Emotion Regulation Predicts Pain and Functioning in Children With Juvenile Idiopathic Arthritis: An Electronic Diary Study

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Objectives This study utilized e-diaries to evaluate whether components of emotion regulation predict daily pain and function in children with juvenile idiopathic arthritis (JIA). **Methods** 43 children ages 8–17 years and their caregivers provided baseline reports of child emotion regulation. Children then completed thrice daily e-diary assessments of emotion, pain, and activity involvement for 28 days. E-diary ratings of negative and positive emotions were used to calculate emotion variability and to infer adaptive emotion modulation following periods of high or low emotion intensity. Hierarchical linear models were used to evaluate how emotion regulation related to pain and function. **Results** The attenuation of negative emotion following a period of high negative emotion predicted reduced pain; greater variability of negative emotion predicted higher pain and increased activity limitation. Indices of positive emotion regulation also significantly predicted pain. **Conclusions** Components of emotion regulation as captured by e-diaries predict important health outcomes in children with JIA.

Key words arthritis; children; electronic daily diary; emotion; pain.

Introduction

Juvenile idiopathic arthritis (JIA) is a chronic inflammatory disease in which arthritis is present in one or more joints for at least 6 weeks with the age of onset prior to 16 years (Duffy, Colbert, Laxer, Schanberg, & Bowyer, 2005). Despite aggressive treatment with contemporary medicines that reduce systemic inflammation, daily pain and accompanying impairments in functioning persist for a subset of children with this disease (Gutiérrez-Suárez et al., 2007; Schanberg, Anthony, Gil, & Maurin, 2003). Research therefore is needed to help determine variables that predict severity of pain and functional limitations in children with JIA.

The role of negative emotion in the experience of pain and functional disability has received particular attention in studies of painful pediatric conditions. According to the biopsychosocial model of pain (Gatchel, Peng, Peters, Fuchs, & Turk, 2007), emotions influence the perception of pain and the extent of functional impairment. For example, prior studies in children with sickle cell disease using paper and pencil diary methodology have shown that increased levels of negative emotions reliably predict increased pain and reduced involvement in normal daily activities (Gil et al., 2003). Similarly, prior paper and pencil daily diary studies in children with JIA have shown that pain and daily functional limitations are higher at times of more intense negative emotions (Schanberg, Gil, Anthony, Yow, & Rochon, 2005). Individual differences in severity of negative mood also have been found to uniquely predict which children with JIA have more severe pain (Packham, Hall, & Pimm, 2002). Thus, extant research has helped establish the role for levels of negative emotions in understanding in which children and for which periods of time pain and functional disability may be greater.

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What remains less clear is the extent to which regulation of emotion may impact pain and functioning. In the broader field of child development, the process by which emotions are regulated has increasingly become a focus for improving the understanding of child health outcomes (Hoeksma, Oosterlaan, & Schipper, 2004; Silk, Steinberg, & Sheffield-Morris, 2003; Zeman, Cassano, Perry-Parrish, & Stegall, 2006). Although definitions vary, emotion regulation generally is thought to comprise the process by which the intensity and expression of activated emotions are adaptively or maladaptively maintained or modulated (Cole, Martin, & Dennis, 2004). Whether regulation of emotion is considered adaptive depends on the goals for a given situation rather than emotion valence. For example, a prevailing perspective based on hedonistic theories of motivation is that the adaptive goal of emotion regulation is to attenuate discomfort or increase pleasure (Erber & Erber, 2000; Gross & Thompson, 2007; Morris & Reilly, 1987; Zeman et al., 2006). Since pain activates negative emotions and thereby invokes modulation efforts to reduce discomfort (Craig, 2003; Price, 2000; Zeman et al., 2006), studying components of emotion regulation may help understand the pain experience and associated activity limitations of children with JIA. In addition, given that children who have trouble attenuating negative emotions may seek to avoid emotionally activating situations (Zeman et al., 2006), these children may be more likely to reduce involvement in social and school activities.

