

# Sex differences in the relationship between maternal fear of pain and children's conditioned pain modulation

Subhadra Evans  
Laura C Seidman  
Kirsten C Lung  
Lonnie K Zeltzer  
Jennie C Tsao

Pediatric Pain Program, Department of Pediatrics, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

**Background:** Parental behaviors, emotions, and cognitions are known to influence children's response to pain. However, prior work has not tested the association between maternal psychological factors and children's responses to a conditioned pain modulation (CPM) task. CPM refers to the reduction in perceived pain intensity for a test stimulus following application of a conditioning stimulus to a remote area of the body, and is thought to reflect the descending inhibition of nociceptive signals.

**Methods:** The present study examined sex differences in the association between maternal anxiety about pain and children's CPM responses in 133 healthy children aged 8–17 years. Maternal pain anxiety was assessed using the Pain Anxiety Symptoms Scale-20. In addition to the magnitude of CPM, children's anticipatory anxiety and pain-related fear of the CPM task were measured.

**Results:** Sequential multiple linear regression revealed that even after controlling for child age and general maternal psychological distress, greater maternal pain anxiety was significantly related to greater CPM anticipatory anxiety and pain-related fear in girls, and to less CPM (ie, less pain inhibition) in boys.

**Conclusion:** The findings indicate sex-specific relationships between maternal pain anxiety and children's responses to a CPM task over and above that accounted for by the age of the child and the mother's general psychological distress.

**Keywords:** diffuse noxious inhibitory controls, pediatric pain, mother-child relationship, cold pressor, pressure pain, laboratory pain

## Introduction

Parents are known to influence their children's pain responses. A plethora of studies demonstrate that parent verbalizations and behaviors are significantly related to the child's experience of pain.<sup>1–8</sup> Parental influences may manifest through behavioral social learning processes, such as when parents reinforce their child's pain-related distress and by modeling pain behaviors, through transmission of threat information and verbal information, or on a background of demonstrated fearful emotions.

The social learning route has been examined via pathways of pain modeling and reinforcement of pain distress. For example, children of mothers who were instructed to exaggerate pain during a child-observed cold pressor task had lower pain thresholds compared with controls.<sup>3</sup> Support for the role of parental attention or reinforcement is evident in studies showing that parental suggestions for coping and distraction techniques are associated with less pain in children undergoing immunizations.<sup>1</sup> Conversely, parental attention directed towards the pain, including empathy, criticism, apologies, and

Correspondence: Jennie C Tsao  
Pediatric Pain Program, Department of Pediatrics, David Geffen School of Medicine at UCLA, 22-464 MDCC, 10833 Le Conte Ave, Los Angeles, CA 90095-1752, USA  
Tel +1 310 825 0731  
Fax +1 310 794 2104  
Email [jtsao@mednet.ucla.edu](mailto:jtsao@mednet.ucla.edu)

reassurance, are related to greater child distress.<sup>2</sup> Laboratory studies show that children whose parents attend to their child's pain have substantially more symptom complaints than children of parents who distracted the child.<sup>4,6,7</sup>

One possible mechanism explaining the association between parent attention and perception of pain by the child involves the transmission of threat from parent to child; even reassurance may act as a signal to the child that the caregiver is anxious, thus exacerbating the child's distress.<sup>9</sup> Adults' fear of pain has been linked to their own pain reports,<sup>10</sup> and in adult patients with chronic pain, pain-related fear has been found to be more disabling than the pain itself.<sup>11</sup> In both clinical and healthy samples, higher levels of pain-related anxiety are related to heightened risk of pain and disability.<sup>12,13</sup> Although untested, it is possible that parental anxiety about pain also impacts children's pain behavior, possibly through modeling of pain escape behaviors or by providing a background of negative emotion.

