The associations between sleep disturbance, psychological dysfunction, pain intensity, and pain interference in children with chronic pain

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ABSTRACT

Objectives: This study aimed to better understand the associations between both sleep disturbance and psychological dysfunction (i.e., anxiety and depressive symptoms, and anger), and pain intensity and pain interference, in a sample of children with chronic pain.

Design: Cross-sectional design.

Methods: Three hundred and forty-two children with chronic pain (8-18 years) completed measures assessing pain intensity, pain interference, sleep disturbance, anxiety, depressive symptoms, and anger. Regression analyses examined the direct, interaction (with sex), and mediation effects of sleep quality and psychological dysfunction on pain intensity and interference.

Results: Sleep disturbance was significantly associated with both pain intensity and pain interference. However, measures of psychological dysfunction were associated significantly only with pain interference. Sex did not moderate these associations. The measures of psychological dysfunction mediated the associations between sleep disturbance and pain interference, but not those between sleep disturbance and pain intensity.

Conclusions: The results confirmed significant cross-sectional associations between both sleep disturbance and psychological dysfunction and pain outcomes in children with chronic pain. Future research to test for causal associations is warranted.

Keywords: adolescents; children; chronic pain; psychological dysfunction; sleep; pain interference

INTRODUCTION

Chronic pain is a common condition among children. Prevalence rates range from 11% to 38%, depending on the samples studied and how chronic pain is defined [1], and five to six percent of children have severe disabling pain [2]. Children with chronic pain usually report that pain interferes with both their physical function (e.g., inability to pursue hobbies or trouble moving; [3–5]) and psychological function (e.g., higher levels of anxiety or depressive symptoms compared to children without chronic pain; [6,7]). Moreover, psychological dysfunction has been found to be significantly associated with levels of pain intensity and pain interference in this population [8–11]. School and social function are also negatively impacted in children with chronic pain, who show higher school absenteeism, difficulties with peers' interactions, and peer victimization, compared to children without chronic pain [12,13].

Sleep is a common health domain that is impaired in children with chronic pain [14–17]. Common sleep problems related to chronic pain are insomnia (i.e., problems with falling asleep, maintaining sleep, feeling unrested, and daytime sleepiness), poor sleep quality, sleepwalking, sleep-related anxiety, and sleep bruxism [16]. Research has shown a positive and statistically significant association between poor sleep quality and pain in children with chronic pain [16,18,19]. These findings are consistent with the possibility that pain can cause sleep disturbances, that disturbed sleep can enhance pain perception, or that the relationship between pain and sleep quality is one of mutual causation in children. However, results in adult populations suggest that sleep

disturbance might be a stronger predictor of subsequent pain than pain a predictor of subsequent sleep disturbance [20]. In adolescents, study findings are mixed. One review concluded that sleep problems are not a risk factor for the onset of musculoskeletal pain [21]. Findings from prospective studies support these conclusions. For example, Mikkelsson and colleagues [22] found that sleep quality was not a risk factor for the onset of non-specific musculoskeletal pain in a sample of schoolchildren after 1 year and 4 years follow-up. Similarly, El-Metwally and colleagues [23] also found that sleep quality was not a risk factor for musculoskeletal pain in a sample of pre or early adolescents after 1 year follow-up[23]. However, in two recent studies (i.e., in a birth cohort study and in a primary care setting study), the presence of sleep problems was identified as a risk factor for having musculoskeletal pain [24,25]. In addition, there is evidence supporting a potential role for sleep disturbance in the transition from acute to chronic pain via sleep's effects on biological, psychological, and social factors [26] .