To date, however, there has been little integration of the broader emotion regulation literature into the study of JIA. In the adult rheumatoid arthritis literature, data have demonstrated that individuals with difficulty regulating negative emotions are likely to have more prolonged or severe pain than individuals with less difficulty (e.g., Affleck et al., 1997; Hamilton, Zautra, & Reich, 2005, 2007). Further, the attenuation of high levels of negative emotions experienced on a given day predicts reduced pain on the next day in adult rheumatoid arthritis patients (Connelly et al., 2007). The only study explicitly addressing emotion regulation in children with JIA involved a sample of 53 adolescents (ages 12–18 years) who completed cross-sectional measures of emotion regulation strategies, internalizing problems, and quality of life (Garnefski, Koopman, Kraaij, & ten Cate, 2009). The primary finding of this study was that adolescents with JIA who used a putatively maladaptive emotion regulation strategy that involved sustaining negative emotions (rumination) were more likely to have internalizing problems and poorer quality of life. These results implied that individual differences in modulating negative emotion may predict important psychosocial outcomes in children with JIA. However, the cross-sectional methodology used did not permit the examination of differences in outcomes that occur when activated negative emotions are reduced or not. Conversely, the few prospective studies that have examined how emotion intensity levels are associated with pain and functioning in children with JIA (Schanberg et al., 2003, 2005) have not evaluated regulation of activated emotions per se and only examined emotional states once per day.

Objectives and Hypotheses of the Present Study

The primary objective of the current study was to evaluate the extent to which components of emotion regulation predict patterns of daily pain and functioning in children with JIA. In particular, we were interested in the extent to which differences in children's variability and attenuation of negative emotion predict pain and function. In addition to baseline measures of differences in children's ability to adaptively modulate negative emotions, electronic (e-) diaries were used to infer and evaluate emotion regulation processes over time *in vivo*. Study hypotheses were generated based on child development, pain, and emotion and motivation theories suggesting that consciously or reflexively attenuating activated negative emotions is a key component of adaptive emotion regulation (Bonanno, 2001; Craig, 2003; Erber & Erber, 2000; Kovacs, Joormann, & Gotlib, 2008). We hypothesized the following: (a) attenuation of activated negative emotion during brief periods of time will reliably predict reduced pain and functional limitations in children with JIA, (b) children assumed to have greater difficulty regulating negative emotion based on greater daily variability/instability in negative emotion levels will have greater overall pain and functional limitations, and (c) children assumed to have deficits in the ability to regulate negative emotion based on baseline self- and parent-report measures of emotion regulation will have greater pain and functional limitations. Finally, given that positive emotion regulation has been excluded from prior studies on the influence of emotions in JIA, we similarly explored the extent to which the upregulation and variability of positive emotion predicted levels of pain and functional limitations in children with JIA.

Methods

Participants

Study participants were recruited consecutively over 15 months from the population of children attending a pediatric rheumatology clinic at an academic medical center in the southeastern United States. Children diagnosed with

JIA were approached for recruitment if they were between the ages of 8 and 18 years and reported joint pain within the past 6 months. Children were excluded if they were (a) diagnosed with a comorbid disorder affecting their current pain and functioning (e.g., mood disorder, fibromyalgia, pervasive developmental disorder), (b) judged by a pediatric rheumatologist to have significant cognitive impairment or illiteracy that would limit understanding of study measures, (c) non-English speaking, (d) physically unable to complete e-diaries, or (e) not currently attending school.

A total of 65 families were approached for recruitment into the study. Of those approached, 14 (21%) declined. Reasons for declining included time constraints, lack of interest, and perceived inability to stay committed once enrolled. Five patients withdrew from the study prior to completion due to reported time constraints or difficulties with wireless signal reliability (for transmitting daily diary responses). Three additional patients were removed from the study by the principal investigator due to persistent lack of reliability in diary completion.

The final sample comprised 43 children (37 females) aged 8–17 years ($M = 13.2$ years, $SD = 2.7$). This sample size together with at least 25 repeated measurements per child is adequate for obtaining reliable parameter estimates in hierarchical linear analyses (Bosker, Snijders, & Guldemond, 2003; Moineddin, Matheson, & Glazier, 2007). The majority of participants self-identified as Caucasian (83%), followed by Black or African-American (14%) and Native Hawaiian or Other Pacific Islander (3%). Two patients (5%) identified as Hispanic. Grade in school ranged from 3 to 12, with 82% of children attending public schools and the remainder attending private schools. Of the sample, 13% were classified by the rheumatologist as having minimal disease severity, 46% mild, 35% moderate, and 5% severe. Primary caregivers were predominantly biological mothers (90%).