Subtle information in the form of parental fear and anxiety can transmit powerful messages to children regarding the noxiousness of pain. In a study of maternal emotional state and children's surgery-related behavior, children whose mothers roomed in for at least one night showed more distress behaviors than children whose mothers did not room in. Moreover, the degree of maternal fear and anxiety was associated with children's distress behaviors.<sup>14</sup> Parental distress and catastrophizing about the child's pain has also been linked to functional disability<sup>15</sup> and heightened experience of pain in children.<sup>16</sup> Support also exists for the role of parents' self-directed cognitions and emotions about pain and the child's perception of pain. Parental catastrophizing about their own pain has been linked to protective responses towards children, in turn predicting children's functional disability.<sup>17</sup> There is also evidence to suggest that the influence of parental anxiety on children's pain responses may differ depending on the sex of the child. We previously found that parents' own anxiety sensitivity (fear of anxiety symptoms) was related to healthy children's laboratory pain intensity, but only in girls.<sup>18</sup> These findings support potential sex differences in the relationship between parental pain anxiety and their child's pain responsivity.

To our knowledge, no published studies have examined sex differences in the relationship between maternal psychological factors, including the mother's anxiety about her own pain and her children's conditioned pain modulation (CPM), also known as diffuse noxious inhibitory controls, a dynamic test paradigm designed to assess the functioning

of endogenous pain inhibitory systems.<sup>19</sup> Deficits in CPM may reflect impairments in central descending inhibitory systems that have been posited as an underlying mechanism in chronic pain.<sup>20</sup> In addition to the magnitude of CPM, we also assessed anticipatory anxiety about CPM and pain-related fear. To account for the possibility of general maternal emotional distress overshadowing the specific role of maternal pain anxiety, we also controlled for maternal global psychological distress. Consistent with our previous findings,<sup>18</sup> we hypothesized that maternal pain anxiety would be more closely related to CPM responses in girls than in boys.

## Materials and methods

### Participants

The participants were 133 healthy children and adolescents aged 8–17 years and their mothers (see Table 1 for demographic information). The sample was recruited through advertisements and community events, and by referrals from previous participants. Study advertisements were posted on online forums (eg, Craigslist) and physical locations (eg, libraries). Study staff also recruited participants at community events, such as festivals and fairs. Previous participants were offered the opportunity to refer their friends/neighbors and to earn an additional \$25 for each family they referred that completed the study.

Eligibility was confirmed by telephone. A research assistant asked parents whether they or their child met any of the following exclusion criteria: acute illness or injury that would potentially impact laboratory performance (eg, fever) or could affect sensitivity of the extremities (eg, Raynaud's disease); daily use of opioids; developmental delay, autism, or significant

**Table 1** Demographic data for children and mothers

	Children (n = 133)	Mothers (n = 133)
Sex [female – n (%)]	70 (52.6%)	133 (100%)
Mean age, years ± SD	13.0 ± 2.9	43.2 ± 7.3
<b>Ethnicity, n (%)</b>		
Hispanic/Latino	41 (30.8%)	37 (27.8%)
Non-Hispanic/non-Latino	92 (69.2%)	96 (72.2%)
<b>Race, n (%)</b>		
White	56 (42.1%)	67 (50.4%)
African-American	33 (24.8%)	34 (25.6%)
Asian	2 (1.5%)	4 (3.0%)
American Indian/Alaska Native	1 (0.8%)	1 (0.8%)
Native Hawaiian/other Pacific Islander	0 (0%)	2 (1.5%)
Multiracial	38 (28.6%)	21 (15.8%)
Unspecified	3 (2.3%)	4 (3.0%)

**Abbreviation:** SD, standard deviation.

anatomic impairment that could preclude understanding of the study procedures or participation in pain induction procedures. Written informed consent forms were completed by parents, and children provided their written assent. The study was approved by the UCLA institutional review board. Each participating family member received \$50 cash for their participation.

## Procedures

The study procedures have been described in detail elsewhere.<sup>21</sup> Briefly, participants were greeted and escorted to separate rooms, with no contact between parent and child until after the session was completed. Participants provided their informed consent/assent and then completed questionnaires. Participants were interviewed by a research assistant about their recent pain history. Child participants were then escorted into the laboratory where they were instructed on the use of the 0–10 Numerical Rating Scale (NRS, described below). After completing a series of pain tasks (described elsewhere<sup>21</sup>), the CPM task was administered.