Valrie and colleagues [19] proposed a model to explain the association between sleep quality and pain in children. Their model poses a bidirectional relationship between pain perception and sleep which interacts with biological factors and mood. The latter variable, mood, is understood in their model as an individual's overall affective state (i.e., incorporating depressive symptoms, anxiety, general mood, and emotional distress), and is hypothesized to mediate the association between pain and sleep quality. The model also hypothesizes that specific factors moderate the associations between sleep, mood and pain (for example sex or ethnicity/culture). There is mounting evidence that positive and negative affect, sex, and ethnicity/culture may all play important roles. For example, Pavlova and colleagues [27]

found that not only depressive symptoms but also anxiety mediated the association between sleep and pain-related outcomes (specifically, pain intensity and pain interference) in a sample of children with chronic pain. Another study which examined the role of positive and negative affect on the associations between sleep quality and pain intensity or disability in a sample of children with chronic pain found that negative affect mediated the relationship between poor sleep quality and increased pain intensity and functional disability, whereas positive affect only explained the relationship between poor sleep quality and functional disability [28]. Previous studies that examined these associations were conducted with samples of children with chronic pain recruited in clinical settings. However, there are no studies that examined the same associations in community samples of children with chronic.

Anger, a negative affect factor [29], has also been found to be positively associated with pain intensity and impaired physical and emotional function, in children and adolescents with chronic pain [30]. There is also experimental data supporting an association between anger and sleep in adults. For example, a recent study found that sleep loss intensifies anger in a sample of healthy adults who were randomly assigned to either an experimental group in which sleep hours were restricted, or to a control group where sleep hours were kept as usual [31]. As a group, these studies indicate that additional research to identify the affect-related variables (both positive and negative) that reliably mediate the relationship between sleep and pain is warranted.

Valrie and colleague's model [19] also suggested that sex might be a factor that could influence the sleep-pain-mood association. However, the role of sex as a

moderator has yet to be completely elucidated given the inconsistency of findings, with some studies showing stronger effects for girls and others for boys. For example, one study with a sample of 28 children with persistent headache complaints and a control group of 108 healthy children showed that sex could play a moderating effect on the association between headache and sleep [32]. In this study, girls reported significantly poorer sleep quality, compared to boys. Similarly, sex was found to moderate the association between depression and anxiety symptoms and functional disability in children with chronic pain [33]. In this study, with a sample of 266 children with chronic pain, a composite score of depressive and anxiety symptoms was positively and significantly associated with disability in girls, but not in boys. Finally, another study found that lower levels of sleep quantity and quality were risk factors for musculoskeletal pain among girls, but not boys[34]. On the other hand, two studies found that having sleep problems was a risk factor for having musculoskeletal pain in boys, but not for girls[24,35]. More research to understand the role of sex as a potential moderator in the role that sleep quality has on pain, and *vice versa*, is needed.

Even though pain intensity and pain interference are related domains, there is evidence that they can show different responses to different pain treatments. For example, research has shown that pain interference responds more quickly to some psychological pain treatments, and also that pain interference is more strongly associated with psychosocial outcomes than is pain intensity[36,37]. Moreover, measures of psychological dysfunction show different patterns of associations with pain intensity and interference in children with chronic pain. For example, even though psychological dysfunction (i.e., depressive and anxiety symptoms) is related to pain interference[38,39],

depressive symptoms tend to be more strongly related to pain interference than pain intensity[40,41]. Thus, when seeking to understand the factors associated with pain and function, it is important to consider both pain intensity and pain interference as dependent variables.

Given these considerations, the primary aim of this study was to better understand the associations between both sleep disturbance and psychological dysfunction (i.e., anxiety, depressive symptom, and anger severity) and pain intensity and pain interference in a sample of children with chronic pain recruited from the community. We hypothesized that sleep disturbance and psychological dysfunction would be statistically significantly associated with pain intensity and pain interference. In addition, we sought to determine if child's sex moderated the associations between sleep disturbance and psychological dysfunction and the outcome variables (pain intensity and pain interference). Given previous research findings briefly summarized in this introduction, we hypothesized a significant moderating effect of sex between sleep disturbance and the outcome variables. Regarding the test for a moderating effect of sex on the associations between psychological dysfunction and the two outcome variables, no moderation effect for pain intensity was anticipated, whereas a moderation effect was hypothesized to emerge for pain interference. Given inconsistent findings with respect to the role of sex on the associations between sleep disturbance and psychological dysfunction and outcome variables in previous research, we did not make any *a priori* hypotheses respect to the direction of these effects here, and viewed the analyses as exploratory. Finally, we hypothesized that psychological dysfunction would mediate the associations between sleep disturbance and the

outcome variables. These analyses are considered as exploratory analyses, and are conducted here to provide an initial test of the factors that may mediate the effects of sleep disturbance on outcome variables.

