Research Paper

PAIN®

OPEN

Association of parental and adolescent emotion-related factors with adolescent chronic pain behaviors

Helen Koechlin[a,b,*], Melanie Beeckman[c], Andrea H. Meier[d], Cosima Locher[a,e,f], Liesbet Goubert[g], Joe Kossowsky[b], Laura E. Simons[h]

Abstract

Chronic pain is a prevalent condition in youth, and the pain experience is strongly influenced by emotional processes. Studying emotion variability and regulation (ER) may help better understand pain behavior. As the development of emotion-related abilities predominantly takes place in the family context, examining ER within parent–adolescent dyads is important. We set out to test the association of parent and adolescent ER and adolescent emotional variability with adolescent pain behavior (ie, pain interference, activity avoidance, and activity engagement). A sample of 56 adolescents (M_{age} = 14.5, 85.7% women) with chronic pain and one of their parents (92.9% mothers) participated in this study. Adolescents completed baseline measures of average pain intensity, ER, and mean positive and negative affect. Furthermore, adolescents completed an electronic diary for 14 consecutive days, reporting on emotional state, activity avoidance, activity engagement, and pain interference. Parents completed measures of ER and their own history of pain. We performed a variable selection procedure, the *least absolute shrinkage and selection operator* method, to determine important predictors of adolescent pain behavior. Adolescent high positive affect was associated with more activity engagement, less pain interference, and less activity avoidance, indicating that positive affect might enhance the willingness to engage in activities in the presence of pain. Adolescent ER strategy *emotional reappraisal* and parents' own history of pain were predictors of less activity engagement. Parent ER was not related to adolescent ER. In conclusion, our results highlight the potential of enhancing positive affect as an intervention target for chronic pain.

Keywords: Chronic pain, Adolescents, Emotion regulation, Parental emotion regulation

1. Introduction

Chronic pain is a common and debilitating condition, affecting approximately 25% of children and adolescents.[50] Emotions and emotional processes are an essential part of the pain experience.[70] Given that pain is associated with a range of negative emotions, studying how people try to regulate their emotions may help to better understand the pain experience and associated behaviors.[81] Emotion regulation (ER) describes the ability of people to influence which emotions they have, when they have them, and how they experience and express them.[34] The *process model of emotion regulation*[36] broadly categorizes different ER strategies into antecedent-focused and response-focused ER strategies. *Antecedent-focused ER* includes those strategies that take place before an emotion is fully developed; hence, their prospect of success is generally greater,[1] eg, modifying a situation that elicits negative emotions or shifting one's attention to pleasant thoughts.[35,51] By contrast, *response-focused ER* emphasizes the regulation of the emotional response, particularly its physiological and behavioral aspects, eg, holding back one's tears in public,[33,52] which would be considered expressive suppression. Emotion regulation is considered maladaptive if it antagonizes personal

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

J. Kossowsky and L. E. Simons contributed equally to this work.

[a] Division of Clinical Psychology and Psychotherapy, Faculty of Psychology, University of Basel, Basel, Switzerland, [b] Department of Anesthesiology, Critical Care and Pain Medicine, Boston Children's Hospital, Harvard Medical School, Boston, MA, United States, [c] Department of Movement and Sports Sciences, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium, [d] Division of Clinical Psychology and Epidemiology, Faculty of Psychology, University of Basel, Basel, Switzerland, [e] Department of Consultation-Liaison Psychiatry and Psychosomatic Medicine, University Hospital Zurich, Zurich, Switzerland, [f] Faculty of Health, University of Plymouth, Plymouth, United Kingdom, [g] Department of Experimental-Clinical and Health Psychology, Faculty of Psychology, Ghent University, Ghent, Belgium, [h] Department of Anesthesiology, Perioperative, and Pain Medicine, Stanford University School of Medicine, Palo Alto, CA, United States

**Corresponding author. Address: Division of Clinical Psychology and Psychotherapy, Faculty of Psychology, University of Basel, Missionsstrasse 62, 4055 Basel, Switzerland. Tel.: +41 61 207 58 31. E-mail address: Helen.Koechlin@childrens.harvard.edu (H. Koechlin).*

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.painjournalonline.com).

PAIN 163 (2022) e888–e898

http://dx.doi.org/10.1097/j.pain.0000000000002508

goals, shows negative short-term or long-term outcomes, or is inappropriate to contextual or social demands.[2] Maladaptive response-focused ER may be an important risk factor for the development and maintenance of chronic pain in adults.[51] Past research has linked greater emotion variability, ie, the range of emotional fluctuations around an individual's average emotional intensity,[71] with more mental health symptoms in adolescents[64,72] and higher ER demands.[40] Importantly, higher negative emotion variability has been associated with greater pain and activity limitations in youth with chronic pain.[14] High negative emotion variability has been conceptualized as a consequence of diminished ER in the context of chronic pain.[30,63]

The development of ER abilities in childhood predominantly takes place in the family context. An important mechanism through which children learn about ER is by observing parents' emotional displays and the strategies chosen to manage emotional states.[60] Children learn the appropriateness of valence, duration, and intensity of emotion expression by observing parent ER behaviors.[3,60] In the context of chronic pain, research suggests that depression and anxiety are prevalent among mothers of children with chronic pain.[12,67] However, the direction of the relationship between maternal emotional functioning and their child's experience of chronic pain remains unknown and is likely bidirectional.[67] To conclude, it is possible that maladaptive ER strategies exhibited by parents could be one mechanism that links parent emotional functioning with greater pain-related dysfunction in adolescents.

The main objective of this study was to examine the association of parent and adolescent ER and adolescent emotional variability with pain interference, activity avoidance, and activity engagement in a sample of adolescents with chronic pain. We hypothesized that (1) adolescent expressive suppression predicts more pain interference and activity avoidance and less activity engagement in adolescents, (2) greater adolescent emotion variability predicts more pain interference and activity avoidance and less activity engagement in adolescents, and (3) parental expressive suppression would indirectly be linked to adolescent pain-related outcomes through adolescent expressive suppression. In addition, we controlled for participants' and parents' demographics and pain-related characteristics because previous studies have found age and sex differences in pediatric pain samples.[50]

2. Methods

2.1. Participants

We included adolescents with various types of chronic pain conditions (eg, headache, abdominal pain, and musculoskeletal pain) and one of their primary caregivers recruited through the Pain Treatment Service at Boston Children's Hospital (between February 2017 and December 2017, number of participants: 28 [50%]) and the Pediatric Pain Management Clinic at Stanford Children's Health (between February 2017 and February 2018, number of participants: 28 [50%]), where they presented for initial clinical evaluation. Approval of each institutional review board was granted before the start of recruitment (Boston Children's Hospital: #P0020989, Stanford: #39092). This study is part of the Child Pain In Context research project. Two publications are available from this project, one focused on the role of parental instructions on the relationship between parental psychological flexibility and adolescent pain-related behavior[7] and the second one explored potential antecedents and consequences of pain-related behavior in adolescents.[6]

Participants were considered eligible for the study if they (1) were between 11 and 17 years, (2) reported persistent or recurrent pain for 3 months or longer, (3) had internet access at home or on an accessible smartphone, (4) did not have significant cognitive impairments (eg, intellectual disability and severe brain injury), (5) did not report severe psychiatric conditions, and (6) had a primary caregiver who was also willing to participate. Screening for psychiatric disorders was performed based on the medical chart review (ie, physician reported) and through the parent. Including adolescents aged 11 to 17 years was chosen based on the age range of patients typically seen in the 2 pain treatment services.