## Conditioned pain modulation task

The CPM task has already been described in detail.<sup>22</sup> Briefly, the CPM protocol measured pain ratings for a test stimulus (5 seconds of pressure to the left thumbnail) when it was administered: alone (TS1); during a conditioning pain stimulus (30 seconds of cold water immersion of the right hand, TS2); 15 seconds after termination of the conditioning pain stimulus (TS3); and 50 seconds later (TS4). Pain ratings using the 0–10 NRS were made immediately following administration of each test stimulus. For the test stimulus, pressure stimuli were applied to the fixed thumbnail of the left hand using a 1 × 1 cm hard rubber probe. The rubber probe was attached to a hydraulic piston, which was controlled by a computer-activated pump to provide repeatable pressure-pain stimuli of rectangular waveform.<sup>23</sup> The amount of pressure applied to the thumbnail remained constant for all four pressures and was individually selected from 24 possible values based on the participant's rating of moderate (6/10 NRS) pressure pain as determined by an earlier task. For the conditioning stimulus, participants submerged their right hand up to approximately 2 inches above the wrist in a cold pressor unit which maintained the water temperature at 5 degrees Celsius and circulated the water to prevent localized warming around the hand.

## Measures

A 0–10 NRS was used to assess pain and anxiety/fear during the laboratory session. Participants were instructed that

0 meant “none” and 10 meant the “worst or most possible”, and that the higher the number, the more pain or anxiety/fear they felt. The NRS has been validated in children 8 years of age and older.<sup>24</sup>

Pain intensity was assessed immediately following each administration of the test stimulus; participants rated the highest level of pain during the trial using the NRS. Anticipatory anxiety was assessed prior to the CPM task and was rated on the NRS. Participants were asked how nervous, afraid, or worried they felt about the upcoming task. Pain-related fear was assessed immediately after the end of the CPM task using the NRS. Participants were asked, at its worst, how nervous, afraid, or worried they felt during the task. The magnitude of CPM was calculated as a difference score between TS1 and TS2. Data for TS3 and TS4 are reported elsewhere.<sup>22</sup> More negative values for the amount of CPM indicate greater CPM and more positive values indicate less CPM.

The Pain Anxiety Symptoms Scale-20-Item Version (PASS-20)<sup>25</sup> was used to assess the mother's fear of pain and pain-related anxiety symptoms. The PASS-20 consists of four 5-item subscales, ie, cognitive, escape/avoidance, fear, and physiological anxiety, and has demonstrated reliability and validity (alpha values for the four subscales range from 0.75 to 0.86, and 0.91 for the total measure).<sup>25</sup>

The Brief Symptom Inventory-18-Item Version (BSI-18) Global Severity Index (GSI)<sup>26</sup> were used to assess mothers' general psychological distress. The GSI is comprised of three subscales, ie, somatization, depression, and anxiety. The BSI-18 has demonstrated reliability and validity. Coefficient alphas for the three subscales range from 0.74 to 0.84 (mean 0.79) and 0.89 for the total measure.<sup>26</sup>

## Results

Bivariate correlations between the parent and child measures were calculated separately for girls and boys, controlling for age of the child. For the PASS-20, in addition to the total score, dimensions corresponding to the following lower-order factors were examined: cognitive anxiety responses, escape and avoidance, fearful thinking, and physiological anxiety responses.

For multivariate analyses, separate sequential multiple regressions were used for each of the dependent variables, ie, CPM anticipatory anxiety, pain-related fear, and magnitude of CPM. To evaluate the relationship between PASS-20 total scores and the CPM variables, child age was entered in the first step of the regression analyses, followed by maternal GSI (step 2) and maternal PASS-20 score (step 3). Multivariate

analyses were conducted separately for boys and girls. Residuals were examined for violation of assumptions and outliers. A standard probability level of 0.05 was used for all analyses.

