set to .01 for all outcomes.

13 First demographic pain information of the sample was analyzed. In order to describe the
14 pain experience of our sample we first used descriptive statistics based on daily pain interview.
15 To describe the meditation experience of the current sample, participants were categorized
16 according to whether or not they currently regularly practiced meditation. Participants were
17 considered to regularly practice if they were currently meditating at least once a week and had
18 been meditating for at least a year. These criteria were selected as evidence suggests that
19 extensive meditation practice may be necessary to see effects on pain responses¹⁶. One-way
20 between-group ANOVA's for continuous variables and chi-square analysis for categorical
21 variables were conducted to examine differences between regular meditators and non-
22 meditators.

23 In order to examine whether sex was related to any variables of interest and might need
24 to be controlled in analyses, a series of independent samples t-tests were conducted comparing
25 outcome measures between males and females. Because there were significant differences
26 between the sexes on a number of variables, it was controlled for in analyses. Bivariate

1 correlations between age and other variables were conducted. Because age was unrelated to
2 any outcome variables it was not controlled for in future analyses.

3 To examine the association between mindfulness and day-to-day pain variables,
4 bivariate correlations were calculated between all variables followed by a hierarchical regression
5 model predicting pain interference after controlling for sex, typical pain intensity, and pain
6 catastrophizing. Following this, a simple mediation model using PROCESS for SPSS¹⁸ was
7 conducted to examine whether pain catastrophizing mediated the relationship between trait
8 mindfulness and pain interference. A 95% bootstrap confidence interval for the indirect effect
9 using 10,000 bootstrap samples was used. Sex and pain intensity were included as covariates.

10 To examine the association between mindfulness and experimental pain a series of
11 bivariate correlations were first conducted. A hierarchical linear regression model was then used
12 to examine the impact of trait mindfulness on pain intensity. Following this, a mediation model
13 using the approach already outlined was conducted to examine the mediating effects of
14 situational catastrophizing on the relationship between mindfulness and pain intensity after
15 controlling for sex.

16 Finally, because the pain tolerance outcome was highly skewed (33.3% of the sample
17 reached the 4-minute ceiling), the pain tolerance variable was dichotomized according to
18 whether the participant reached ceiling (1) or removed their hand before the ceiling time (0). For
19 descriptive statistics, chi square and logistic regression analysis were conducted. Logistic
20 regression analyses were then carried out in the same fashion as the linear regression models.
21 Follow-up mediation analysis with PROCESS for SPSS was conducted using maximum
22 likelihood logistic regression to examine whether the effects of trait mindfulness on pain
23 tolerance were mediated by catastrophizing. A 95% bootstrap confidence interval for the indirect
24 effect using 10,000 bootstrap samples was used to test for the indirect effect.

25 ***Results for Day-to-day Pains***

26 *Pain and Meditation Characteristics of Community-Recruited Sample.*

1 In this sample, 81 participants' (41%) reported a pain that occurred at least once a week,
2 for a duration of three months, and was not muscle pain from regular physical activity and thus
3 could be considered a recurrent pain. The most commonly reported pains were headache
4 (32%), back pain (20%), muscle pain (18%), and stomachaches (12%), only 1 participant
5 reported having experienced no pain over the previous three months. In addition, 53% of
6 participants reported having taken some form of pain medication in the previous three months,
7 and 14% had missed school as a result of their pain. Forty-eight participants (24%) reported
8 that they currently had some form of meditation practice. Twenty-one participants meditated at
9 least once a week, and had been doing so for at least one year, and were classified as regular
10 meditators. Among these regular meditators, most adolescents ($n = 14$ (67%)) reported that
11 they typically meditated for 15 minutes or less. A comparison between regular meditators and
12 non-meditators showed no difference on age ($F(1,197) = .01, p = .913$), trait mindfulness
13 ($F(1,197) = .83, p = .362$), typical pain intensity ($F(1,197) = .10, p = .752$), pain catastrophizing
14 ($F(1,197) = .60, p = .439$), pain anxiety ($F(1,197) = 2.45, p = .119$), or pain interference
15 ($F(1,197) = .07, p = .789$). However, there were more females in the regular meditator group
16 than males (females = 18, males = 3, $\chi^2(1) = 3.83, p = .05$)