Of the 84 parent–adolescent dyads who initially consented or assented to participate, 56 dyads (ie, 67%) completed a set of baseline self-report questionnaires followed by a 14-day diary assessment period, during which parents and adolescents answered questions daily. The most common reason for noncompletion was the lack of interest after initial consent (n = 19).

2.2. Procedure

After their first visit at the respective pain management center, participants and their parents were informed about the study and asked whether they wanted to participate. Informed consent was obtained on paper or online before the start of the study: Parents signed an informed consent for their own and their (minor-aged) adolescent's participation, and adolescents additionally gave their informed assent.

Participants received an online link to access and complete the baseline self-report questionnaires. The 2-week diary assessment period was scheduled to start on the Monday after the completion of the baseline measures. Automatic messages containing the diary surveys were sent to the participants each day for 14 consecutive days. Adolescents received prompts twice a day (afternoon and evening), and parents received one prompt in the evening. Afternoon and evening assessments were chosen because the wording of the outcome variables (pain-related interference, activity avoidance, and activity engagement) always started with "since the previous diary entry." Hence, we assessed opportunities to engage or avoid activities by assessing midday and at the end of the day. If an adolescent or a parent did not complete any of the required diary entries on 3 consecutive days despite reminder calls, the family was given the option to withdraw from the study. All study data were collected and managed using research electronic data capture, hosted at Boston Children's Hospital and Stanford University. Research electronic data capture is a secure, web-based application designed to support data capture for research studies.[43] All communication with participants regarding recruitment and consent was performed via the parent, using either text message or e-mail. In case adolescents had their own phone and assented to it, prompts for the daily diary assessment were sent to their phones.

Participants who started the 2-week diary period received one 10-dollar gift voucher (1 per family) at the end of the first week irrespective of the number of completed diary entries. In addition, participating dyads received a 20-dollar gift voucher at the end of the second week unless they withdrew from the study during the first week.

2.3. Measures

2.3.1. Baseline assessment

At baseline, both the adolescent and one of their parents completed a series of questionnaires (note: additional questionnaires not used in this analysis but collected for the Child Pain In Context study are reported elsewhere).[5,6]

2.3.1.1. Sociodemographic information

A short baseline questionnaire was completed on adolescent age, sex, ethnic background, and grade in school. The participating parent was asked to report on adolescent pain characteristics (ie, pain location and duration), parent sex, marital status, and education level. In addition, they reported on both parents' pain history by indicating whether they or the child's other parent have had a history of pain problems lasting 3 months or greater in their lifetime. To assess adolescents' average level of pain, we used the question "In the past 6 months, how intense was your average level of pain?" from the baseline questionnaire.

2.3.1.2. Adolescent pain severity

Adolescent pain severity was measured using the child version of the Graded Chronic Pain Scale[76,77] that asks adolescents to rate current and average pain intensity in the past 6 months on a 11-point Numerical Rating Scale, with 0 indicating no pain and 10 indicating worst possible pain. The Graded Chronic Pain Scale consists of 7 items and grades chronic pain in pain intensity and disability. Subscale scores for pain intensity and pain-related disability are combined to calculate a chronic pain grade that enables classification into 5 hierarchical categories, ie, grades 0 (pain free) to IV (high disability regardless of pain intensity). For this study, we used the one item that asked about the average pain intensity of the past 6 months to get an impression of the participants' average levels of pain.

2.3.1.3. Positive and negative affect

Positive and negative affect was measured using the short version of the Positive and Negative Affect Schedule for Children (PANAS-C).[21,55,80] The PANAS uses words that describe positively or negatively valenced emotions and asks the child to rate the extent to which they currently feel each of 5 positively (ie, proud, joyful, cheerful, happy, and lively) and 5 negatively valenced emotion descriptors (ie, blue, miserable, afraid, scared, and sad) on a 3-point rating scale ranging from "very slightly or not at all" to "extremely." Internal consistency for the positive affect subscale was $\alpha = 0.92$ and $\alpha = 0.91$ for the negative affect subscale in this sample.

2.3.1.4. Adolescent emotion regulation

Adolescent ER was assessed using the ER Questionnaire for Children and Adolescents (ERQ-CA)[40] that asks about the routine use of 2 ER strategies, namely, cognitive reappraisal (ie, cognitively reframing a situation's meaning; antecedent-focused ER strategy) and expressive suppression (ie, the suppression of emotional expression; response-focused ER strategy). The ERQ-CA is based on the adult version of the ER Questionnaire and has been revised for use in children and adolescents. It consists of a total of 10 items. Cronbach $\alpha = 0.83$ for the cognitive reappraisal subscale and $\alpha = 0.78$ for the expressive suppression in this sample.

2.3.1.5. Parent emotion regulation

Parent ER was assessed using the ERQ,[37] a 10-item questionnaire that assesses routine use of cognitive reappraisal and expressive suppression. Internal consistency was $\alpha = 0.90$ for the cognitive reappraisal subscale and $\alpha = 0.82$ for the expressive suppression subscale in this sample.

2.3.2. Daily assessment

Both the adolescent and one of their parents completed a set of daily questions for 14 consecutive days, assessing emotional variability, pain interference, activity avoidance, and activity engagement. We used parents' baseline values and adolescents' baseline as well as adolescent daily reports for this analysis. Items were developed by the research team who made adjustments to items of existing questionnaires to be suitable for daily or momentary use and were subsequently validated using the discriminant content validity procedure.[49]

2.3.2.1. Emotional variability

Emotional variability was measured by computing an index representing adolescent emotional variability of both positive and negative emotions (based on[14,72]), as rated by adolescents. Adolescents completed the PANAS items twice a day for 14 consecutive days. A ratio was computed of each adolescent's aggregate standard deviation of positive emotion scores relative to their grand mean of positive emotion scores across the 14-day period. Higher scores indicate greater variability of positive emotions. The same ratio was computed for negative emotions.

2.3.2.2. Pain interference

Pain interference was measured using one item, namely, "I experienced problems with completing activities because of the pain" and was rated on a scale ranging from 0 ("not at all true") to 4 ("totally true") by adolescents.

2.3.2.3. Activity avoidance due to pain

Activity avoidance due to pain was assessed using 3 items based on the "avoidance of activities" subscale of the Fear of Pain Questionnaire for Children[73] and adjusted for use in the daily assessment. Three items were selected to reflect different types of pain-related avoidance strategies: "I skipped my planned activities because I expected them to trigger or increase my pain," "I stopped what I was doing because my pain started to get worse," and "I spent my time resting instead of doing my activities because of my pain." The mean of the 3 items was used to create the outcome "activity avoidance" as rated by adolescents. Possible scores range from 0 ("not at all true") to 4 ("totally true"). Within-dyads α was 0.81 (afternoon assessment) and 0.82 (evening assessment), and between-dyads α was 0.95 (afternoon assessment) and 0.93 (evening assessment).

