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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 pain. 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 impairment. Clinicians and researchers have identified pain catastrophizing as an important variable in predicting adolescents’ responses to pain in both acute and chronic contexts. Pain catastrophizing refers to tendency to magnify the threat value of pain, to ruminate about pain, and to feel helpless in the face of pain. 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. 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. Mindfulness refers to a state of consciousness that involves attending to moment-to-moment experience in a nonjudgmental and accepting manner. This nonjudgmental awareness of experience appears to be at odds with the negative evaluations of painful sensations that characterize pain catastrophizing, and some evidence suggests that pain catastrophizing may mediate the relationship between mindfulness and other pain variables. 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), mindfulness-based cognitive therapy (MBCT), and acceptance and commitment therapy (ACT), 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.
Furthermore, modifications of these interventions have been developed specifically for youth. Research suggests that trait mindfulness is enhanced through mindfulness-based interventions. These interventions have a growing evidence-base for adult chronic pain populations and have been shown to provide benefit for individuals experiencing acute experimental pain. Theoretical definitions of mindfulness which emphasize its non-judgmental focus on present moment experience, also point out that it appears antithetical to variables known to negatively impact the pain experience, such as pain-related catastrophizing, which are secondary negative evaluations of current and past pain experience, as well as concerns regarding future pain. Supporting this hypothesis, several studies have shown that among adults with chronic pain, trait mindfulness is associated with decreased pain-related disability and has a unique relationship with cognitive reactions to pain such as catastrophizing. Furthermore, longitudinal research with adults has found evidence that reductions in catastrophizing may be the active mechanism that mediates the relationship between mindfulness and chronic pain outcomes. These findings have potentially important theoretical implications, as pain catastrophizing is a central variable in the fear-avoidance model of pain, which has recently been adapted for pediatric populations. Specifically this model predicts that catastrophic interpretations of pain lead to increases in pain-related fear and ultimately to increases in pain-related disability and interference. If increases in mindfulness are associated with decreases in catastrophizing, and ultimately decreases in pain-related interference, mindfulness may also warrant further attention in research examining the pediatric fear-avoidance model of pain.

While there is increasing interest in the use of mindfulness-based interventions with pediatric populations, research examining the association between mindfulness and pain variables in adolescents is lacking. Research that has been conducted in pediatric community samples has found that trait mindfulness is associated with decreases in somatic complaints and that mindfulness-based interventions result in decreased somatic symptoms among teens.
with psychological disorders\(^3\). However, research with younger children (aged 10 – 14 years) that compared the effects of a brief mindfulness-based intervention to a distraction-based intervention for acute experimental pain did not find evidence that mindfulness was related to pain responses\(^2\).

The current project was designed to extend this literature by examining the relationship of trait mindfulness to daily and acute experimental pain among community-recruited adolescents. Overall, it was hypothesized that increased levels of trait mindfulness would be associated with more positive outcomes related to daily pain and that this relationship would be mediated by reductions in catastrophic thinking about pain. Specifically, given that mindfulness is characterized by a non-judgmental focus on the present moment, it was believed that adolescents who tend to be more mindful in daily life would be less likely to react to painful physical sensations in a catastrophic manner, and that because of these reductions in catastrophic reactions to pain, more mindful adolescents would experience less pain-related interference in their lives. It was therefore hypothesized that higher levels of mindfulness would be associated with decreased levels of day-to-day pain interference, and that this association would be mediated by reductions in pain catastrophizing. In the acute experimental pain setting, it was once again predicted that adolescents who tend to be more mindful would be less likely to interpret the physical sensations experienced during the task in a catastrophic fashion, and because of this reduction in catastrophic thoughts during the task, would report lower levels of subjective pain intensity, and would demonstrate increased tolerance of the task. It was therefore hypothesized that higher trait mindfulness would be associated with lower levels of experimental pain intensity and increases in pain tolerance, and that this relationship would be mediated by reductions in catastrophizing thoughts during the task.