## Descriptive statistics and reliability

Table 2 shows the means and standard deviations for the maternal variables of global distress (BSI-18 GSI) and pain anxiety (PASS-20), and the child variables of CPM anticipatory anxiety, fear, and CPM magnitude by sex. Maternal scores on the BSI-18 GSI were within the normative range.<sup>26</sup> Mean and subscale scores for the mother and child variables did not differ between boys and girls. Child age was inversely correlated with CPM anticipatory anxiety ( $r = -0.18, P < 0.05$ ), indicating that older age was associated with less anxiety.

## Bivariate analyses

Partial correlations for boys and girls controlling for child age among the child and parent measures are shown in Table 3. For girls, CPM anticipatory anxiety and CPM pain-related fear were significantly related to the maternal PASS-20 total score (as well as the cognitive anxiety and physiological response subscales). CPM magnitude was not significantly related to the maternal variables in girls. For boys, neither CPM anticipatory anxiety nor CPM pain-related fear was significantly related to maternal PASS-20 or GSI. However, in boys, CPM magnitude was significantly related to maternal PASS-20 total score (as well as the escape/avoidance, fearful thinking, cognitive anxiety, and physiological subscales). Maternal GSI was not significantly related to any of the

CPM variables in boys or girls. Maternal GSI and PASS-20 were only modestly correlated, suggesting that these measures assess some overlapping, but also distinct, areas of psychological distress.

## Multivariate analyses

Results for sex-specific predictors of CPM magnitude and CPM anticipatory anxiety and pain-related fear are presented in Table 4A (girls) and 4B (boys). For CPM anticipatory anxiety in boys, child age (step 1) explained a significant portion of variance (7%), but neither maternal GSI (step 2) nor maternal PASS-20 (step 3) was significant. For CPM pain-related fear, none of the variables were significant predictors in boys. For CPM magnitude, neither child age (step 1) nor maternal GSI (step 2) accounted for a significant portion of the variance in boys. However, entry of maternal PASS-20 total scores (step 3) resulted in a significant incremental increase in the prediction of child CPM magnitude ( $t = 3.15; P = 0.00$ ), accounting for an additional 14% of the variance (see Table 4B). The full model containing all predictors accounted for 20% (16% adjusted) of the variance in CPM magnitude for boys. None of the variables were significant predictors for CPM anticipatory anxiety in boys.

For CPM anticipatory anxiety in girls, neither child age (step 1) nor maternal GSI (step 2) explained a significant portion of variance, but addition of maternal PASS-20 (step 3) contributed 9% of the variance ( $t = 2.45; P = 0.02$ ). The full model containing all predictors accounted for 12% (8% adjusted) of the variance in CPM anticipatory anxiety for girls (see Table 4A). For CPM pain-related fear in girls, only maternal PASS-20 (step 3) contributed a significant portion of variance (9%). For CPM magnitude in girls, none of the predictors accounted for a significant portion of the variance. Figure 1 shows the TS1 and TS2 pain and anticipatory anxiety ratings according to PASS-20 scores (categorized as above versus below the median) for boys and girls separately.

## Discussion

We hypothesized that maternal anxiety about pain would be more strongly associated with CPM responses in girls than in boys. However, we found more complex sex-specific relationships. In girls, higher maternal pain anxiety was related to greater anticipatory anxiety and fear of the CPM task. In boys, higher maternal pain anxiety was associated with less CPM, ie, less pain inhibition. The significant role of maternal pain anxiety in boys' CPM magnitude and girls' CPM anticipatory anxiety and pain-related fear was evident even