METHODS

Participants

The study sample was recruited from primary and secondary schools in Reus, a city in the south-east of Catalonia, Spain, using convenience sampling. The inclusion criteria for the study were: (1) being between 8 and 18 years old; (2) being able to read, write and speak in Spanish; and (3) having chronic pain. Pain was considered chronic if it had lasted for at least three months, and there had been a minimum of one pain episode each week in the previous three months [42,43]. We chose one pain episode per week as a minimum cutoff in order to ensure that there was at least some regular recurrence of pain that could impact sleep. This cutoff is consistent with other studies conducted with children from the community[44–46]. Children were excluded if they had an intellectual disability that interfered with their participation in the study. Four hundred and seventy-seven children met the inclusion criteria for the study, however, just 342 completed all the measures and were included in the final analyses. In order to determine the number of subjects needed for the analyses, we computed the sample size needed to test the study hypotheses using a power analysis. The minimum number of participants required to conduct the multiple regression analyses was 279 to obtain a medium effect size (f^2=.15) with 10 predictor variables and a

probability of error of 0.01 using G*Power 3.1. [47,48]. We have reduced the probability error to 0.01 (instead of 0.05) in order to balance the need to control for alpha inflation due to multiple testing, against the need to minimize the risk for Type 2 error.

Procedure

Eighteen schools in Reus, Catalonia (Spain), were invited to participate in the study by sending them an email. Two primary schools, three secondary schools, and three schools which had the two education stages accepted to participate. According to International Standard Classification of Education (ISCED) [49], primary schools corresponds to ISCED level 1 and secondary schools to ISCED level 2 and 3. Following the acceptance of the school board, all parents of children aged from 8 to 18 attending these schools (N=3637) were asked to provide their consent to allow their children to participate. Of these, 38% agreed. However, even though 1382 parents agreed that their child could participate, only those children who met the inclusion criteria and were in the class the day that researchers collected data (477 children) were included in this study. Children were asked to respond to a paper-and-pencil survey within school time following the instructions provided by research staff. All study procedures were approved by the Ethics Committee of the Pere Virgili Institute (*Institut d'Investigació Sanitària Pere Virgili)*.

Measures

Demographic information

The study participants were asked to provide information regarding their sex, age, and school grade.

Pain characteristics: pain location, frequency, and intensity

Participants were asked to provide information about the characteristics of any pain problem(s) they had experienced in the last 3 months including their location, frequency, and intensity. We used a pain site checklist to assess pain location. It included 11 specific locations (i.e., head, neck, chest, shoulders, back, arms, hands, bottom/hips, belly/pelvis, legs, feet) and an "other" category. Pain frequency was assessed using a 5-point Likert scale (1 = "Every day, " 2 = "More than once a week," 3 = "Once a week," 4 = "One or twice times per month," 5 = "Once in the last 3 months"). Finally, children reported the usual (average) pain intensity in the last seven days for each location where they experienced pain. They were asked to report the usual pain intensity using a 0-10 Numerical Rating Scale (NRS-11) where 0 = "No pain" and 10 = "Very much pain." The NRS-11 has been shown to provide reliable and valid scores when used with children as young as 6 years old [50]. For participants who rated the average intensity of more than one pain problem, we used the highest rating as their average pain intensity in the analyses.