**Materials and Methods**

The data were collected as part of a larger study examining two distinct research questions. The purpose of the present article was to examine the association between trait
mindfulness and self-reported daily and experimental pain variables. The primary purpose of
other manuscript from this larger study was to examine the effect of a novel mindful-attention
manipulation on experimental pain variables, although the manuscript also examined the
relationship between state mindfulness and pain variables [Petter, McGrath, & Chambers,
2013]. Methods presented below therefore contain details relevant to the present study only.
Ethical approval for this study was obtained from the health centre research ethics board and all
participants provided informed consent.

Participants

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

Participants were excluded if they met any of the following criteria: (1) inability to follow
instructions in English or read and write fluently in English; (2) significant uncorrected hearing or
vision impairment; (3) diagnosis of attention-deficit/hyperactivity disorder; (4) health-related
medical condition that could be made worse by placing the hand in cold water (e.g., circulation
disorders, heart problems, injuries to the arms or hands); or (5) having previously taken part in a
study involving a cold pressor task. Participants with health conditions that are not made worse
by placing the hand in cold water (e.g., asthma, chronic pain conditions) were allowed to take
part in the study.
Before being enrolled in the study, exclusionary criteria were assessed by a screening interview. No adolescents withdrew following enrolment in the study. One minor adverse event was reported with a participant feeling light-headed following participation in the experimental pain task. However, these symptoms were transient and subsided quickly after the participant lay down and was offered a snack and drink. Due to deviation from protocol this participant was removed from the final analysis. One more participant was also excluded due to a perceived inability to adequately understand the content of questionnaires and answer questions appropriately as noted by the researcher who was present during their participation.

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

**Measures**

**Trait Mindfulness**

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

**Pain Catastrophizing**

The Pain Catastrophizing Scale (PCS)\textsuperscript{32} was used to measure trait levels of pain catastrophizing. This 13-item scale assesses the tendency to catastrophize about pain (e.g.,
“When I have pain I feel I can’t stand it anymore”). Items are answered on a 5-point Likert scale.

Simplified anchors were used on the scale (e.g., “not at all” = 0, to “extremely” = 4), and the stem “When I have pain” was placed in front of each item. The PCS is a widely used measure in pain research and in this sample showed excellent internal consistency with $\alpha = .904$.

**Daily Pain**

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

**Pain Interference**

The National Institute of Health PROMIS Pediatric Pain Interference Scale Short Form 8a (PPPIS-8a) was used to assess pain interference. The PPPIS is an 8-item measure of
how much pain interferes with day-to-day functioning (e.g., “I had trouble doing schoolwork when I had pain”) over a 7-day recall period. Items are answered on a 5-point Likert scale with anchors of 0 – “Never” and 4 – “Almost Always”, raw scores are then converted to T-scores with a population mean of 50 and a standard deviation of 10 using a standardized scoring template. T-scores range from 34 – 78 with higher scores reflecting higher levels of pain interference. The PPPIS has been normed in community populations using item-response theory\textsuperscript{35}. In this sample the scale showed good internal consistency with $\alpha = .870$.

**Meditation Experience**

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

**Experimental Pain Task**

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

Situational Pain Catastrophizing

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

Experimental Pain Intensity

A verbally administered 11-point numerical rating scale was used as the measure of pain intensity following the cold pressor. Participants were asked to rate their pain on a scale from 0 – 10 where “0” represents no pain, and “10” represents the worst pain possible. These types of numerical ratings scales are well validated for use with pediatric populations\(^38\).

Procedure

After completing the initial screening interview and providing informed consent participants took part in the study either at a research centre at a tertiary care hospital, or at their school. As part of the study protocol, adolescents initially completed the measures of trait mindfulness (CAMM) and pain catastrophizing (PCS). Following completion of these measures participants completed the day-to-day pain interview and the measure of pain interference (PPIS-8a). Next, participants completed the brief interview related to their meditation experience and then went to a separate room to complete the cold pressor task. During the cold pressor participants were accompanied by an experimenter who remained in the room, but seated behind the participant out of their sight to record pain tolerance times. Immediately after
withdrawal of the limb from the water during the cold pressor task, or after reaching the 4-minute ceiling, participants reported their average pain intensity and completed the measure of situational catastrophizing (SCQ). They then received a $20 honorarium if they took part at the research centre or had $20 donated on their behalf to a fundraising event if they took part through their school.