Procedure

Patients scheduled for evaluation in the pediatric rheumatology clinic were prescreened for inclusion criteria by a research assistant and reviewed with the study rheumatologist. A study information letter was sent to the families of potential participants approximately 1 week in advance of a scheduled appointment. During the baseline study visit, interested families provided written informed consent (and written assent for children at least 12 years of age) according to the requirements of the Institutional Review Board; children younger than 12 years of age were provided with a developmentally tailored description of the study and asked to provide verbal assent. Subsequently, enrolled children and their caregivers independently completed baseline self-report measures on computers in private rooms within the clinic.

Following completion of baseline measures, children were trained in use of the customized e-diaries on a Smartphone (T-Mobil Dash™) and completed an entry while supervised by a research assistant to demonstrate comprehension. Information on typical time for school, coming home from school, dinner, and bedtime was gathered from the family in order to program audible alerts to cue the child to complete a diary entry at selected times during the day. Data gathered via e-diary at each time point included pain characteristics, activity limitations, and intensity of positive and negative emotions. E-diaries are an established method for validly collecting daily data on pain, activities, and emotions from youth (Palermo, Valenzuela, & Stork, 2004; Suveg, Payne, Thomassin, & Jacob, 2010).

After completing baseline assessments and e-diary training, participants took the Smartphones home along with a printed instruction manual for reference. Participants were instructed to complete three surveys per day at the cued times for a total of 28 days. At the completion of each survey, data were uploaded from the phone automatically to a password-secured internet server through the phone's wireless data plan. In the rare instances in which no wireless signal was available, data were temporarily stored on the phone and automatically uploaded the next time a cellular or wireless fidelity (wi-fi) signal became available. Completion of the e-diaries was monitored through a secure online server by a research assistant. Families received regular, weekly calls from the research assistant in order to promote completion and to address any barriers to diary completion. At the end of the diary period, phones were returned in a prepaid mailer that was given to families at enrollment. Technical difficulties were rarely encountered with the e-diary methodology but included issues with cellular signal reception and server downtime. No phones were damaged or lost during data collection.

Measures

E-diary Emotion Regulation Measures

Items from the Positive and Negative Affect Schedule for Children (PANAS-C; Laurent et al., 1999) were used on the e-diary to capture the overall intensity of positively and negatively valenced emotions; these data subsequently were used for the purpose of deriving indices of inferred emotion variability and adaptive emotion regulation. Children were asked to rate the extent to which they currently felt each of five positively valenced and five negatively valanced emotion descriptors (e.g., ''happy,'' ''mad'') using a 3-point rating scale ranging from ''very slightly or not at

all'' to ''extremely.'' The average within-subject correlation between the positive and negative subscales for the current study was small ($r = -.27$), supporting the relative independence of the scales.

Index of Adaptive Emotion Regulation

To evaluate hypotheses pertaining to whether pain or functioning changes at times when a child's activated negative emotions are adaptively attenuated, we used a method of coding based on prior adult studies (Connelly et al., 2007; Paquet, Kergoat, & Dubé, 2005) that infers times of adaptive emotion regulation for each individual. We defined periods of activated negative emotions as any time for which children's PANAS-C negative emotion score was greater than 0.5 *SD* of his/her grand mean negative emotion score. We then examined the next consecutive time of assessment to determine if the negative emotion score had returned to the child's grand mean negative emotion score or lower; if so, a score of 1 was assigned to indicate adaptive attenuation of negative emotion, and if not, a score of 0 was assigned to indicate unregulated negative emotion. A missing value was assigned if no data was available at the assessment immediately following the period of activated negative emotions.

A similar method was used for defining adaptive regulation of positive emotions: We identified times at which children's PANAS-C positive emotion score was lower than 0.5 *SD* of the child's grand mean positive emotion score, and assigned a score of 1 if by the next time of assessment the positive emotion score had returned to the child's grand mean positive emotion score or greater; a missing value was recorded if no data were available at the consecutive assessment. For our sample, a total of 735 moments contained periods of activated negative emotions and 29% of these times were adaptively attenuated. A total of 1,418 moments contained periods of reduced positive emotions and 19% of these times were adaptively upregulated.