Pain interference

Pain interference was assessed using the Pediatric Patient-Reported Outcomes Measurement Information System (PROMIS) Pediatric Pain Interference 8a Short Form v2.0 [51]. The study participants were requested to indicate how often pain interfered with each of the eight activities during the last 7 days using a 5-point Likert scale (1=”Never,” 2=”Almost never,” 3=”Sometimes,” 4=”Often,” 5=”Almost always”). In order to obtain pain interference scores, direct scores were summed and transformed to T-scores (ranging from 0 to 100, with a mean score of 50 and standard deviation of 10). This scale has provided valid and reliable scores when used with children as young as 8 years old [51]. In the current sample, the measure showed a Cronbach’s alpha of 0.84. The Spanish short form used is available at http://www.healthmeasures.net/explore-measurement-systems/promis.

Sleep disturbance

To assess sleep disturbance, we used 5 sleep disturbance items of the item Bank v1.0 of the Pediatric Patient-Reported Outcomes Measurement Information System (PROMIS) [51]. Participants were asked to rate their sleep disturbance during the last 7 days rating on each item using a 5 point Likert scale (1 = ”Never,” 2 = ”Almost never,” 3 = ”Sometimes,” 4 = ”Often,” 5 = ”Almost always”). In order to obtain sleep disturbance scores, direct scores were summed and transformed to T-scores. The internal consistency of the measure in the current sample was good, with a Cronbach’s alpha of 0.85. Even though sleep quality is a multidimensional construct, we decided to use a single score reflecting sleep quality in the analyses, in order to minimize the number of tests conducted. We chose the PROMIS Sleep Disturbance scale for this

purpose because this measure includes items that assess a variety of sleep quality domains (such as sleep depth difficulties and concerns about getting to sleep or satisfaction with sleep) and scores from this scale have demonstrated validity and reliability when it is used with children[52–54].

Depressive symptoms and anxiety

Depressive symptoms and anxiety were measured using the depression and anxiety subscales of the Pediatric Patient-Reported Outcomes Measurement Information System (PROMIS) Pediatric-25 Profile Form v2.0. [51]. Participants were asked to rate the frequency with which they experienced 4 depressive and 4 anxiety symptoms in the last 7 days using a 5-point Likert scale (1 = ”Never,” 2 = ”Almost never,” 3 = ”Sometimes,” 4 = ”Often,” 5 = ”Almost always”). In order to obtain depressive symptoms and anxiety scores, direct scores were summed and transformed to T-scores. The Pediatric-25 Profile Form scales have been shown to be able to obtain reliable and valid scores of depressive symptoms and anxiety [51]. In this sample, the internal consistency of the scores was good for both scales (Depressive symptoms: Cronbach’s alpha = .84; Anxiety: Cronbach’s alpha = .85). The Spanish short form used in this study is available at http://www.healthmeasures.net/explore-measurement-systems/promis .

Anger

Anger was assessed using the Pediatric Patient-Reported Outcomes Measurement Information System (PROMIS) Pediatric Anger 5a Short Form v2.0. [51]. With this measure, study participants rated the frequency that they had five different anger responses in the last 7 days using a 5-point Likert scale (1 = ”Never,” 2 = ”Almost never,” 3 = ”Sometimes,” 4 = ”Often,” 5=”Almost always”). In order to obtain anger scores, direct scores were summed and transformed to T-scores. Research supported the reliability and validity of the Anger short form scores for assessing anger in children with cancer, rheumatic disease, and Sickle cell disease [51]. In our sample, the internal consistency (Cronbach’s alpha) of the measure used was good (α = .87). The Spanish short form used in this study is available at http://www.healthmeasures.net/explore-measurement-systems/promis.