**Table 2** Child CPM variables and mother psychosocial variables

	Mean $\pm$ SD	
	Boys	Girls
Child CPM anxiety	4.05 $\pm$ 3.0	4.11 $\pm$ 2.9
Child CPM magnitude	-1.46 $\pm$ 2.0	-1.51 $\pm$ 2.3
Child CPM fear	4.31 $\pm$ 3.3	4.20 $\pm$ 2.8
Mothers' PASS-20 escape/avoidance subscale	9.63 $\pm$ 4.8	9.37 $\pm$ 6.2
Mothers' PASS-20 fear subscale	3.86 $\pm$ 4.5	3.87 $\pm$ 4.7
Mothers' PASS-20 cognitive subscale	8.21 $\pm$ 5.8	7.37 $\pm$ 5.8
Mothers' PASS-20 physiological anxiety subscale	3.48 $\pm$ 4.4	3.45 $\pm$ 4.5
Mothers' PASS-20 total score subscale	25.17 $\pm$ 16.5	23.67 $\pm$ 17.8
Mothers' BSI-18 Global Severity Index	6.95 $\pm$ 6.7	6.39 $\pm$ 6.0

**Note:** One mother had partially missing data so is not included in the physiological responses subscale or the total score.

**Abbreviations:** CPM, conditioned pain modulation; PASS-20, Pain Anxiety Symptoms Scale, 20-item version; BSI-18, Brief Symptom Inventory, 18-item version; SD, standard deviation.

**Table 3** Partial correlations (controlling for child age) among child and parent measures

	1	2	3	4	5	6	7	8
<b>Child CPM anxiety</b>								
Child amount of CPM	-0.311 <i>-0.010</i>							
Child CPM fear	0.838 <sup>b</sup> <i>0.815<sup>b</sup></i>	-0.278 <i>-0.128</i>						
Mother PASS-20 avoidance	0.202 <i>0.164</i>	-0.072 <i>0.382<sup>b</sup></i>	0.177 <i>0.091</i>					
Mother PASS-20 fearful thinking	0.204 <i>0.065</i>	-0.128 <i>0.351<sup>b</sup></i>	0.151 <i>-0.066</i>	0.523 <sup>b</sup> <i>0.536<sup>b</sup></i>				
Mother PASS-20 cognitive anxiety	0.333 <sup>b</sup> <i>0.227</i>	-0.071 <i>0.395<sup>b</sup></i>	0.306 <i>0.136</i>	0.599 <sup>b</sup> <i>0.720<sup>b</sup></i>	0.679 <sup>b</sup> <i>0.690<sup>b</sup></i>			
Mother PASS-20 physiological responses	0.298 <i>0.204</i>	-0.072 <i>0.339<sup>b</sup></i>	0.277 <i>0.058</i>	0.661 <sup>b</sup> <i>0.467<sup>b</sup></i>	0.703 <sup>b</sup> <i>0.756<sup>b</sup></i>	0.810 <sup>b</sup> <i>0.627<sup>b</sup></i>		
Mother PASS-20 total score	0.343 <sup>b</sup> <i>0.197</i>	-0.135 <i>0.431<sup>b</sup></i>	0.288 <i>0.071</i>	0.821 <sup>b</sup> <i>0.810<sup>b</sup></i>	0.827 <sup>b</sup> <i>0.864<sup>b</sup></i>	0.892 <sup>b</sup> <i>0.910<sup>b</sup></i>	0.905 <sup>b</sup> <i>0.819<sup>b</sup></i>	
Mother BSI-18 Global Severity Index	0.192 <i>-0.116</i>	-0.120 <i>0.235</i>	0.060 <i>-0.164</i>	0.251 <i>0.189</i>	0.315 <sup>b</sup> <i>0.387<sup>b</sup></i>	0.342 <sup>b</sup> <i>0.275<sup>a</sup></i>	0.374 <sup>b</sup> <i>0.296<sup>a</sup></i>	0.394 <sup>b</sup> <i>0.332<sup>b</sup></i>

**Notes:** <sup>a</sup>*P* < 0.05; <sup>b</sup>*P* < 0.01. Regular typeface indicates girls; italicized indicates boys.

**Abbreviations:** PASS-20, Pain Anxiety Symptoms Scale-20-Item Version; CPM, Conditioned Pain Modulation; BSI-18, Brief Symptom Inventory.

after accounting for the effects of child age and maternal general psychological distress. The findings are consistent with the notion of parental transmission of pain anxiety, and suggest that boys and girls are differentially affected by the cognitive, behavioral, and physiological aspects of this construct.