17 *Relationship between Participant Sex, Mindfulness, and Day-to-day Pain Variables*

18 Females were found to have significantly lower scores on the measure of trait
19 mindfulness (females, $M = 22.49, SD = 6.98$; males, $M = 25.21, SD = 6.98, t(196) = -2.62, p$
20 $<.01$), and higher pain catastrophizing (females, $M = 20.13, SD = 9.38$; males, $M = 14.95, SD =$
21 $8.41, t(196) = 3.79, p <.001$) and pain-related interference (females, $M = 51.84, SD = 5.58,$
22 males, $M = 48.35, SD = 7.67, t(196) = 2.80, p <.01$), although there was no difference in typical
23 pain intensity (females, $M = 5.00, SD = 1.77$; males, $M = 4.46, SD = 1.69, t(196) = 2.04, p =$
24 $.043$).

25 *Bivariate Correlations Between Age, Mindfulness, and Day-to-day Pain Variables*

1 Table 1 shows the bivariate correlations between age, mindfulness, and day-to-day pain
2 variables. Age was unrelated to any variables of interest. All relationships between mindfulness
3 and day-to-day pain variables were in expected directions. Specifically, trait mindfulness was
4 negatively correlated with typical pain intensity, pain catastrophizing, and pain interference.

5 *Prediction of Day-to-day Pain Interference by Trait Mindfulness.*

6 The results of the regression model predicting day-to-day pain interference by trait
7 mindfulness, after controlling for earlier variables in the fear-avoidance model, are presented in
8 Table 2. After controlling for the effects of sex, pain intensity, and pain catastrophizing, trait
9 mindfulness remained a significant predictor of day-to-day pain interference accounting for
10 approximately 5% of the unique variance ($\Delta R^2 = .053$, $p < .001$), overall this model accounted for
11 38.5% of the variance in pain interference.

12 *Mediation Analysis of the Effects of Trait Mindfulness on Pain Interference, through Pain*

13 *Catastrophizing*

14 After controlling for the effects of sex and pain intensity, results of the mediation analysis
15 were consistent with predictions, as the total effect of trait mindfulness on pain interference was
16 significant with a path coefficient of $-.476$ ($SE = .07$), $p < .001$, the direct effect of trait
17 mindfulness on pain interference remained significant with a path coefficient of $-.333$, ($SE =$
18 $.08$), $p < .001$ and the indirect effect of trait mindfulness on pain interference through
19 catastrophizing had a path coefficient of $-.143$ ($Boot SE = .05$) ($95\% CI = -.27$ to $-.04$). A Sobel
20 test showed that the mediation path was significantly different from zero ($z = -3.07$, $p < .01$).

21 **Results for Experimental Pain Variables**

22 *Demographic Characteristic, Mindfulness and Experimental Pain*

23 Females and males did not differ significantly on situational catastrophizing during the
24 pain task (females, $M = 8.95$, $SD = 5.58$; males, $M = 7.52$, $SD = 5.11$) ($t(195) = 1.74$, $p = .083$)
25 or average pain intensity (females, $M = 6.17$, $SD = 1.69$; males, $M = 5.75$, $SD = 1.96$) ($t(196) =$
26 1.56 , $p = .120$) or pain tolerance ($\chi^2 = .920$, $p = .337$). Age was unrelated to situational