Results

Data Analysis

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

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

In order to examine whether sex was related to any variables of interest and might need to be controlled in analyses, a series of independent samples t-tests were conducted comparing outcome measures between males and females. Because there were significant differences between the sexes on a number of variables, it was controlled for in analyses. Bivariate
correlations between age and other variables were conducted. Because age was unrelated to any outcome variables it was not controlled for in future analyses.

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

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

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

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

*Pain and Meditation Characteristics of Community-Recruited Sample.*
In this sample, 81 participants’ (41%) reported a pain that occurred at least once a week, for a duration of three months, and was not muscle pain from regular physical activity and thus could be considered a recurrent pain. The most commonly reported pains were headache (32%), back pain (20%), muscle pain (18%), and stomachaches (12%), only 1 participant reported having experienced no pain over the previous three months. In addition, 53% of participants reported having taken some form of pain medication in the previous three months, and 14% had missed school as a result of their pain. Fourty-eight participants (24%) reported that they currently had some form of meditation practice. Twenty-one participants meditated at least once a week, and had been doing so for at least one year, and were classified as regular meditators. Among these regular meditators, most adolescents (n = 14 (67%)) reported that they typically meditated for 15 minutes or less. A comparison between regular meditators and non-meditators showed no difference on age (F(1,197) = .01, p = .913), trait mindfulness (F(1,197) = .83, p = .362), typical pain intensity (F(1,197) = .10, p = .752), pain catastrophizing (F(1,197) = .60, p = .439), pain anxiety (F(1,197) = 2.45, p = .119), or pain interference (F(1,197) = .07, p = .789). However, there were more females in the regular meditator group than males (females = 18, males = 3, χ²(1) = 3.83, p = .05).

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

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

**Bivariate Correlations Between Age, Mindfulness, and Day-to-day Pain Variables**
Table 1 shows the bivariate correlations between age, mindfulness, and day-to-day pain variables. Age was unrelated to any variables of interest. All relationships between mindfulness and day-to-day pain variables were in expected directions. Specifically, trait mindfulness was negatively correlated with typical pain intensity, pain catastrophizing, and pain interference.

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

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

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

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

Results for Experimental Pain Variables

Demographic Characteristic, Mindfulness and Experimental Pain

Females and males did not differ significantly on situational catastrophizing during the pain task (females, $M = 8.95$, SD = 5.58; males, $M = 7.52$, SD = 5.11) ($t(195) = 1.74$, $p = .083$) or average pain intensity (females, $M = 6.17$, SD = 1.69; males, $M = 5.75$, SD = 1.96) ($t(196) = 1.56$, $p = .120$) or pain tolerance ($\chi^2 = .920$, $p = .337$). Age was unrelated to situational
catastrophizing ($r = -.117, p = .101$) or average pain intensity ($r = -.074, p = .298$) or pain
tolerance $\beta = .188$ (SE = .084, Wald = 5.04 (df = 1), $p = .025$). Bivariate correlations showed that
trait mindfulness was significantly related to catastrophizing during the pain task ($r = -.403, p < .001$) and pain intensity during the pain task ($r = -.293, p < .001$). Logistic regression showed
that mindfulness was significantly related to pain tolerance $\beta = .073$ (SE = .024), Wald = 9.49 (df
= 1), $p < .01$. Situational catastrophizing was also related to pain intensity ($r = .492, p < .001$),
and predicted pain tolerance $\beta = -.154$ (SE = .034), Wald = 20.35 (df = 1), $p < .001$.