Fear of pain is an important affective process implicated in the development of chronic pain.<sup>27</sup> Individuals who respond to pain with anxiety or fear are more likely to engage in a vicious cycle of avoidance, increased pain perception, and worsening health than individuals who confront pain. However, the relationship between another family member's anxiety and fear of pain and an individual's own pain responses is less studied.

To our knowledge, no other work has examined maternal pain anxiety in relation to child responses to a CPM task.

Previous studies that have examined parental cognitions and emotions and associations with children's perception of pain have generally found that negative cognitive-affective experiences in the parent are linked to heightened pain or fear in children. Two types of study in this area can be differentiated. First are studies examining the impact of parental emotions and thoughts regarding the child's experience on the child's pain outcomes. For example, one study found associations between parental catastrophizing/fear about the child's pain and child-reported fear

**Table 4A** Multiple linear regressions of mother psychological measures and child age on child CPM responses for girls

Step	Variables entered	$\beta$	Model R <sup>2</sup>	Adjusted R <sup>2</sup>	Change in R <sup>2</sup>
CPM AA (DV)					
Step 1	Age	-0.060	0.004	-0.013	0.004
Step 2	Mother BSI GSI	0.180	0.036	0.004	0.032
Step 3	Mother PASS-20	0.325 <sup>a</sup>	0.124	0.080	0.088
CPM magnitude (DV)					
Step 1	Age	-0.227	0.051	0.036	0.051
Step 2	Mother BSI GSI	-0.100	0.061	0.031	0.010
Step 3	Mother PASS-20	-0.113	0.072	0.026	0.011
CPM fear (DV)					
Step 1	Age	-0.048	0.002	-0.014	0.002
Step 2	Mother BSI GSI	0.052	0.005	-0.028	0.003
Step 3	Mother PASS-20	0.320 <sup>a</sup>	0.091	0.045	0.086

**Notes:**  $\beta$  = Standardized regression coefficient; Model R<sup>2</sup> = coefficient of determination (goodness of fit) for overall regression model after entry of each independent variable; Adjusted R<sup>2</sup> = R<sup>2</sup> adjusted for number of IVs and sample size; Change in R<sup>2</sup> = incremental contribution of an independent variable to R<sup>2</sup> in the total set of independent variables. <sup>a</sup>*P* < 0.05.

**Abbreviations:** CPM, conditioned pain modulation; AA, anticipatory anxiety; BSI-18 GSI, Brief Symptom Inventory Global Severity Index; PASS-20, Pain Anxiety Symptoms Scale; DV, dependent variable; IV, independent variable.



**Table 4B** Multiple linear regressions of mother psychological measures and child age on child CPM responses for boys

Step	Variables entered	$\beta$	Model R <sup>2</sup>	Adjusted R <sup>2</sup>	Change in R <sup>2</sup>
CPM AA (DV)					
Step 1	Age	-0.261 <sup>a</sup>	0.068	0.052	0.068
Step 2	Mother BSI GSI	-0.115	0.081	0.049	0.013
Step 3	Mother PASS-20	0.255	0.139	0.093	0.057
CPM magnitude (DV)					
Step 1	Age	-0.106	0.011	-0.005	0.011
Step 2	Mother BSI GSI	0.236	0.066	0.033	0.054
Step 3	Mother PASS-20	0.395 <sup>b</sup>	0.204	0.162	0.139
CPM fear (DV)					
Step 1	Age	-0.199	0.040	0.023	0.040
Step 2	Mother BSI GSI	-0.163	0.065	0.033	0.026
Step 3	Mother PASS-20	0.137	0.082	0.034	0.017

**Notes:**  $\beta$  = Standardized regression coefficient; Model R<sup>2</sup> = coefficient of determination (goodness of fit) for overall regression model after entry of each independent variable; Adjusted R<sup>2</sup> = R<sup>2</sup> adjusted for number of IVs and sample size; Change in R<sup>2</sup> = incremental contribution of an independent variable to R<sup>2</sup> in the total set of independent variables. <sup>a</sup>P < 0.05; <sup>b</sup>P < 0.01.