1 catastrophizing ($r = -.117, p = .101$) or average pain intensity ($r = -.074, p = .298$) or pain
2 tolerance $\beta = .188$ ($SE = .084, Wald = 5.04$ ($df = 1$), $p = .025$). Bivariate correlations showed that
3 trait mindfulness was significantly related to catastrophizing during the pain task ($r = -.403, p$
4 $<.001$) and pain intensity during the pain task ($r = -.293, p <.001$). Logistic regression showed
5 that mindfulness was significantly related to pain tolerance $\beta = .073$ ($SE = .024$), $Wald = 9.49$ (df
6 $= 1$), $p <.01$. Situational catastrophizing was also related to pain intensity ($r = .492, p <.001$),
7 and predicted pain tolerance $\beta = -.154$ ($SE = .034$), $Wald = 20.35$ ($df = 1$), $p <.001$.

8 *Prediction of Experimental Pain Intensity by Trait Mindfulness.*

9 The results of the regression model predicting experimental pain variables by trait
10 mindfulness are presented in Table 3. After controlling for the effects of sex and situational
11 catastrophizing during the cold pressor task, trait mindfulness was not a significant predictor of
12 pain experienced during the cold pressor accounting for less than 1% of the unique variance
13 ($\Delta R^2 = .009, p = .124$).

14 *Mediation Analysis of the Effects of Trait Mindfulness on Experimental Pain Intensity Through* 15 *Catastrophizing.*

16 Given that trait mindfulness was no longer a significant predictor of experimental pain
17 intensity after controlling for situational catastrophizing, a mediation model was tested. Results
18 of this mediation analysis were consistent with predictions. The total effect of trait mindfulness
19 on pain intensity was significant with a path coefficient of $-.072$ ($SE = .018$), $p <.001$, the direct
20 effect of trait mindfulness on pain intensity was not significant with a path coefficient of $-.027$
21 ($SE = .018$), $p = .124$, and the indirect effect of trait mindfulness on pain intensity through
22 catastrophizing was significant with a path coefficient of $-.045$ (Boot $SE = .011$) (95% $CI = -.068$
23 to $-.026$). A Sobel test showed that the mediation path was significantly different from zero ($z = -$
24 $4.36, p <.001$). Results of this model can be found in Figure 1.

25 *Prediction of Experimental Pain Tolerance by Trait Mindfulness*

1 Next a hierarchical logistic regression model using trait mindfulness to predict the
2 dichotomous pain tolerance outcome after controlling for sex, and situational catastrophizing
3 during the cold pressor in Step 1 was conducted. Although the overall model was a significant
4 predictor of pain tolerance outcome $\chi^2(3) = 26.87, p < .001$, Nagelkerke $R^2 = .177$, the addition of
5 mindfulness in the final step of the analysis did not add significantly to the model $\chi^2(1) = 2.13, p$
6 $= .145$. Of the final variables in the model, only situational catastrophizing uniquely contributed
7 to the prediction of whether participants reached ceiling or not $\beta = -.137$ (SE = .039), Wald =
8 14.32 (df = 1), $p < .001$, while trait mindfulness did not $\beta = .037$ (SE = .026), Wald = 2.08 (df = 1),
9 $p = .149$.

10 *Mediation of the Effects of Trait Mindfulness on Pain Tolerance through Catastrophizing*

11 Given that trait mindfulness was no longer a significant predictor of experimental pain
12 tolerance after controlling for situational catastrophizing, a mediation model was tested. Results
13 of the mediation model indicated that consistent with predictions the total effect of trait
14 mindfulness on pain tolerance was significant with a product coefficient of .072 (SE = .024), $z =$
15 2.99, $p < .01$, the direct effect of trait mindfulness on pain tolerance was not significant with a
16 product coefficient of .038 (SE = .026), $z = 1.44, p = .15$, while the indirect effect through
17 catastrophizing had a product coefficient of .042 (Boot SE = .015) 95% CI = .018 - .076). A
18 sobel test revealed that the mediation path was significantly different from zero ($z = 3.15, p$
19 $< .01$).