Data analyses

We first computed percentages, means, and standard deviations of the sociodemographic and pain-related variables to describe the sample. Next, we evaluated the suitability of the data for the planned regression analyses by examining normality of residuals (normal predicted-probability plots), by using scatter plots to assess homoscedasticity (the extent to which error variance is constant for all predictor values) and, as well, by computing the variance inflation factors (VIF) to evaluate multicollinearity. We used two hierarchical regression analyses to test the first study hypothesis, that sleep disturbance and psychological dysfunction would be positively associated with the outcome variables (i.e., pain intensity and pain interference). In the first step of these analyses, we regressed each of the outcome

variables on sex as a control variable. Pain intensity was included as control variable only when the outcome variable was pain interference. In the second step, we entered sleep disturbance and the measures of psychological dysfunction (i.e., anxiety and depressive symptoms, and anger). Finally, in the third step, to test the second hypothesis that sex would moderate the association between sleep disturbance and psychological dysfunction and the outcome variables, we entered interaction terms of sex with sleep disturbance and sex with psychological dysfunction (i.e. Sex X Sleep Disturbance, Sex X Depression, Sex X Anxiety, Sex X Anger) as a block. The moderation models tested are shown in Figures 1 and 2. We planned to interpret any significant interaction effects that emerged using the visualization strategy recommended by Hayes and Rockwood [55], which involves computing regression lines representing the associations between the criteria and the sleep disturbance of girls and boys. All the assumptions for multiple linear regression analyses were met; that is, (1) the residuals of variables were normally distributed according to the normal predicted-probability plot (P-P) plots, (2) scatterplot of the residuals showed homoscedastic distribution, and (3) multicollinearity was not a problem in our sample (VIFs were lower than 10 except for interaction terms).

To confirm that age was not a main factor in these analyses, first we examined mean differences between the study variables between two age groups (the younger group, 8-12 years, and the older group, 13-18 years). Differences were not found for most variables, only pain intensity found a significant difference showing that pain intensity level was slightly higher in younger children than the older ones. Therefore, both groups were quite balanced. Second, we also conducted two regression analyses, one with the younger group and another one with the older group. Since we just found

differences in the regression analyses when the outcome variable was pain interference, in order to reduce complexity in the presentation of the results and reduce redundant information we decided not to include the stratified analyses for the pain intensity outcome.

Finally, in order to address the mediation hypothesis, we used bootstrap methods to estimate the confidence intervals for the total and specific indirect effects of the independent variable (i.e., sleep disturbance) to the outcome variables (i.e., pain intensity and pain interference) through the mediator variables (i.e., anxiety and depressive symptoms, and anger). The specific mediation models are illustrated in Figures 3 to 8 in the Results section.

We conducted mediation analyses in this cross-sectional design in order to provide an initial examination of the factors that may mediate the effects of the predictors on outcome, and that therefore should be examined more closely as mediators in future longitudinal studies. However, it is important to remember that the findings from these analyses cannot be used to draw casual conclusions.

[Insert Figures 1 and 2 about here]

All analyses were conducted using IBM SPSS Statistics 25 (IBM, https://www-01.ibm.com/support/docview.wss?uid=swg24043678, with the addition of the custom dialogs for SPSS (PROCESS) developed by Hayes (http://afhayes.com/introduction-to-mediation-moderation-and-conditional-process-analysis.html).

RESULTS

Sample characteristics

Of the 342 children with chronic pain who provided complete data for the study, 67% were girls. The mean age of participants was 12.67 years (SD=2.44, range= 8 to 18 years). The most common pain locations were the head (39%), the back (35%), and the legs (23%). Further information about the sample characteristics can be found in Table 1.

[Insert Table 1 about here]

Association between sleep and psychological dysfunction and pain intensity

The results of the regression analyses with pain intensity as the criterion variable are presented in Table 2. Only sleep disturbance and psychological dysfunction contributed significantly as a block (6% of the variance; ($F(4,336) = 5.37$, $p < .001$). However, after examining beta weights, just sleep disturbance ($\beta = .23$, $p < .001$) contributed significantly to the prediction of pain intensity, whereas the psychological dysfunction variables (i.e., depressive symptoms, anxiety, and anger) ($\beta = -.05$, $\beta = -.,04$ and $\beta = .09$; $p > .05$) did not. None of the interaction effects involving sex were statistically significant.