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

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

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

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

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

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

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

Discussion

The purpose of this study was to examine the association between trait mindfulness and day-to-day and acute experimental pain among adolescents. Based on research with adult populations, which has shown that individuals higher in trait mindfulness show more adaptive responses to clinical24,25,29 and experimental pain22,38, it was predicted that higher mindfulness would be associated with less negative reactions to pain across settings. It was further
hypothesized that the relationship between mindfulness and pain variables would be mediated by reductions in pain catastrophizing. Results were largely consistent with these predictions, in regards to day-to-day pains, mindfulness was found to be a unique predictor of pain interference, accounting for approximately 5% of the unique variance in this variable, although the relationship between trait mindfulness and pain interference was only partially mediated by pain catastrophizing. In an experimental setting, mindfulness was found to have an indirect association with pain intensity and pain tolerance, which was mediated by changes in pain catastrophizing as hypothesized.

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

This is the first study to demonstrate that mindfulness plays an important role in acute experimental pain responses among youth. As hypothesized teens that were more mindful had fewer catastrophic thoughts during the acute experimental pain task and because of this, experienced less pain and had higher pain tolerance. These findings build on several studies in the adult literature that have shown that specific aspects of trait mindfulness are associated with
reduced pain sensitivity during painful stimulation among experienced meditators and that trait mindfulness is associated with decreased anxiety and pain intensity among university students undergoing a brief mindfulness-based intervention. Only one other study in a pediatric population (aged 10 – 14 years) has examined the impact of trait mindfulness on acute experimental pain responses, with no evidence that trait mindfulness was associated with pain responses among children receiving brief attention-based interventions for acute pain.

The findings of this study further demonstrate the unique relationship that exists between trait mindfulness and pain catastrophizing in influencing pain variables across a variety of age ranges and settings. It appears that reductions in catastrophic thoughts during painful events are one of the potential mechanisms whereby mindfulness may influence pain variables. This is consistent with theoretical work on the construct of mindfulness which argues that the ability to maintain focus on moment-to-moment experience should inhibit secondary elaborative processing of physical sensations and may buffer against catastrophic thoughts that are characterized by ruminating about pain, magnification of the threat value of pain, and feelings of helplessness to control pain. These results are potentially important, as research with pediatric populations has shown that catastrophizing is a predictor of pain and distress during medical procedures, pain and disability among youth with chronic pain, and prospectively predicts the development of chronic pain and disability in community samples. These findings may also have implications for pediatric psychological models of pain such as the fear-avoidance model, which has recently been adapted for use in pediatric populations. Specifically, this model predicts that in a sub-set of youth, maladaptive psychological responses to a painful event (such as catastrophizing), lead to increases in pain-related anxiety and avoidance, which results in increases in pain-related interference and disability. Within this model, this study offers preliminary evidence that mindfulness may be thought of as an adaptive psychological response to pain that may lead to appropriate responses to painful events that result in limited
interference and appropriate recovery. In this sense, adolescents higher in mindfulness may possess psychological resilience in regards to painful events.