20 **Discussion**

21 The purpose of this study was to examine the association between trait mindfulness and
22 day-to-day and acute experimental pain among adolescents. Based on research with adult
23 populations, which has shown that individuals higher in trait mindfulness show more adaptive
24 responses to clinical^{24,25,29} and experimental pain^{22,38}, it was predicted that higher mindfulness
25 would be associated with less negative reactions to pain across settings. It was further

1 hypothesized that the relationship between mindfulness and pain variables would be mediated
2 by reductions in pain catastrophizing. Results were largely consistent with these predictions, in
3 regards to day-to-day pains, mindfulness was found to be a unique predictor of pain
4 interference, accounting for approximately 5% of the unique variance in this variable, although
5 the relationship between trait mindfulness and pain interference was only partially mediated by
6 pain catastrophizing. In an experimental setting, mindfulness was found to have an indirect
7 association with pain intensity and pain tolerance, which was mediated by changes in pain
8 catastrophizing as hypothesized.

9 These results indicate that mindfulness is negatively associated with typical pain
10 intensity and pain catastrophizing, and is a unique and non-redundant predictor of how much
11 pain interferes in the lives of adolescents. These findings are consistent with previous research
12 with adults, which have shown that mindfulness plays an important role in cognitive and
13 behavioural reactions to daily pain^{10,24,25,29}. This is the first study to examine the relationship
14 between trait mindfulness and pain in a community recruited sample, as previous research in
15 this field has largely focused on populations with long-standing chronic pain who present at
16 tertiary care centers. This is an important extension of this field of research as mild / moderate
17 levels of pain and pain interference are relatively common among adolescents, while chronic
18 debilitating pain is less common²⁰. This study builds on the field of research examining the
19 relationship between mindfulness and physical and psychological well-being among
20 adolescents that has shown that higher levels of trait mindfulness are associated with higher
21 quality of life and lower levels of somatic complaints and negative affect in this age range¹⁷.

22 This is the first study to demonstrate that mindfulness plays an important role in acute
23 experimental pain responses among youth. As hypothesized teens that were more mindful had
24 fewer catastrophic thoughts during the acute experimental pain task and because of this,
25 experienced less pain and had higher pain tolerance. These findings build on several studies in
26 the adult literature that have shown that specific aspects of trait mindfulness are associated with

1 reduced pain sensitivity during painful stimulation among experienced meditators¹⁶ and that trait
2 mindfulness is associated with decreased anxiety and pain intensity among university students
3 undergoing a brief mindfulness-based intervention³⁹. Only one other study in a pediatric
4 population (aged 10 – 14 years) has examined the impact of trait mindfulness on acute
5 experimental pain responses, with no evidence that trait mindfulness was associated with pain
6 responses among children receiving brief attention-based interventions for acute pain²⁸.

7 The findings of this study further demonstrate the unique relationship that exists between
8 trait mindfulness and pain catastrophizing in influencing pain variables across a variety of age
9 ranges and settings. It appears that reductions in catastrophic thoughts during painful events
10 are one of the potential mechanisms whereby mindfulness may influence pain variables. This is
11 consistent with theoretical work on the construct of mindfulness which argues that the ability to
12 maintain focus on moment-to-moment experience should inhibit secondary elaborative
13 processing of physical sensations⁶ and may buffer against catastrophic thoughts that are
14 characterized by ruminating about pain, magnification of the threat value of pain, and feelings of
15 helplessness to control pain¹³. These results are potentially important, as research with pediatric
16 populations has shown that catastrophizing is a predictor of pain and distress during medical
17 procedures³⁷, pain and disability among youth with chronic pain¹³, and prospectively predicts the
18 development of chronic pain and disability in community samples³⁶. These findings may also
19 have implications for pediatric psychological models of pain such as the fear-avoidance model,
20 which has recently been adapted for use in pediatric populations¹. Specifically, this model
21 predicts that in a sub-set of youth, maladaptive psychological responses to a painful event (such
22 as catastrophizing), lead to increases in pain-related anxiety and avoidance, which results in
23 increases in pain-related interference and disability. Within this model, this study offers
24 preliminary evidence that mindfulness may be thought of as an adaptive psychological response
25 to pain that may lead to appropriate responses to painful events that result in limited

1 interference and appropriate recovery. In this sense, adolescents higher in mindfulness may
2 possess psychological resilience in regards to painful events.