**Abbreviations:** CPM, Conditioned Pain Modulation; AA, anticipatory anxiety; BSI-18 GSI, Brief Symptom Inventor-18-Item Version Global Severity Index; PASS-20, Pain Anxiety Symptoms Scale-20-Item Version; DV, dependent variable; IV, independent variable.

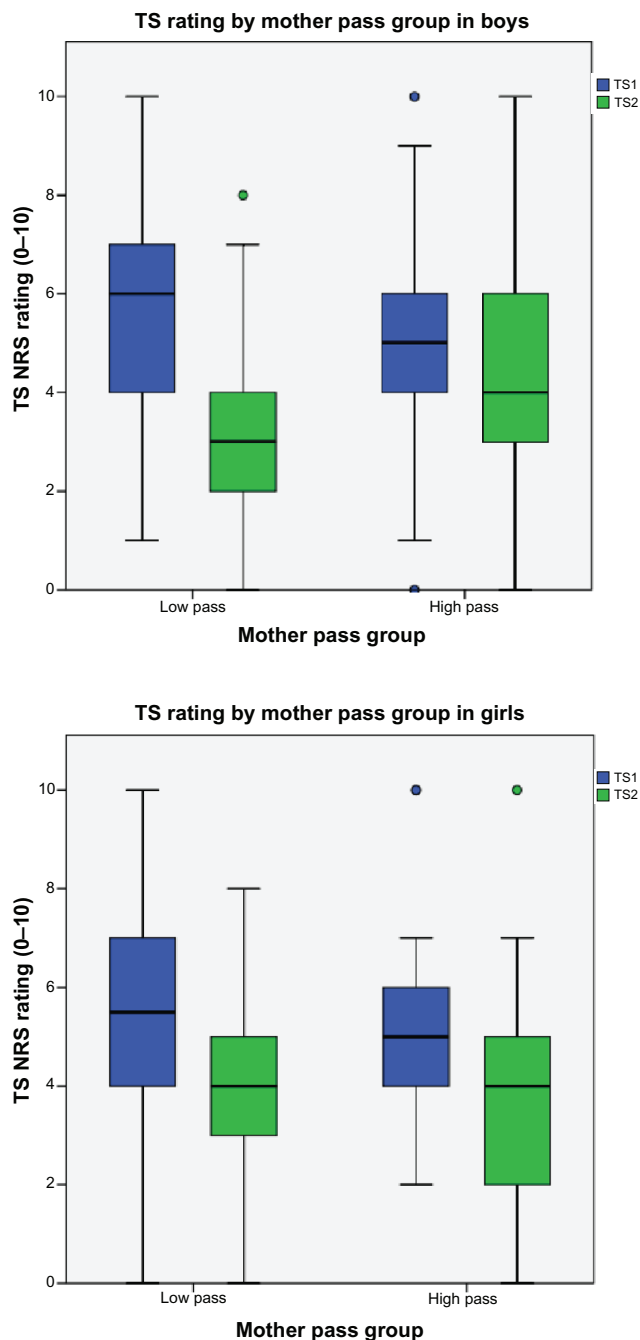
of medical procedures.<sup>28</sup> The child's sex was controlled in analyses, rather than examined separately, suggesting that the findings held for both boys and girls. Second are studies that have examined parents' self-directed negative emotions and thoughts and their children's pain outcomes. For example, parental self-directed catastrophizing has been linked to functional disability in children,<sup>17</sup> and we previously found parents' own anxiety sensitivity was related to girls' laboratory pain intensity.<sup>18</sup> Our findings sit with this literature, and together indicate that, whether parental fear of pain is specific to the child's experience or provides a general backdrop of negative emotion, children are adversely affected.