2.3.2.4. Activity engagement despite the pain

Activity engagement despite the pain was measured by means of 2 items and assessed when adolescents engaged in activities in the presence of pain (ie, a pain intensity score of one or higher). The following items were used: "I have put effort into completing activities that I find important or fun while I was in pain" and "I persisted in carrying out my planned activities while I was in pain." These items were based on the "activity engagement" subscale of the Chronic Pain Acceptance Questionnaire for Adolescents (CPAQ-A),[59] which has been found to be a valid measure of pain acceptance (including activity engagement).[59] The total score was computed as the mean of the 2 items, with possible scores ranging from 0 to 4. Within-dyads α was 0.63 (afternoon assessment) and 0.73 (evening assessment), and between-dyads α was 0.92 (afternoon assessment) and 0.93 (evening assessment).

2.4. Statistical analyses

Statistical analyses were performed using *R*[69] for the least absolute shrinkage and selection operator (LASSO) analysis, using the packages caret[53] and glmnet,[28] MPlus[61] for the within-level and between-level reliabilities of activity engagement and activity avoidance, and SPSS[46] for all other analyses.

We used descriptive statistics to summarize patient characteristics. For daily assessments, a daily mean score for pain interference, activity avoidance, and activity engagement was calculated by taking the average of afternoon and evening scores. The daily mean scores were aggregated across the 14-day period to obtain an average across all days for each variable, if at least 75% of the items were completed. If less than 75% of the items were completed, the total score was not calculated and considered missing. The bivariate Pearson correlation coefficients between all variables used in this study were calculated. Reliability for activity avoidance and activity engagement was calculated using a multilevel confirmatory factor analysis framework to estimate within-level and between-level reliabilities of the scales.[29] To investigate the relationship between predictors and pain behavior outcomes, a multiple regression model was considered to be unsuitable because of the sample size of the current study. Multiple regression models often suffer from overfitting and hence low predictive accuracy (predictive accuracy refers to the ability of a statistical model to not only fit the training data well but also fit corresponding new [test] data that has been previously unseen)[42] when the number of predictors is high relative to the number of participants. To avoid model overfit, we performed a variable selection procedure, namely, the LASSO method, a machine learning approach. In the LASSO model, coefficients are deliberately shrunk by implying a penalty term to the likelihood function when fitting the model. As a consequence, the LASSO models are somewhat more biased than those obtained from multiple regression models but less variable, ie, they exhibit increased predictive accuracy[44] for a deviation of the estimated coefficient from the true underlying (and unknown) parameter. Thus, when replicating the current study, the predictors whose coefficients have not been shrunk to zero by the LASSO are likely to remain predictive. Our LASSO model contained 14 predictors, namely, our predictors of interest (ie, adolescent's baseline mean positive and negative affect, adolescent's variability of positive and negative emotions, adolescent's expressive suppression, adolescent's cognitive reappraisal, parent's expressive suppression, and parent's cognitive reappraisal) and variables we controlled for (ie, adolescent age and sex, adolescent pain duration in months, average adolescent pain intensity over the past 6 months, parent's own chronic pain history, and other parent's chronic pain history). All predictors were standardized before using the LASSO. We conducted repeated (n = 10) 10-fold cross validation to assess the model's predictive accuracy, ie, how well the LASSO model performs when applied to test rather than training data.[65] We thereby used the root mean square error (ie, the square root of the variance of the residuals) and the *R*-squared (R^2) as measures of model accuracy.[47] Both the multiple regression model and the LASSO model contained exactly the same set of standardized predictors. Thus, the difference in the results between the 2 models is based on how the beta coefficients were estimated. Although they were not shrunk in the multiple regression model, they were shrunk in the LASSO using the regularization parameter λ. The optimal value for λ was determined using repeated (n = 10 complete sets) 10-fold cross validation.

To examine indirect links between parental ER (ie, expressive suppression or cognitive reappraisal) and adolescent pain-related outcomes (pain interference, activity avoidance, and activity engagement) through adolescent ER (expressive suppression or cognitive reappraisal; see **Fig. 1**), 6 indirect models were tested using a bootstrapping resampling method described by Hayes[45] by means of the PROCESS plug-in in SPSS (version 3.4). Instead of inspecting *P* values to conclude for significance of the effects, bootstrapping methods focus on confidence intervals (CIs) and effect sizes. According to this analytic method, a significant indirect effect (ab) is observed if the 95% bootstrap CI does not include 0. We examined bias-corrected bootstrap confidence intervals (BC CIs) because they are the most accurate with a high level of statistical power, especially with smaller samples sizes (N < 80) (see Ref. 58 for more information).

3. Results

3.1. Sample characteristics

The final sample consisted of 56 adolescents (M_{age} 14.5 years, SD = 1.9) and their parents (93% mothers) of 84 adolescent–parent dyads who initially consented or assented to participate (ie, 64%). The most common reason for noncompletion was lack of interest after initial consent (N = 19). Most of the adolescents were women (85.7%) and Anglo-American (66.1%). Their mean pain duration was 26.6 months with a SD of 23.1, and their current level of pain was rated as M = 5.1 with a SD = 2.6 on a Likert scale from 0 to 10. Detailed information on the sample is listed in **Table 1**. Of those dyads who consented, 49 provided data for all variables of interest in this study and were used for the LASSO analyses and the indirect models.

3.2. Predictors and outcome measures

Of a total of 784 possible daily diary observations for adolescent variables (ie, one observation per day or per participant for 14 consecutive days), 625 data points were available for daily adolescent activity avoidance (ie, 20% missing), 528 for daily adolescent activity engagement (ie, 32% missing), 642 for daily pain interference (ie, 18% missing), and 710 for daily positive affect and negative affect (ie, 9% missing; used to calculate positive and negative emotion variability). The bivariate Pearson correlation coefficients between all variables used in this study are listed in **Table 2**. We interpreted effects >0.1 as small, those >0.3 as medium, and those >0.5 as large.[9] In this sample, positive emotional variability scores ranged from 0 to 0.68 and negative emotional variability scores ranged from 0 to 0.88. This is similar to previous samples,[14] with a slightly higher anchor for the negative emotional variability in our study.

3.2.1. Pain-related interference

Pain-related interference was positively correlated with pain intensity ($r = 0.291$, $P < 0.01$) and variability of negative affect ($r = -0.274$, $P < 0.01$) as well as with baseline mean positive affect ($r = -0.296$, $P < 0.01$) and baseline mean negative affect ($r = 0.291$, $P < 0.01$; see **Table 2**).

Four predictors were found to be important (ie, nonzero) in the LASSO regression model (in descending order): adolescent baseline mean positive affect, adolescent variability of negative affect, parental expressive suppression, and adolescent variability of positive affect (**Table 3**). Thus, lower mean adolescent positive affect at baseline, lower variability of adolescent negative emotions, less parent expressive suppression, and higher variability in adolescent positive emotions were all associated with more pain-related interference. The magnitude of individual effects was small, particularly for adolescent variability of positive emotions and parent expressive suppression (**Table 3**). Root mean square error and R^2 for this model were 0.93 and 0.37, respectively, after cross validation and were enhanced relative to the respective values of a corresponding multiple regression model (**Table 4**).