3 There were also important differences in the relationship between mindfulness and
4 different pain variables. For day-to-day pains, mindfulness had a weak relationship with typical
5 pain intensity, a strong relationship with pain catastrophizing, and a moderate relationship with
6 pain interference¹². It therefore appears that non-judgmental awareness of the present moment
7 has a more profound impact on the way adolescents reacts to painful sensations, and the
8 impact pain has on their lives, than on the actual sensations of pain. Mindfulness was also
9 found to have a direct effect on pain interference over and above its indirect relationship through
10 pain catastrophizing. It is therefore likely that mindfulness is associated with pain interference
11 through multiple mechanisms. For example, in addition to predicting lower levels of negative
12 automatic thoughts, mindfulness has also been found to predict an increased ability to let go of
13 negative thoughts when they occur¹⁵. Over time, this ability to let go of catastrophic thoughts
14 may result in more mindful youth seeing them as less bothersome and intrusive, thus allowing
15 them to continue to engage in meaningful behaviours (e.g., social activities, school) with less
16 interference. In the acute experimental pain context, mindfulness had a small to moderate
17 association with pain intensity, and a moderate relationship with pain catastrophizing. Once
18 again, this indicates that it has a stronger relationship with cognitive reactions to pain rather
19 than pain sensations themselves. However, contrary to the findings with day-to-day pain
20 interference (but consistent with predictions), trait mindfulness was not found to have a direct
21 effect on pain intensity or pain tolerance, as the relationship between mindfulness and pain
22 variables was mediated by reductions in state catastrophizing. In combining the findings across
23 day-to-day and experimental settings, it appears that during acute episodes of pain, adolescents
24 higher in trait mindfulness are less likely to respond to physical sensations of pain in a
25 catastrophic fashion, which may decrease subjective pain intensity and increase pain tolerance.
26 Over time, as pain is encountered regularly, adolescents who are more mindful and

1 catastrophize less about pain would therefore experience less interference in their life as a
2 result of pain. However, it appears that the relationship between mindfulness and pain
3 interference may be more complex than its relationship with acute pain responses and it may
4 influence this variable through multiple mechanisms.

5 Given the relatively strong and consistent relationship between trait mindfulness and
6 important pain variables, it is possible that interventions that increase trait mindfulness among
7 adolescents could offer benefit for youth with pain. Encouragingly, previous research with
8 adolescent psychiatric outpatients has demonstrated that mindfulness appears to be a
9 modifiable variable in youth, and improvements in mindfulness are significantly related to
10 reductions in somatic symptoms^{3,7}. It should be noted that more traditional cognitive-behavioural
11 pain management programs, which include a brief component of mindfulness training may also
12 result in significant increases in trait mindfulness following program completion¹⁰. However, the
13 potential clinical implications of the current research should be interpreted cautiously given that
14 this research was conducted with a community-based sample of adolescents and was largely
15 cross-sectional in nature.