There were also important differences in the relationship between mindfulness and different pain variables. For day-to-day pains, mindfulness had a weak relationship with typical pain intensity, a strong relationship with pain catastrophizing, and a moderate relationship with pain interference\textsuperscript{12}. It therefore appears that non-judgmental awareness of the present moment has a more profound impact on the way adolescents react to painful sensations, and the impact pain has on their lives, than on the actual sensations of pain. Mindfulness was also found to have a direct effect on pain interference over and above its indirect relationship through pain catastrophizing. It is therefore likely that mindfulness is associated with pain interference through multiple mechanisms. For example, in addition to predicting lower levels of negative automatic thoughts, mindfulness has also been found to predict an increased ability to let go of negative thoughts when they occur\textsuperscript{15}. Over time, this ability to let go of catastrophic thoughts may result in more mindful youth seeing them as less bothersome and intrusive, thus allowing them to continue to engage in meaningful behaviours (e.g., social activities, school) with less interference. In the acute experimental pain context, mindfulness had a small to moderate association with pain intensity, and a moderate relationship with pain catastrophizing. Once again, this indicates that it has a stronger relationship with cognitive reactions to pain rather than pain sensations themselves. However, contrary to the findings with day-to-day pain interference (but consistent with predictions), trait mindfulness was not found to have a direct effect on pain intensity or pain tolerance, as the relationship between mindfulness and pain variables was mediated by reductions in state catastrophizing. In combining the findings across day-to-day and experimental settings, it appears that during acute episodes of pain, adolescents higher in trait mindfulness are less likely to respond to physical sensations of pain in a catastrophic fashion, which may decrease subjective pain intensity and increase pain tolerance. Over time, as pain is encountered regularly, adolescents who are more mindful and
catastrophize less about pain would therefore experience less interference in their life as a result of pain. However, it appears that the relationship between mindfulness and pain interference may be more complex than its relationship with acute pain responses and it may influence this variable through multiple mechanisms.

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

While this study offers a number of unique insights into the influence of mindfulness on adolescent pain across a number of outcomes, there are several limitations that require consideration. The most obvious limitation of the current study is the cross-sectional design, which precludes making conclusions regarding the causal nature of the relationships being examined, especially among the day-to-day pain variables. Well-designed longitudinal research is needed to examine whether trait mindfulness is a prospective predictor of pain variables, and whether changes in trait mindfulness (e.g., as a result of intervention) result in the expected changes in pain-related variables, and furthermore whether these changes are mediated by pain catastrophizing. Secondly, the daily pain interview was developed exclusively for the purpose of this study, and relied upon retrospective recall data related to day-to-day pain, which may be influenced by recall biases. In particular, among pediatric populations, the use of
retrospective measures may lead to inflated estimates of day-to-day pains. In order to gain a more refined understanding of the relationship between mindfulness and day-to-day pain, future research should consider the use of real-time diary data to gain a more thorough understanding of how mindfulness impacts pain variables in real-time. Additionally, all of our major outcome variables (with the exception of the pain tolerance measure) were based on a common method of reporting (self-report) which could have potentially influenced the correlations observed among variables. Future research in this field should consider multiple methods of measures including observer report and additional behavioral measures to help address this issue.

It should be noted that there are also limitations concerning the generalizability of the current study results based on the unique sample. First of all, adolescents with a regular meditation practice were explicitly sought out for the purposes of this study. In this sample, a personal meditation practice was not related to trait levels of mindfulness, a finding that appears counter to the hypothesis that a meditation practice should increase mindfulness. A potential explanation for this finding is that the extent that adolescents in this sample were engaging in a meditation practice may not have been extensive enough to see differences in trait mindfulness. Adolescents were classified as a regular meditator if they meditated at least once a week, for a period of a year, and the majority of our sample (67%) reported that they typically meditated for 15 minutes or less. It is therefore possible that many of the adolescents classified as regular meditators did not have an extensive enough practice to experience changes in trait mindfulness, as most mindfulness-based interventions for adults promote a daily meditation practice of approximately 45 minutes. In fact, mindfulness-based interventions for teens also promote a longer and more regular practice. Another potential limitation concerning the generalizability of relates to the specific efforts made to recruit through a private school, and meditation centers (e.g., yoga studios). Because there is a cost associated with some of these services we may also have recruited adolescents from a relatively high socioeconomic background. Furthermore, although this sample was recruited through the community, a
relatively high number of participants (41%) who took part reported experiencing some form of recurrent pain. This number appears higher than typical prevalence rates, which estimate that approximately a third of adolescents report recurrent pain\textsuperscript{31}. A potential explanation for this finding is that adolescents with a recurrent pain condition may have been more likely to enroll in this study given that they were aware that the research was on pain. Based on these limitations, these results should be interpreted cautiously, as the external validity to typical adolescents, as well as adolescents who present in clinical settings with chronic pain are not known.

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

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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.