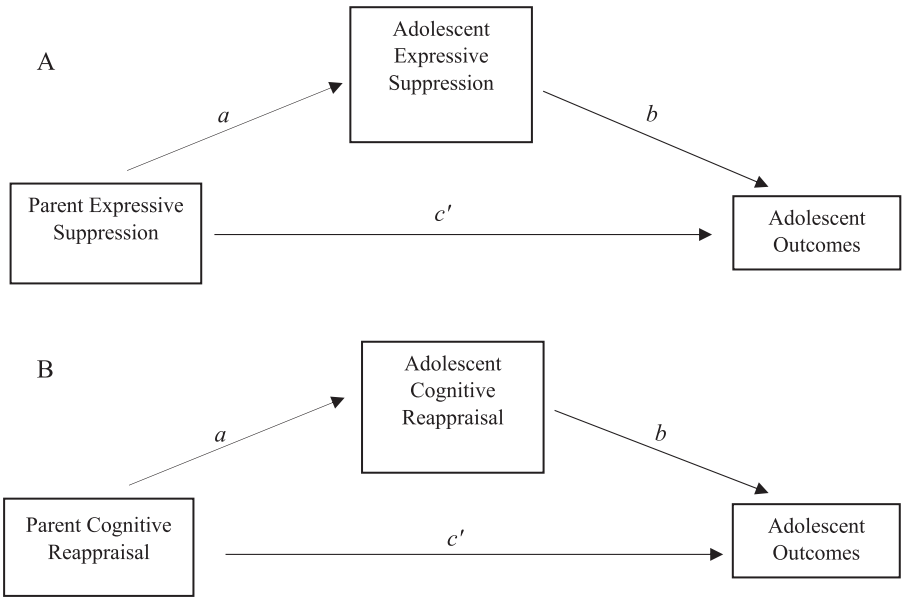

Figure 1. Mediation models were examined for each of the adolescent outcomes (total = 6 models). (A) Mediation model with adolescent expressive suppression as a mediator between parent expressive suppression and adolescent outcomes (ie, pain interference, activity avoidance, and activity engagement). (B) Mediation model with adolescent cognitive reappraisal as a mediator between parental cognitive reappraisal and adolescent outcomes. These relations were tested using a bootstrapping method. This is a modern approach to test statistical mediation which evolved as a response to several critiques towards the frequently used "normal theory" or "causal steps" methods based on a method by Baron and Kenny.[4] One of the most common critiques is that this type of approach lacks power and has the risk for inflation of type I errors.[24] A bootstrap approach focuses only on the indirect effect ($a \times b$), which is assumed to be the most relevant to conclude if mediation has occurred. There is no need of a direct effect (c') to indicate mediation. If there is a mediated effect ($a \times b$) in the absence of a direct effect, this is classified as an 'indirect-only' mediation (typology offered by Zhao et al.[82]).

3.2.2. Activity engagement

Bivariate correlations revealed significant correlations between activity engagement and baseline mean positive affect ($r = 0.341$, $P < 0.01$) and activity engagement and parent expressive suppression ($r = -0.310$, $P < 0.01$; see **Table 2**).

For the outcome activity engagement, 9 predictors were nonzero based on the LASSO model (**Table 3**): adolescent baseline mean positive affect, adolescent variability of positive affect, parent expressive suppression, adolescent cognitive reappraisal, average adolescent pain intensity over the past 6 months, other parent's history of chronic pain, parent cognitive reappraisal, adolescent baseline mean negative affect, and adolescent variability of negative affect. Thus, higher adolescent average pain intensity, more negative emotions at baseline, more frequent adolescent and parent cognitive reappraisal, and the presence of pain history in one parent were all associated with less adolescent activity engagement. It has to be noted, however, that the magnitude of the effects for parent cognitive reappraisal, adolescent baseline mean negative affect, and adolescent variability of negative affect were only very slightly above 0. Root mean square error and R^2 were 0.95 and 0.32, respectively, after cross validation and improved relative to the respective values of a corresponding multiple regression model, although to a lesser degree than what we observed for pain interference (**Table 4**).

3.2.3. Activity avoidance

Activity avoidance was significantly associated with baseline mean positive affect ($r = -0.506$, $P < 0.01$) and with baseline mean negative affect ($r = 0.320$, $P < 0.01$; see **Table 2**).

Only one predictor, namely, adolescent baseline mean positive affect, was nonzero based on the LASSO model (**Table 3**). Less baseline mean positive affect was associated with more activity avoidance. Root mean square error and R^2 were 0.85 and 0.37, respectively, after cross validation and again superior to the respective values of a corresponding multiple regression model (**Table 4**).

3.2.4. Association between parent emotion regulation and adolescent outcome through adolescent emotion regulation

Bootstrap analyses (with 5000 resamples) showed a significant direct contribution of parent expressive suppression on activity engagement ($c' = -0.22$, $P = 0.03$) but not on pain interference ($c' = -0.12$, $P = 0.27$) or activity avoidance ($c' = -0.05$, $P = 0.53$; **Fig. 1**, Model A). Furthermore, none of the hypothesized indirect links between parent expressive suppression and these outcomes through adolescent expressive suppression were found to be significant ($ab_{\text{pain interference}} = -0.002$, SE = 0.02, 95% BC CI: −0.05 to 0.03; $ab_{\text{activity engagement}} = -0.01$, SE = 0.02, 95% BC CI: −0.07 to 0.02; and $ab_{\text{activity avoidance}} = -0.005$, SE = 0.02, 95% BC CI: −0.06 to 0.02).

Bootstrap analyses (with 5000 resamples) showed no significant direct contributions of parent cognitive reappraisal on adolescent outcomes ($c'_{\text{pain interference}} = 0.08$, $P = 0.52$; $c'_{\text{activity engagement}} = -0.004$, $P = 0.98$; and $c'_{\text{activity avoidance}} = 0.09$, $P = 0.10$; **Fig. 1**, Model B). Furthermore, none of the hypothesized indirect links between parent cognitive reappraisal and these outcomes through adolescent cognitive reappraisal were found to be significant ($ab_{\text{pain interference}} = -0.04$, SE = 0.06, 95% BC CI: −0.19 to 0.04; $ab_{\text{activity engagement}} = -0.004$, SE = 0.03, 95% BC CI: −0.07 to 0.07; and $ab_{\text{activity avoidance}} = -0.02$, SE = 0.04, 95% BC CI: −0.11 to 0.05).

Table 1

Sample characteristics adolescent and parent.

Demographic variables	M (SD) or % (N)
Adolescent characteristics	
Age (y)	14.50 (1.90)
Gender	
Female	85.7 (48)
Male	14.3 (8)
Race	
Anglo-American	66.1 (37)
African American	3.6 (2)
Asian	1.8 (1)
Multiracial	3.6 (2)
Choose to not answer	1.8 (1)
Missing	23.1 (13)
Primary pain	
Headache	12.5 (7)
Abdominal pain	19.6 (11)
Musculoskeletal pain	55.4 (31)
Others	12.5 (7)
Pain duration (mo)	26.59 (23.10)
Pain grades	
Grade 0	0 (0)
Grade I	10.7 (6)
Grade II	12.5 (7)
Grade III	21.4 (12)
Grade IV	51.8 (29)
Parent characteristics	
Relation to the child	
Mother	92.9 (52)
Father	7.1 (4)
Ethnic background	
Hispanic	12.5 (7)
Non-Hispanic	85.7 (48)
Missing	1.8 (1)
Marital status	
Married	71.4 (40)
Divorced	12.5 (7)
Separated	3.6 (2)
Never married	12.5 (7)
Employment status	
Full time	51.8 (29)
Part time	23.2 (13)
Homemaker	17.9 (10)
Unemployed	3.6 (2)
Disabled	3.6 (2)
Education level	
High school or less	5.4 (3)
Some college or vocational school	10.7 (6)
College degree	44.6 (25)
Graduate or professional school	39.3 (22)
Parent pain history: yes (%)	44.6
Child's other parent pain history: yes (%)	25

Grade 0, pain free; Grade I, low pain intensity, low disability; Grade II, high pain intensity, low disability; Grade III, moderate disability regardless of the pain intensity; Grade IV, high disability regardless of the pain intensity.