16 While this study offers a number of unique insights into the influence of mindfulness on
17 adolescent pain across a number of outcomes, there are several limitations that require
18 consideration. The most obvious limitation of the current study is the cross-sectional design,
19 which precludes making conclusions regarding the causal nature of the relationships being
20 examined, especially among the day-to-day pain variables. Well-designed longitudinal research
21 is needed to examine whether trait mindfulness is a prospective predictor of pain variables, and
22 whether changes in trait mindfulness (e.g., as a result of intervention) result in the expected
23 changes in pain-related variables, and furthermore whether these changes are mediated by
24 pain catastrophizing. Secondly, the daily pain interview was developed exclusively for the
25 purpose of this study, and relied upon retrospective recall data related to day-to-day pain, which
26 may be influenced by recall biases. In particular, among pediatric populations, the use of

1 retrospective measures may lead to inflated estimates of day-to-day pains³⁴. In order to gain a
2 more refined understanding of the relationship between mindfulness and day-to-day pain, future
3 research should consider the use of real-time diary data to gain a more thorough understanding
4 of how mindfulness impacts pain variables in real-time. Additionally, all of our major outcome
5 variables (with the exception of the pain tolerance measure) were based on a common method
6 of reporting (self-report) which could have potentially influenced the correlations observed
7 among variables. Future research in this field should consider multiple methods of measures
8 including observer report and additional behavioral measures to help address this issue.

9 It should be noted that there are also limitations concerning the generalizability of the
10 current study results based on the unique sample. First of all, adolescents with a regular
11 meditation practice were explicitly sought out for the purposes of this study. In this sample, a
12 personal meditation practice was not related to trait levels of mindfulness, a finding that appears
13 counter to the hypothesis that a meditation practice should increase mindfulness⁹. A potential
14 explanation for this finding is that the extent that adolescents in this sample were engaging in a
15 meditation practice may not have been extensive enough to see differences in trait mindfulness.
16 Adolescents were classified as a regular meditator if they meditated at least once a week, for a
17 period of a year, and the majority of our sample (67%) reported that they typically meditated for
18 15 minutes or less. It is therefore possible that many of the adolescents classified as regular
19 meditators did not have an extensive enough practice to experience changes in trait
20 mindfulness, as most mindfulness-based interventions for adults promote a daily meditation
21 practice of approximately 45 minutes²¹. In fact, mindfulness-based interventions for teens also
22 promote a longer and more regular practice³. Another potential limitation concerning the
23 generalizability of relates to the specific efforts made to recruit through a private school, and
24 meditation centers (e.g., yoga studios). Because there is a cost associated with some of these
25 services we may also have recruited adolescents from a relatively high socioeconomic
26 background. Furthermore, although this sample was recruited through the community, a

1 relatively high number of participants (41%) who took part reported experiencing some form of
2 recurrent pain. This number appears higher than typical prevalence rates, which estimate that
3 approximately a third of adolescent report recurrent pain³¹. A potential explanation for this
4 finding is that adolescents with a recurrent pain condition may have been more likely to enroll in
5 this study given that they were aware that the research was on pain. Based on these limitations,
6 these results should be interpreted cautiously, as the external validity to typical adolescents, as
7 well as adolescents who present in clinical settings with chronic pain are not known.

8 In conclusion, among adolescents trait mindfulness was found to be a strong predictor of
9 a number of important outcomes related to both daily and experimental pain. Similar to findings
10 in adult populations, mindfulness appears to have a unique relationship with pain
11 catastrophizing, which was found to mediate many of the important relationships between
12 mindfulness and pain variables. Taken together these findings offer preliminary evidence that
13 adolescents who are higher in trait mindfulness may be at decreased risk for more negative pain
14 responses both in terms of day-to-day pains and responses to acute pain. This research
15 highlights a need for further examination of mindfulness within psychological models of pain
16 such as the pediatric fear-avoidance model. Further research examining the role of mindfulness-
17 based interventions either on their own or as part of a larger cognitive-behavioural protocol, in
18 helping adolescents cope with pain also appears warranted.

19
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3

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5

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Figure Captions

Figure 1. Path coefficients for the mediation model of the total, direct, and indirect effects of trait mindfulness on pain intensity through situational catastrophizing. Standard errors are in parentheses. * $p < .05$. ** $p < .01$. *** $p < .001$.