Our findings relate to a novel aspect of pain assessment, namely CPM, and thus go beyond previous investigations. CPM is thought to reflect central pain inhibitory processes and is relatively unstudied in children. We have also demonstrated relationships between maternal psychological factors and daughters' pain and anxiety responses to traditional, static laboratory pain tasks.<sup>18,29,30</sup> Both the current study and this prior research suggest alignment between mother and daughter pain-related psychological functioning. However, this is the first instance of a significant relationship between maternal psychological status and sons' pain responses in our work.

One limitation is that due to the correlational nature of the study design, we did not examine mechanisms and can only speculate about the possible pathways from maternal pain anxiety to girls' versus boys' CPM responses. Overall, our results support the theory of social referencing, in that the child is influenced by the mother's emotional state, with the

child referring to her for interpretation of events provoking anxiety. Over time, it is possible that mothers high in pain anxiety respond to their child's pain in an anxiety-provoking manner. Mothers may also indirectly fuel anxiety in their children by providing a model of fear in response to pain.<sup>5</sup> Our findings indicate that such maternal expressions of concern over pain may be of particular relevance to pain-related anxiety in girls. Perhaps the sex-specific relationships seen here are a product of sex-specific tendencies. Girls are at greater risk of anxiety symptoms than boys,<sup>31</sup> while CPM is more robustly observed in adult men than in adult women.<sup>32</sup> Maternal pain anxiety may be a powerful influence for children, with its impact manifesting in areas of development to which girls and boys are differentially susceptible. Such possibilities are speculative and require further study.

Additional limitations should be mentioned. As noted above, no statements regarding causality or the means by which maternal pain anxiety might affect the outcome of child CPM testing can be made. In addition, our study design cannot rule out the possibility that the reduction in test stimulus pain intensity during application of the conditioning stimulus was due to habituation rather than pain inhibition. The typical protocol for CPM testing in human subjects does not control for nonspecific effects due to the application of a second stimulus during administration of a test stimulus. However, two existing studies in adults found that the effects of CPM were not evident when a non-noxious stimulus (eg, immersion in room temperature water) was administered.<sup>33,34</sup> Future pediatric investigations should include non-noxious controls in order to isolate endogenous analgesic effects on CPM from nonspecific effects.<sup>34</sup> Second, we did not have



**Figure 1** Child test stimulus pain ratings by mother pain anxiety scores categorized by median split (high vs low).

**Abbreviations:** TS1, Test stimulus pain rating Time 1 (baseline); TS2, Test stimulus rating pain rating Time 2 (during conditioning stimulus); PASS, Pain Anxiety Symptoms Scale; NRS, Numeric rating scale (0 = no pain; 10 = worst pain).

sufficient data from fathers to determine whether fathers' versus mothers' pain anxiety differentially affects boys versus girls. Also, we did not examine the possible effects of parental involvement with child-rearing (eg, working parents versus stay-at-home parents; children raised by family members other than parents) on transmission of parental anxiety to children's pain-related responses. To our knowledge, no

existing work has investigated this topic, and it remains an important area for future research on parent-child pain relationships. Third, the sample included a wide age group, which on the one hand offers greater generalizability, but on the other, may have obscured findings relevant to one particular age group. In order to account for the possible effects of age upon the results, we controlled for age in all analyses. It was our intention to include a broad representation of children across childhood and adolescence.

## Conclusion

Low CPM, reflecting low pain inhibitory capacity, has been identified as a risk factor in the development of chronic pain.<sup>35</sup> The present findings suggest a particular influence of maternal pain anxiety on girls' anxiety related to such a "pain inhibits pain" task, and to the magnitude of an observed CPM effect for boys. The mechanisms underlying these associations should be explored in future research. It is possible that parental influences, such as anxiety about pain, have a profound developmental effect upon the emergence of central pain inhibitory systems, especially in boys. Longitudinal work addressing a range of parental psychological factors and the development of children's endogenous pain inhibitory capacity over time should be undertaken to parse out the cause and effect relationship between parental psychological health and children's central pain modulation. In addition, future research should investigate the extent to which children's central inhibitory pain processes may be influenced by interventions targeting pain-related anxiety in parents via behavioral modification.

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## Disclosure

The authors report no conflicts of interest in this work.

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