All indirect models were rerun using data from mothers alone. Those analyses did not return different results (see Supplementary Materials for detailed information, available at http://links.lww.com/PAIN/B517).

4. Discussion

Previous research has extensively studied the role of negative affect in chronic pain in adolescents,[23,48,78] partially given by its dominant role in psychological comorbidities of chronic pain, especially depression.[74] In this study, we examined the role of emotion-related factors, such as ER, positive and negative emotion variability in pain-related interference, specifically activity avoidance, and activity engagement. Adolescent baseline mean positive affect was a consistent predictor across all outcomes in the hypothesized directions: Higher positive affect was associated with less mean pain-related interference, less activity avoidance, and more activity engagement. This is in line with previous research indicating that higher positive affect is related to an attenuated perception of pain.[23] In pediatric studies, more positive affect has been linked to significantly lower pain intensity,[22] which may be explained by the broaden-and-build theory of positive emotions. This theory states that positive emotions such as joy, interest, and contentment may allow people to broaden their thought–action repertoires.[27] Interest, for example, creates the urge to explore, expand, and take in new information.[26] This is in sharp contrast to negative emotions which carry immediate and adaptive benefits in survival-threatening situations by narrowing the thought–action repertoire to the immediate danger.[26,34] Within the broaden-and-build theory, positive affect can be conceptualized as a factor that promotes resilience.[25] In the context of chronic pain, this might mean that positive emotions enhance the possibility to engage in activities despite the pain. A recent review has highlighted the potential of positive affect interventions to reduce pain sensitivity and foster well-being despite pain and suggested that positive affect might be useful to handle some of the challenges faced in the treatment of patients with chronic pain.[41] Moreover, the dynamic model of affect[17] specifies how positive and negative states function relatively independent from each other in safe and predictable environments. However, under conditions characterized by uncertainty, including pain and stress, the 2 affective states become inversely correlated,[66] ie, it becomes progressively difficult to maintain positive affective states during periods of high pain intensity, which in turn increases vulnerability to negative affective states and future pain episodes.[17,66] Stress reduction techniques, such as mindfulness training, can help to broaden emotional awareness and support patients in retaining positive emotions also during times of high pain.[16]

In addition, we found that adolescent higher variability of positive emotions predicted less pain interference and more engagement in activities. This is in contrast to the results of a recent meta-analysis that found higher variability in positive emotions in youth with internalizing mental disorders compared with healthy peers.[71] This might be due to greater emotional reactivity in adolescents (compared with children and adults) because adolescence is commonly described as a time of inner "emotional turmoil."[56] Children and adolescents high in emotional reactivity are disproportionally negatively affected by adverse environments but profit enormously from supportive settings.[8,10,18] It might be that adolescents in our study were exposed to situations or supportive individuals (parents, peers, and teachers) that boosted positive affect and facilitated healthy regulation of emotions.[79]

Moreover, our results showed that greater negative emotion variability predicted less pain-related interference. This result is not in line with our hypothesis because greater emotional variability is generally linked with higher ER demands and has been found to be related to greater overall pain and more functional limitations in a previous study.[14] In this context, it is important to keep in mind that while emotion variability can reveal information about ER processes, ER is certainly not the only source of observed variability.[54] Factors such as the frequency and intensity of events in daily life, biological diurnal patterns of

Table 2

Correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Age	—																
2. Gender	0.109	—															
3. Baseline mean positive affect	−0.90	−0.202	—														
4. Baseline mean negative affect	0.194	0.208	**−0.458***	—													
5. Average pain intensity past 6 mo	−0.136	0.159	−0.009	0.078	—												
6. Cognitive reappraisal	0.010	−0.014	0.162	−0.098	−0.197	—											
7. Expressive suppression	0.217	−0.046	−0.191	**0.289†**	0.106	0.166	—										
8. Positive emotion variability	0.046	0.116	**−0.587***	0.008	−0.098	0.075	0.055	—									
9. Negative emotion variability	0.196	−0.106	−0.080	−0.255	−0.175	0.150	0.037	**0.322***	—								
10. Activity avoidance	−0.066	0.160	**−0.506***	**0.320†**	0.143	−0.139	−0.073	0.221	−0.149	—							
11. Activity engagement	−0.034	−0.092	**0.341***	−0.236	−0.199	−0.028	−0.100	−0.027	−0.016	**−0.266†**	—						
12. Pain duration	0.169	0.022	0.073	0.038	−0.242	0.259	0.191	−0.050	−0.153	0.030	0.058	—					
13. Pain-related interference	0.019	0.212	**−0.296†**	**0.291†**	0.216	−0.255	−0.026	0.109	**−0.274†**	**0.682***	−0.107	0.074	—				
14. Parent gender	−0.147	−0.113	−0.023	0.046	−0.045	0.095	0.056	0.129	−0.142	0.129	−0.033	−0.208	0.137	—			
15. Parent: Pain 3 mo or longer	−0.124	−0.147	−0.088	−0.109	−0.106	0.092	−0.001	**0.256†**	0.136	−0.011	0.056	0.113	−0.083	0.110	—		
16. Parent's cognitive reappraisal	−0.139	−0.010	0.100	0.007	0.014	0.169	0.035	−0.058	−0.116	0.118	−0.041	−0.015	0.045	0.105	0.134	—	
17. Parent's expressive suppression	0.063	−0.125	−0.236	−0.045	−0.073	−0.108	0.088	0.200	0.241	−0.058	**−0.310†**	−0.179	−0.098	−0.255	0.012	−0.161	—
18. Other parent's pain history	−0.143	0.178	0.034	−0.129	0.030	0.072	−0.194	0.201	−0.138	−0.037	−0.105	0.008	0.031	0.122	0.177	0.060	0.091

P values < 0.05 are marked in bold. Variables refer to adolescent unless stated otherwise.

* $P < 0.01$ (2-tailed).

† $P < 0.05$ (2-tailed).

Table 3

Predictors of pain interference, activity engagement, and activity avoidance based on the LASSO model.

Predictor	Outcome pain interference	Outcome activity engagement	Outcome activity avoidance
Adolescent age	0.00	0.00	0.00
Adolescent gender	0.00	0.00	0.00
Adolescent pain duration (in mo)	0.00	0.00	0.00
Adolescent average pain intensity (over the past 6 mo)	0.00	**−0.19**	0.00
Adolescent's baseline mean positive affect	**−0.28**	**0.39**	**−0.27**
Adolescent's baseline mean negative affect	0.00	**−0.01**	0.00
Adolescent's variability of positive emotions	**0.01**	**0.29**	0.00
Adolescent's variability of negative emotions	**−0.21**	−0.00	0.00
Adolescent's expressive suppression	0.00	0.00	0.00
Adolescent's cognitive reappraisal	0.00	**−0.19**	0.00
Parent's history of chronic pain problem (yes or no)	0.00	0.00	0.00
Other parent's history of chronic pain problem (yes or no)	0.00	**−0.15**	0.00
Parent's expressive suppression	**−0.04**	**−0.25**	0.00
Parent's cognitive reappraisal	0.00	**−0.02**	0.00

Values in bold are different from 0 and were hence not shrunk by the LASSO algorithm. Coefficients are standardized and thus denote by how many standard deviations the outcome (pain interference, activity avoidance, and activity engagement) changes for a change in the predictor by one standard deviation.
LASSO, least absolute shrinkage and selection operator.

emotion fluctuation, and previous experiences also critically influence the patterns of emotion variability.[54] Hence, additional factors that are associated with emotional processes, pain, or both that were not assessed in our study might modulate the relationship between negative emotional variability and pain interference.