Emotion Variability

In order to evaluate the hypothesis that children with greater daily variability/instability of negative emotion levels would have greater overall pain and functional limitations, we adapted a method used by Silk et al. (2003) to compute an index representing a child's tendency to have greater emotional ups and downs. A ratio was computed of each child's aggregate standard deviation of negative emotion scores relative to his/her grand mean of negative emotion scores; higher scores indicate greater variability of negative emotions. A similar index was derived for positive emotions. For our sample, scores ranged from .05 to .52 (positive emotion variability) and from .03 to .46 (negative emotion variability).

Cross-Sectional Measures of Emotion Regulation

Both a parent and a child report questionnaire were used at baseline to quantify individual differences in children's ability to adaptively regulate negative emotions.

Child Self-Reported Emotion Regulation

The Children's Emotion Management Scale (Zeman, Shipman, & Penza-Clyve, 2001) is a child self-report measure that assesses individual differences in maladaptive attenuation of sadness and anger (e.g., ''I whine/fuss about what's making me sad'') and in use of adaptive coping strategies in emotion-eliciting situations (e.g., ''I try to calmly deal with what is making me mad''). Children respond to items using a scale ranging from 1 (hardly ever) to 3 (often). Adapting the method used by Suveg et al. (2010), item scores from the three subscales (maldaptive inhibition, dysregulated expression, and emotion regulation coping) were reverse-scored and averaged to form a composite index of maladaptive emotion regulation. The possible range of mean scores therefore was 1 to 3, with higher scores reflecting greater problems with regulating negative emotions. Adequate construct validity has been demonstrated for the study age range in healthy children and children with mood disorders (Suveg & Zeman, 2004; Zeman et al., 2001). Internal consistency (Cronbach's α) for the composite index in the current sample was .78.

Parent Report of Child Emotion Regulation

The Emotion Regulation Scale (Shields & Cicchetti, 1997) was administered as a parent proxy report of child emotion regulation. The Emotion Regulation Scale comprises 10 questions that ask parents to describe their child's ability to attenuate negative emotional arousal in optimal ways using a 5-point agreement scale (e.g., ''tends to go to pieces under stress'' and ''overreacts to minor frustrations''). A mean composite score was formed for analyses with a possible score range of 1–5; higher scores suggest that a given child has greater problems in attenuating negative emotions. The measure has been found to have good internal consistency, good convergent validity with observational and interview measures of emotion regulation, and the ability to differentiate between ''well-regulated'' and dysregulated school-aged children (Shields & Cicchetti, 1997). Cronbach's alpha for the total score for the current sample was .82.

Outcome Measures

Pain and functional limitations were assessed via e-diaries.

Pain

Current pain intensity was quantified using a horizontal visual analog scale with anchors ''no pain'' to ''worst possible pain.'' A 50 mm horizontal line that was half-filled in with blue color was shown on the Smartphone screen and children were asked to move the filled-in portion of the line up or down to represent their current pain level. Scores were transformed to a 0–100 scale. An electronic visual analog scale previously was validated for the measurement of pain intensity in children and adolescents with JIA (Stinson et al., 2008).

Functional Limitations

Social, academic, and physical functional limitations were assessed using questions derived from the Activity Scale for Kids (Young, Wiliams, Yoshida, & Wright, 2000), which primarily assesses physical function/activities of daily living, and the Child Activity Limitations Questionnaire (Palermo, Lewandowski, Long, & Burant, 2008), which primarily measures academic and social functioning. Children were asked to report the extent of difficulty they were having with each of eight items during each daily time interval using a 4-point scale ranging from ''Not very difficult'' to ''Extremely difficult.'' A different set of eight items were asked at the morning, afternoon, and evening assessments based on activities more likely to occur at those times. For example, a question about difficulties putting on clothes was asked in the morning assessment only, whereas questions about social activity limitations were asked at the afternoon and evening times. The same sets of morning, afternoon, and evening questions were asked during weekday and weekend times. Most school-related items were asked during afternoon assessments only if the child endorsed attending school on the given day; one school item about difficulties completing homework was asked regardless of whether or not the child attended school that day. An additive summary score was calculated for each time point, with higher scores indicating greater overall activity limitations. Internal consistency (Cronbach's α) for the total scale for this sample was .88 (morning), .94 (afternoon), and .91 (evening). Activity limitations were significantly correlated within the day ($r = .90$ between morning and afternoon, $r = .88$ between afternoon and evening, and .77 between morning and evening).

Analyses

Diary completion rates were compared by sex, age, disease severity, and aggregated pain intensity using independent sample *t*-tests or product–moment correlations. Data from the baseline and aggregated daily measures were summarized using means, variances, frequency distributions, and zero-order correlations. SPSS software was used for descriptive analyses.

Primary study hypotheses were evaluated using hierarchical linear models, which account for nesting of data by independently partitioning variance into within-child (Level 1) and between-child (Level 2) components. These models implicitly manage missing data by using all data available from children in the sample to generate maximum likelihood coefficient estimates. HLM software (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2004) was used for all hierarchical linear model analyses. To test Hypothesis 1, the dichotomous index of adaptive regulation of negative emotions at a given time was specified as a predictor of level of pain or functional limitations at that time. The derived model intercept coefficient of interest represented the average expected change in pain or functional limitations for intervals during which negative emotions were adaptively regulated; this coefficient and its standard error were tested against a *t*-distribution for statistical significance ($p < .05$). If the coefficient was significant and negative, this was interpreted as lending support for the study hypothesis that adaptive regulation of negative emotions is associated with reduced pain and activity limitations. A similar procedure was used to evaluate the extent to which upregulation of positive emotions predicted pain and functional limitations.

To test Hypothesis 2, scores on the derived index of variability of negative emotions were specified as a Level 2 predictor of overall level of pain and functional limitations. The derived slope coefficient of interest represented the expected difference from an average child's level of pain or functional limitations associated with a child one unit higher than the average child in variability of negative emotions. If the coefficient was significant and positive, this was interpreted as lending support for the study hypothesis that children having greater variability of negative emotions have greater pain and activity limitations. A similar procedure was used to evaluate the association of positive emotion variability with pain and functioning outcomes.

To test Hypothesis 3, scores on the cross-sectional measures of child emotion regulation (the Children's Emotion Management Scale and Emotion Regulation Scale) were separately specified as Level 2 predictors of overall level of pain and functional limitations. The derived slope coefficient of interest represented the expected difference from the average child's level of pain or functional limitations associated with a child one unit higher than the average child on the given cross-sectional measure of child emotion regulation. If the coefficient was significant and positive, this was interpreted as lending support for the study hypothesis that children having greater difficulty

with regulating negative emotions based on baseline self- and parent-report measures will have greater overall pain and functional limitations.

Results

Diary Completion

Children on average completed 2.06/3 assessments per day ($SD = 0.46$). Overall e-diary completion rates ranged from 41% to 100% of possible assessments. There were no significant relationships between completion rates and age, sex, disease severity, or pain intensity. However, children were reliably more adherent during the first two weeks ($M = 79\%$ completion, $SD = 18\%$) than the last 2 weeks ($M = 55\%$ completion, $SD = 24\%$), $t(92) = 2.85$, $p = .01$.

Descriptive Statistics and Zero-order Correlations

Table I presents descriptive statistics for the primary study variables. Results of zero-order correlations indicated that pain intensity was strongly related to activity limitations ($r = .67$, $p < .05$). Adaptive attenuation of negative emotions was associated with reduced pain intensity ($r = -.16$, $p < .05$) and reduced activity limitations ($r = -.18$, $p < .05$). For positive emotions, whether or not positive emotions were adaptively upregulated was not significantly associated with reduced pain intensity or activity limitations ($r = -.05$ and $-.06$, respectively).