Regarding the developmental stage, it might be worth noting that adolescents generally experience more frequent and intense emotions compared with children or adults,[72] increasing the ER demands at a time of profound transformation related to ER development.[40] Previous research has found that adults who routinely use cognitive reappraisal experience more positive emotions compared with people who used this strategy less often.[37,40] One reason for this might be that cognitive reappraisal is part of the *antecedent ER* strategies that are typically used before the full-blown emotional response in the process model of ER.[39] In our sample, cognitive reappraisal was found to be a predictor for less activity engagement in the LASSO model; however, bivariate associations between the variables were not significant. Although we were not able to identify why this is the case, a recent systematic literature review also pointed out that antecedent-focused ER might not be directly associated with pain.[51] Hence, it may be that unmeasured confounding variables explain the link between more cognitive reappraisal and less activity engagement.

Parental ER, specifically expressive suppression, was also a consistent predictor of adolescent pain-related interference and activity engagement. Our indirect models supported these findings from the LASSO model in part: We found a significant direct contribution of parental expressive suppression on less engagement in activities through adolescent expressive suppression but no significant direct contribution of parental cognitive reappraisal on any adolescent outcomes. In addition, we found no evidence for direct associations between parental and adolescent habitual use of ER strategies. Previous studies have stated that there is little research examining a potentially direct relationship between parental ER and adolescent social or emotional outcomes, although it is assumed that parental emotional factors are integral to an adolescent's development of ER capacities.[3,60] Furthermore, parents of children or adolescents with chronic pain experience high levels of stress and anxiety compared to parents of healthy children, and maladaptive ER is considered a key component of several mental disorders.[67] In contrast to our own findings, results of previous studies lend support to our initial hypothesis that stated that parental expressive suppression would indirectly be linked to adolescent pain-related outcomes through adolescent expressive suppression. Nevertheless, a systemic approach that takes the adolescent's and the parents' experience, emotional state, and behavior into account is crucial when treating children and adolescents with chronic pain.

Table 4

Model fit for multiple regression and LASSO models based on training or test data.

Outcome	Model	RMSE	R^2
Pain interference	Multiple regression based on training data	0.78	0.38
Pain interference	Multiple regression based on test data	1.17	0.29
Pain interference	LASSO for test data	0.93	0.37
Activity engagement	Multiple regression based on training data	0.72	0.47
Activity engagement	Multiple regression based on test data	1.08	0.31
Activity engagement	LASSO for test data	0.95	0.32
Activity avoidance	Multiple regression based on training data	0.70	0.50
Activity avoidance	Multiple regression based on test data	1.01	0.35
Activity avoidance	LASSO for test data	0.85	0.37

Lower values for RMSE and higher values for R^2 denote better model fit. Model fit indices based on training data are only available for the multiple regression model and are known to be overly optimistic.
LASSO, least absolute shrinkage and selection operator; RMSE, root mean square error.

4.1. Strengths and limitations

This study has several strengths. Data from adolescents and one of their parents were collected, including parental ER and information on parents' history of chronic pain. Our outcomes

not only focused on daily pain interference but also on activity engagement and activity avoidance, which might better capture the influence chronic pain has on adolescents' daily life. One of them, activity engagement, is a positive outcome, ie, an outcome that involves positive behaviors or emotions despite pain. The inclusion of positive outcomes is recommended to capture resilience in the context of chronic pain that might contribute to an upward spiral of sustainability despite pain.[31] The data used for this study were collected over a period of 2 weeks; hence, it is likely to depict a representative image of the daily lives of the included sample. Regarding our analyses, we used the LASSO procedure to select predictors of our outcomes, indicating that they are likely to remain predictive in a potential replication study. This is preferable over other methods, such as stepwise regression, where the risk of excluding important predictors and finding random results is higher.

Besides these strengths, our study also suffers from limitations. First, our sample size was limited. Second, we aggregated data across the dairy period and did not examine day-to-day changes to receive a reliable value for the respective values. Without these temporal associations (ie, day-to-day), interpretations regarding causality are impossible. A larger sample size would be needed to conduct analyses suitable to examine temporal associations (eg, multilevel modeling). In addition, we used self-report measures for parent and adolescent behavior. Although self-report is considered the gold standard when it comes to pain assessment,[11] self-reports can be biased (eg, because of socially desirable answers and memory bias).[57] Finally, most of the parents included in this study were mothers; thus, we cannot generalize conclusions to fathers.

4.2. Implications and future studies

One important clinical implication of our results is to consider including positive affect in the description and research of pediatric pain problems. As positive affect seems to be related with pain-related interference, activity avoidance, and activity engagement, pain interventions could consider including positive affect. Previous literature supports the notion that positive affect might play an important role in pain and its treatment and should be studied further.[23,41,68] Based on the broaden-and-build theory, increasing positive affect might support patients to optimize living with chronic pain by fostering their resilient qualities.[15] Fostering adolescents' skills and resilient qualities might support an increase in their well-being despite their pain. Future studies in the context of pediatric chronic pain could routinely assess not only negative but also positive affect, to clarify the directionality of the association between chronic pain and positive affect. Regarding ER, we suggest that future studies should assess environmental factors, such as diurnal patterns of emotions, previous experiences, parental psychopathology, parent ER, and frequency and intensity of potentially emotion-eliciting events in daily life, by using a multimethod approach (eg, psychophysiology, observation, and questionnaires).[19,32,38,75]

Previous studies have highlighted the unique contribution of paternal behavior to child outcomes.[13,20,62] Hence, future studies could include fathers and mothers to disentangle the association of both parents' ER and pain history.

5. Conclusion

This study examined emotion-related predictors of pain-related interference, avoidance of activity, and activity engagement in a sample of adolescents with chronic pain and their parents. Adolescent positive affect was found to be a constant predictor across all pain behavior outcomes. Our study is in line with recent research highlighting the importance of positive affect in the pain experience and points to its potential in pain treatment.

Conflict of interest statement

The authors report no conflicts of interest.

Acknowledgements

H. Koechlin is sponsored by a Swiss National Science Foundation Fellowship (P400PS_186658). This study was supported by a grant from the Special Research Fund of Ghent University (BOF15/24j/017) awarded to Liesbet Goubert. The authors thank Fae Kronman, Farah Mahmud, and Maya Hernandez for their help in setting up the study, recruiting participants, and collecting data.

Appendix A. Supplemental digital content

Supplemental digital content associated with this article can be found online at http://links.lww.com/PAIN/B517.