With regard to emotion variability, greater variability of negative emotions was related to greater pain intensity ($r = .39$, $p < .05$) and activity limitations ($r = .31$, $p < .05$). Greater variability of positive emotions also was related to greater pain intensity ($r = .29$, $p < .05$) but was not significantly related to functional limitations ($r = .11$, $p = .47$). Figure 1 graphically shows differences in overall pain intensity levels for children in the upper and lower quartiles for variability of negative and positive emotions. Neither the parent- or child-reported baseline indices of emotion regulation were related to pain or activity limitations ($r = .02$–$.14$).

Primary Analyses

Hypothesis 1: Attenuation of Negative Emotions as a Predictor of Pain and Functional Limitations

We hypothesized that attenuating activated negative emotions to average or minimal levels would be associated with reduced pain and functional limitations. Results suggested that periods in which activated negative emotions were attenuated back to average or lower levels were reliably associated with reduced activity limitations ($b = -1.42 \pm .55$, $t(804) = -2.59$, $p = .01$). The association of successful attenuation of negative emotions with reduced pain was in the anticipated direction but not significant, $b = -2.31 \pm 1.46$, $t(804) = -1.59$, $p = .11$.

Hypothesis 2: Variability of Negative Emotions as a Predictor of Pain and Functional Limitations

We hypothesized that children assumed to have difficulty with regulating negative emotions based on greater variability in negative emotion levels will have greater overall pain and functional limitations. Results supported this hypothesis; children who had greater than typical variability of negative emotions also reliably had higher pain and functional limitations ($b = 55.68 \pm 22.94$, $t(41) = 2.17$, $p = .02$ and $b = 12.93 \pm 5.06$, $t(41) = 2.09$, $p = .02$, respectively).

Hypothesis 3: Baseline Differences in Child Emotion Regulation as Predictors of Pain and Functional Limitations

We hypothesized children with JIA identified by baseline cross-sectional measures as having greater problems with regulating negative emotions would have greater overall pain and functional limitations. Results did not support this hypothesis; children with greater problems with

Table I. *Descriptive Statistics for Pain Intensity, Activity Limitations, and Emotion Variables*

Variable	Grand *M* (*SD*)	Possible Range	Range of child means
Pain intensity	27.35 (21.08)	0–100	0.25–70.12
Activity limitations	5.73 (5.36)	0–32	0–23.00
Emotion regulation ability—child report (CEMS mean score)	1.87 (0.31)	1–3	1.19–2.36
Emotion regulation ability—parent report (ERQ mean score)	2.01 (0.68)	1–5	1.00–3.40
Negative emotion variability	0.25 (0.12)	0[a]	0.03–0.46
Positive emotion variability	0.24 (0.10)	0[a]	0.05–0.52
Adaptive regulation of negative emotions (% of moments)	12.74 (5.78)	0–100	2.50–22.45
Adaptive regulation of positive emotion (% of moments)	17.72 (5.59)	0–100	6.94–29.41

Notes. CEMS = 'Children's Emotion Management Scale; ERQ = Emotion Regulation Questionnaire.

[a]The upper limit depends on the standard deviation of the data (the numerator of this index) and therefore is not fixed.

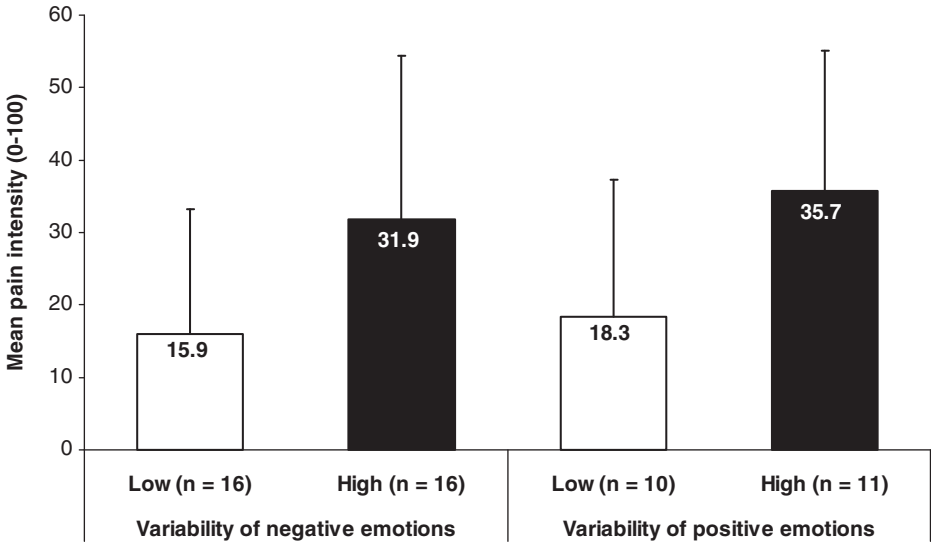

Figure I. Individual differences in pain intensity across days as a function of variability of negative and positive emotions. *Note*. "Low" and "high" groups represent the lower and upper quartiles, respectively. Error bars represent *SD*.