Article history:
Received 25 May 2021
Received in revised form 20 September 2021
Accepted 24 September 2021
Available online 12 October 2021

References

[1] Aldao A. The future of emotion regulation research: capturing context. Perspect Psychol Sci 2013;8:155–72.
[2] Aldao A, Sheppes G, Gross JJ. Emotion regulation flexibility. Cogn Ther Res 2015;39:263–78.
[3] Bariola E, Gullone E, Hughes EK. Child and adolescent emotion regulation: the role of parental emotion regulation and expression. Clin Child Fam Psychol Rev 2011;14:198–212.
[4] Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J Pers Soc Psychol 1986;51:1173–82.
[5] Beeckman M, Hughes S, Kissi A, Simons LE, Goubert L. How an understanding of our ability to adhere to verbal rules can increase insight into (Mal)adaptive functioning in chronic pain. J Pain 2019;20:1141–54.
[6] Beeckman M, Simons LE, Hughes S, Loeys T, Goubert L. A network analysis of potential antecedents and consequences of pain-related activity avoidance and activity engagement in adolescents. Pain Med 2020;21:e89–e101.
[7] Beeckman M, Simons LE, Hughes S, Loeys T, Goubert L. Investigating how parental instructions and protective responses mediate the relationship between parental psychological flexibility and pain-related behavior in adolescents with chronic pain: a daily diary study. Front Psychol 2019;10:2350.
[8] Belsky J, Pluess M. The nature (and nurture?) of plasticity in early human development. Perspect Psychol Sci 2009;4:345–51.
[9] Benesty J, Chen J, Huang Y, Cohen I. Pearson correlation coefficient. In: Cohen I, Huang Y, Chen J, Benesty J, editors. Noise reduction in speech processing. Springer topics in signal processing. Berlin, Heidelberg: Springer, 2009. p. 1–4.
[10] Boyce WT, Ellis BJ. Biological sensitivity to context: I. An evolutionary–developmental theory of the origins and functions of stress reactivity. Dev Psychopathol 2005;17:271–301.
[11] Breivik H, Borchgrevink PC, Allen SM, Rosseland LA, Romundstad L, Hals EK, Kvarstein G, Stubhaug A. Assessment of pain. Br J Anaesth 2008;101:17–24.
[12] Campo JV, Bridge J, Lucas A, Savorelli S, Walker L, Di Lorenzo C, Iyengar S, Brent DA. Physical and emotional health of mothers of youth with functional abdominal pain. Arch Pediatr Adolesc Med 2007;161:131–7.
[13] Connell AM, Goodman SH. The association between psychopathology in fathers versus mothers and children's internalizing and externalizing behavior problems: a meta-analysis. Psychol Bull 2002;128:746–73.

[14] Connelly M, Bromberg MH, Anthony KK, Gil KM, Franks L, Schanberg LE. Emotion regulation predicts pain and functioning in children with juvenile idiopathic arthritis: an electronic diary study. J Pediatr Psychol 2012;37: 43–52.
[15] Cousins LA, Kalapurakkel S, Cohen LL, Simons LE. Topical review: resilience resources and mechanisms in pediatric chronic pain. J Pediatr Psychol 2015;40:840–5.
[16] Davis MC, Zautra AJ. An online mindfulness intervention targeting socioemotional regulation in fibromyalgia: results of a randomized controlled trial. Ann Behav Med 2013;46:273–84.
[17] Davis MC, Zautra AJ, Smith BW. Chronic pain, stress, and the dynamics of affective differentiation. J Pers 2004;72:1133–59.
[18] De Villiers B, Lionetti F, Pluess M. Vantage sensitivity: a framework for individual differences in response to psychological intervention Soc Psychiatry Psychiatr Epidemiol 2018;53:545–54.
[19] De Witte NAJ, Sütterlin S, Braet C, Mueller SC. Getting to the heart of emotion regulation in youth: the role of interoceptive sensitivity, heart rate variability, and parental psychopathology. PLoS One 2016;11:e0164615.
[20] Donado C, Friedrich Y, Kossowsky J, Locher C, Koechlin H. Exposure to parental depressive symptoms: a longitudinal analysis on the association with adolescents' depressive symptoms and adjustment problems. J Dev Behav Pediatr 2020;41:522–33.
[21] Ebesutani C, Regan J, Smith A, Reise S, Higa-McMillan C, Chorpita BF. The 10-item positive and negative affect schedule for children, child and parent shortened versions: application of item response theory for more efficient assessment. J Psychopathol Behav Assess 2012;34:191–203.
[22] Evans S, Djilas V, Seidman LC, Zeltzer LK, Tsao JCI. Sleep quality, affect, pain and disability in children with chronic pain: is affect a mediator or moderator? J Pain 2017;18:1087–95.
[23] Finan PH, Garland EL. The role of positive affect in pain and its treatment. Clin J Pain 2015;31:177–87.
[24] Frazier PA, Tix AP, Barron KE. Testing moderator and mediator effects in counseling psychology research. J Couns Psychol 2004;51:115–34.
[25] Fredrickson B, Tugade M, Waugh C, Larkin G. What good are positive emotions in crises? A prospective study of resilience and emotions following the terrorist attacks on the United States on September 11th, 2001. J Personal Soc Psychol 2003;84:365–76.
[26] Fredrickson BL. The broaden–and–build theory of positive emotions. Philosophical Trans R Soc Lond Ser B: Biol Sci 2004;359:1367–77.
[27] Fredrickson BL. What good are positive emotions? Rev Gen Psychol 1998;2:300–19.
[28] Friedman J, Hastie T, Tibshirani R. Regularization paths for generalized linear models via coordinate descent. J Stat Softw 2010;33:1–22.
[29] Geldhof GJ, Preacher KJ, Zyphur MJ. Reliability estimation in a multilevel confirmatory factor analysis framework. Psychol Methods 2014;19: 72–91.
[30] Gerhart JI, Burns JW, Bruehl S, Smith DA, Post KM, Porter LS, Schuster E, Buvanendran A, Fras AM, Keefe FJ. Variability in negative emotions among individuals with chronic low back pain: relationships with pain and function. PAIN 2018;159:342–50.
[31] Goubert L, Trompetter H. Towards a science and practice of resilience in the face of pain. Eur J Pain 2017;21:1301–15.
[32] Gratz KL, Roemer L. Multidimensional assessment of emotion regulation and dysregulation: development, factor structure, and initial validation of the difficulties in emotion regulation scale. J Psychopathol Behav Assess 2004;26:41–54.
[33] Gross JJ. Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. J Pers Soc Psychol 1998;74:224–37.
[34] Gross JJ. Emotion regulation. Handbook of emotions. New York: The Guilford Press, 2008.
[35] Gross JJ. Emotion regulation: current status and future prospects. Psychol Inq 2015;26:1–26.
[36] Gross JJ. The emerging field of emotion regulation: an integrative review. Rev Gen Psychol 1998;2:271–99.
[37] Gross JJ, John OP. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. J Pers Soc Psychol 2003;85:348–62.
[38] Gross JJ, Levenson RW. Emotional suppression: physiology, self-report, and expressive behavior. J Pers Soc Psychol 1993;64:970–86.
[39] Gross JJ, Thompson RA. Emotion regulation: conceptual foundations. Handbook of emotion regulation. New York, NY: Guilford Press, 2007. p. 3–24.
[40] Gullone E, Taffe J. The emotion regulation questionnaire for children and adolescents (ERQ-CA): a psychometric evaluation. Psychol Assess 2012; 24:409–17.
[41] Hanssen MM, Peters ML, Boselie JJ, Meulders A. Can positive affect attenuate (persistent) pain? State of the art and clinical implications. Curr Rheumatol Rep 2017;19:80.
[42] Harrell F. Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis. 2nd ed. Springer International Publishing, 2015. Available at: https://www.springer.com/de/book/9783319194240. Accessed September 11, 2019.
[43] Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42:377–81.
[44] Hastie T, Tibshirani R, Friedman J. The elements of statistical learning. New York, NY: Springer New York, 2009.
[45] Hayes AF. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. 1st ed. New York: Guilford Publications, 2013.
[46] IBM Corp. IBM SPSS statistics for Mac. New York: IBM Corp, 2015.
[47] Jacobucci R, Grimm KJ, McArdle JJ. Regularized structural equation modeling. Struct Equ Modeling 2016;23:555.
[48] Janssen SA. Negative affect and sensitization to pain. Scand J Psychol 2002;43:131–7.
[49] Johnston M, Dixon D, Hart J, Glidewell L, Schröder C, Pollard B. Discriminant content validity: a quantitative methodology for assessing content of theory-based measures, with illustrative applications. Br J Health Psychol 2014;19:240–57.
[50] King S, Chambers CT, Huguet A, MacNevin RC, McGrath PJ, Parker L, MacDonald AJ. The epidemiology of chronic pain in children and adolescents revisited: a systematic review. PAIN 2011;152:2729–38.
[51] Koechlin H, Coakley R, Schechter N, Werner C, Kossowsky J. The role of emotion regulation in chronic pain: a systematic literature review. J Psychosom Res 2018;107:38–45.
[52] Koole SL. The psychology of emotion regulation: an integrative review. Cogn Emot 2009;23:4–41.
[53] Kuhn M. caret: classification and regression training, 2020. Available at: https://CRAN.R-project.org/package=caret. Accessed October 16, 2019.
[54] Kuppens P, Verduyn P. Looking at emotion regulation through the window of emotion dynamics. Psychol Inq 2015;26:72–9.
[55] Laurent J, Catanzaro SJ, Joiner TE Jr, Rudolph KD, Potter KI, Lambert S, Osborne L, Gathright T. A measure of positive and negative affect for children: scale development and preliminary validation. Psychol Assess 1999;11:326–38.
[56] Levesque RJR. Adolescent turmoil. In: Levesque RJR, ed. Encyclopedia of Adolescence. New York, NY: Springer, 2011. p. 69–70.
[57] Logan DE, Claar RL, Scharff L. Social desirability response bias and self-report of psychological distress in pediatric chronic pain patients. PAIN 2008;136:366–72.
[58] Mallinckrodt B, Abraham WT, Wei M, Russell DW, Frazier PA, Tix AP, Barron KE. Advances in testing the statistical significance of mediation effects. J Couns Psychol 2006;53:372–8.
[59] McCracken LM, Gauntlett-Gilbert J, Eccleston C. Acceptance of pain in adolescents with chronic pain: validation of an adapted assessment instrument and preliminary correlation analyses. Eur J Pain 2010;14:316–20.
[60] Morris AS, Silk JS, Steinberg L, Myers SS, Robinson LR. The role of the family context in the development of emotion regulation. Soc Dev 2007; 16:361–88.
[61] Muthén LK, Muthén BO. MPLUS (Version 6.11). [Computer Software]. Los Angeles, CA: Muthén & Muthén. 2007.
[62] Narayanan MK, Nærde A. Associations between maternal and paternal depressive symptoms and early child behavior problems: testing a mutually adjusted prospective longitudinal model. J Affect Disord 2016; 196:181–9.
[63] Nes LS, Roach AR, Segerstrom SC. Executive functions, self-regulation, and chronic pain: a review. Ann Behav Med 2009;37:173–83.
[64] Neumann A, van Lier PA, Frijns T, Meeus W, Koot HM. Emotional dynamics in the development of early adolescent psychopathology: a one-year longitudinal study. J Abnorm Child Psychol 2011;39:657–69.
[65] Olsen LR, Zachariae BH. cvms: cross-validation for model selection, 2019. Available: https://github.com/ludvigolsen/cvms. Accessed October 3, 2019.
[66] Ong AD, Zautra AJ, Reid MC. Chronic pain and the adaptive significance of positive emotions. Am Psychol 2015;70:283–4.
[67] Palermo TM, Valrie CR, Karlson CW. Family and parent influences on pediatric chronic pain: a developmental perspective. Am Psychol 2014; 69:142–52.
[68] Peters ML, Smeets E, Feijge M, van Breukelen G, Andersson G, Buhrman M, Linton SJ. Happy despite pain: a randomized controlled trial of an 8-week internet-delivered positive psychology intervention for enhancing well-being in patients with chronic pain. Clin J Pain 2017;33: 962–75.