regulating negative emotions based on parent proxy report or child self-report did not have higher pain intensity ($b = -2.42 \pm 4.99$, $t(41) = -.48$, $p = .63$ and $b = 10.40 \pm 11.42$, $t(41) = 0.91$, $p = .37$, respectively). Similarly, children with greater problems with regulating negative emotions based on parent report or self-report did not have higher functional limitations ($b = 0.14 \pm 1.23$, $t(41) = -0.12$, $p = .90$ and $b = 2.32 \pm 2.75$, $t(41) = .84$, $p = .40$, respectively).

Positive Emotion Regulation as a Predictor of Pain and Activity Limitations

With respect to positive emotion regulation variables, periods during which positive emotions were upregulated to average or higher levels following a drop were associated with reduced pain ($b = -5.14 \pm 1.09$, $t(1549) = -4.71$, $p < .01$) but not with reduced activity limitations ($b = -0.11 \pm 0.39$, $t(1549) = -0.27$, $p = .79$). Similarly, children having greater than typical variability of positive emotions reliably had higher daily pain ($b = 60.29 \pm 27.64$, $t(41) = 2.18$, $p = .04$) but no greater activity limitations ($b = 5.88 \pm 4.77$, $t(41) = 1.23$, $p = .23$).

Discussion

Prior studies have found significant unaccounted for daily variability and individual differences in levels of pain and functional impairment experienced by comparably treated children with JIA. Based on biopsychosocial pain models and recent literature on the role of emotion regulation in children's health, the current study used both cross-sectional measures and e-diary methodology to examine the extent to which inferred emotion regulation indices predicted pain and function outcomes in children with JIA. Results indicated that attenuation of high levels of negative emotion predicted reduced activity limitations and to a lesser extent reduced pain. Children with greater daily instability/variability of negative emotion also reliably had greater pain and more functional limitation. In addition, upregulation of positive emotion following a time of low positive emotion predicted reduced pain; children with greater instability/variability of daily positive emotion reliably had higher overall pain. However, differences in children's ability to regulate emotion based on cross-sectional questionnaires did not reliably predict differences in children's level of overall pain or functional limitation.

Results of the current study regarding the potential benefits of attenuating activated negative emotion extend prior literature in pediatric psychology and child development. Prior studies have demonstrated that children with JIA tend to report more pain and reduced involvement in their usual school or social activities on days when they experience a high level of negative emotion (Schanberg et al., 2005). Individual differences in levels of anxiety also predict greater daily pain and reduced participation in social and school activities in children with JIA

(Schanberg et al., 2003). Further, coping strategies that prolong the experience of negative emotion have been shown to adversely affect quality of life in children with JIA (Garnefski et al., 2009). However, these prior studies did not directly evaluate how reducing elevated negative emotion intensity within particular time frames affects pain and function. From the child development literature, reducing negative emotion following a period of greater distress is thought to be an important aspect of adaptive emotion regulation, leading to better well-being. For example, children's difficulty ''repairing'' activated negative emotion within a brief (albeit yet undetermined) interval of time is theorized to determine risk for mood disorders and lead to peer rejection and avoidance of age appropriate activities (Kovacs et al., 2008; Zeman et al., 2006). In the present study, the inferred reduction of activated negative emotion between consecutive assessment times (average of 8.5 hr) was associated with fewer limitations in normal daily activities and, to some extent, reduced pain in children with JIA. Thus, further research into whether and how children with JIA reduce negative emotion once activated may suggest ways to optimize symptom control and daily function.

In the present study, individual differences in the extent of negative emotion variability within a day and over time also were an important predictor of overall pain and functional limitation. Prior studies in JIA have not directly examined stability of emotions. However, child development research has suggested that greater instability of negative emotion is a component of maladaptive emotion regulation and is linked to adverse outcomes such as depression (e.g., Silk et al., 2003). The mechanism linking high negative emotion variability to greater pain and activity limitation remains unknown. However, instability of negative emotion may share an underlying neurophysiological mechanism important in both the maintenance of inflammatory conditions and the perception of and response to pain (Craig, 2003; Price, 2000; Rosenkranz, 2007). Additional insights into important clinical outcomes in JIA, therefore, may be garnered in future studies by combining emotion regulation variables with physiological data (e.g., measurement of stress hormones and inflammatory mediators).

Contrary to study hypotheses, scores on parent- and self-report cross-sectional measures of emotion regulation did not predict greater daily pain or functional limitation. Conversely, indices of emotion regulation derived from e-diary methodology were significantly associated with study outcomes. One explanation for this difference may be that the former measures depend on self-awareness or observation of behaviors, whereas the latter measures were inferred from *in vivo* data on emotion intensity. Although both approaches capture important aspects of emotion regulation, our data suggest that prospectively assessing emotion regulation may be more informative for understanding differences in pain and function over time and between children with JIA.

Another unique feature of the present study was the effort to infer and evaluate components of positive emotion regulation. The exclusive focus on negative emotion regulation is common in the emotion regulation literature (Silk et al., 2003) and in prior research in children with JIA (Schanberg et al., 2003, 2005). However, developing theories in positive psychology have indicated that the processes by which individuals initiate and maintain positive emotions are relevant for buffering against stress and promoting healthy coping (Fredrickson, 2001). In the present study, we found that a rise in positive emotions back to normal or higher levels following a drop was related to reduced pain, whereas children with greater instability of daily positive emotions had higher overall pain. It is presently unclear why these significant findings for positive emotion regulation did not extend to activity limitation outcomes, whereas negative emotion regulation indices were significantly associated with activity limitation. However, indices of negative and positive emotion regulation in the present study were modestly related and therefore may differentially relate to outcomes. Future research might consider looking at regulation of types of positive emotions that vary in arousal level (e.g., excitement vs. calmness) to determine whether there are differences in impact on activity limitations and pain. With additional data in this area, pain interventions may be enhanced by incorporating strategies that promote successful positive emotion regulation (e.g., Berg, Snyder, & Hamilton, 2008).

There are several limitations to consider when interpreting the findings of the current study. The sample had minimal disease severity and was predominantly female, limiting generalizability of results and preventing meaningful evaluation of sex differences as a moderator in emotion regulation (Silk et al., 2003). It also is unclear from the present data what strategies children chose to regulate their emotions since emotion regulation was inferred in order to capture potential emotion regulation processes that did not require conscious awareness. Future work is needed to identify strategies that lead to successful emotion regulation and desirable clinical outcomes, since such data could then help guide interventions. Also, there was significant variability in children's adherence to completing thrice daily e-diaries (41–100%) and children tended to be less adherent in completing diaries over time; thus, the data analyzed may have not been entirely representative of typical days

for all children in the sample. In addition, e-diaries rely on self-report and therefore inferences of this study assumed that children were aware of and accurately reported on internal states. It is possible that some observed associations between variables reflect reporting biases. Finally, although we evaluated how changes in emotions from a prior moment to a current moment related to current outcomes, we did not formally evaluate lag relationships among variables or establish directionality using this methodology. Future studies may consider additional time series analyses to evaluate emotion regulation relationships to outcomes over longer lag intervals.

In sum, this study provides initial support for the significance of emotion regulation processes in predicting pain and function outcomes in JIA and suggests that e-diary methodology may uniquely capture these predictive relationships. Future studies using mobile technology may extend the present findings by using mobile electronic devices as a medium not only for assessment but for intervention. For example, Smartphones could be used as a means of prompting the use of tailored emotion regulation strategies *in vivo*, at times of negative emotion spikes or positive emotion drops. Using these tools, it may be possible to guide children through a coping strategy in real time, with immediate feedback in order to improve pain and function in the moment.

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