[69] R Core Team. R: a language and environment for statistical computing. Vienna, Austria: The R Foundation for Statistical Computing, 2020. Available at: https://www.R-project.org/. Accessed October 16, 2019.
[70] Raja SN, Carr DB, Cohen M, Finnerup NB, Flor H, Gibson S, Keefe FJ, Mogil JS, Ringkamp M, Sluka KA, Song X-J, Stevens B, Sullivan MD, Tutelman PR, Ushida T, Vader K. The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises. PAIN 2020;161:1976–82.
[71] Reitsema AM, Jeronimus BF, van Dijk M, de Jonge P. Emotion dynamics in children and adolescents: a meta-analytic and descriptive review. Emotion 2021. doi: 10.1037/emo0000970. Available at: https://research.rug.nl/en/publications/emotion-dynamics-in-children-and-adolescents-a-meta-analytic-and-. Accessed April 19, 2021.
[72] Silk JS, Steinberg L, Morris AS. Adolescents' emotion regulation in daily life: links to depressive symptoms and problem behavior. Child Develop 2003;74:1869–80.
[73] Simons LE, Sieberg CB, Carpino E, Logan D, Berde C. The fear of pain questionnaire (FOPQ): assessment of pain-related fear among children and adolescents with chronic pain. J Pain 2011;12:677–86.
[74] Soltani S, Kopala-Sibley DC, Noel M. The co-occurrence of pediatric chronic pain and depression: a narrative review and conceptualization of mutual maintenance. Clin J Pain 2019;35:633–43.
[75] Tottenham N, Hare TA, Casey BJ. Behavioral assessment of emotion discrimination, emotion regulation, and cognitive control in childhood, adolescence, and adulthood. Front Psychol 2011;2:39.
[76] Vervoort T, Logan DE, Goubert L, De Clercq B, Hublet A. Severity of pediatric pain in relation to school-related functioning and teacher support: an epidemiological study among school-aged children and adolescents. PAIN 2014;155:1118–27.
[77] Von Korff M, Ormel J, Keefe FJ, Dworkin SF. Grading the severity of chronic pain. PAIN 1992;50:133–49.
[78] Wiech K, Tracey I. The influence of negative emotions on pain: behavioral effects and neural mechanisms. Neuroimage 2009;47:987–94.
[79] Williams WC, Morelli SA, Ong DC, Zaki J. Interpersonal emotion regulation: implications for affiliation, perceived support, relationships, and well-being. J Pers Soc Psychol 2018;115:224–54.
[80] Wilson K, Gullone E, Moss S. The youth version of the positive and negative affect schedule: a psychometric validation. Behav Change 1998;15:187–93.
[81] Zeman J, Cassano M, Perry-Parrish C, Stegall S. Emotion regulation in children and adolescents. J Dev Behav Pediatr 2006;27:155–68.
[82] Zhao X, Lynch JG Jr, Chen Q. Reconsidering Baron and Kenny: myths and truths about mediation analysis. J Consumer Res 2010;37:197–206.