[Insert Table 2 about here]

Associations between sleep and psychological dysfunction and pain interference

The results of the regression analyses with pain interference as the outcome variable are presented in Table 3. Sex and pain intensity as a block explained 6% of the variance of the criterion ($F(2,339) = 11.00$, $p < .001$). Sleep disturbance and psychological dysfunction as a block also contributed to an additional 35% of the variance ($F(4,335) = 50.53$, $p < .001$). An examination of the beta weights indicated that the contribution of sleep disturbance and the three psychological dysfunction variables (i.e., depressive symptoms, anxiety, and anger) was similar, although anxiety (β = .23, p < .001) and anger (β = .22, p < .001) were somewhat stronger than sleep disturbance (β = .18, p < .001) and depressive symptoms (β = .17, p < .01). None of the interaction effects involving sex were statistically significant.

[Insert Table 3 about here]

Age stratified regression analyses for pain interference

Regression analyses for younger group showed that sex and pain intensity as a block did not significantly explain the variance of the criterion ($F(2,150) = 2.40$, $p > .05$). However, sleep disturbance and psychological dysfunction as a block contributed to 34% of the variance ($F(4,146) = 14.43$, $p < .001$). An examination of the beta weights indicated that the contribution of sleep disturbance and the three psychological dysfunction variables (i.e., depressive symptom, anxiety, and anger) was similar, although anger (β = .25, p < .01) was somewhat stronger than sleep disturbance (β =

.15, p < .05), anxiety (β = .19, p < .05) and depressive symptoms (β = .20, p < .05). In the older group, sex and pain intensity as a block explained a 10% of the variance of the criterion ($F(2,150) = 2.40$, $p > .05$) and sleep disturbance and psychological dysfunction as a block explained an additional 38% of the variance ($F(4,182) = 27.01$, $p < .001$). Beta weights showed that sleep disturbance (β = .20, p < .01), anxiety severity (β = .28, p < .001) and anger (β = .20, p < .01) significantly contributed, whereas depressive symptoms did not significantly contribute (β = .14, p > .05). None of the interaction effects involving sex were statistically significant in any of the age groups.

Psychological dysfunction as a mediator of the association between sleep disturbance and pain intensity

Depressive symptoms. We did not find support for a model with depressive symptoms as a mediator for the association between sleep disturbance and pain intensity (see Figure 3). Even though sleep disturbance was found to be significantly associated with depressive symptoms (*path a*: β=.37, t(340)=6.90, p < .001), depressive symptoms were not significantly associated with pain intensity (*path b*: β=-.00, t(339)=-.25, p=.80). Given that path *a* was statistically significant, but path *b* was not significant, the indirect effect was not tested. A diagram of the model is presented in Figure 3.

[Insert Figure 3 about here]

Anxiety symptoms. We did not find support for a model with anxiety as a mediator for the association between sleep disturbance and pain intensity (see Figure 4). Even though sleep disturbance was found to be significantly associated with anxiety (*path a*: β=.29, t(340)=5.08, p < .001), anxiety was not significantly associated with pain intensity (*path b*: β=-.00, t(339)=-.35, p=.73). Given that path *a* was statistically significant, but path *b* was not significant, the indirect effect was not tested. A diagram of the model is presented in Figure 4.

[Insert Figure 4 about here]

Anger. We did not find support for a model with anger as a mediator for the association between sleep disturbance and pain intensity (see Figure 5). Even though sleep disturbance was found to be significantly associated with anger (*path a*: β=.45, t(340)=6.74, p < .001), anger was not significantly associated with pain intensity (*path b*: β=.01 t(339)=.82, p=.41). Given that only path *a* was statistically significant, but path *b* was not significant, the indirect effect was not tested. A diagram of the model is presented in Figure 5.

[Insert Figure 5 about here]

Psychological dysfunction as a mediator of the association between sleep disturbance and pain interference

Depressive symptoms. Support for a model in which depressive symptoms was a mediator of the association between sleep disturbance and pain interference was found. Sleep disturbance was found to be significantly associated with depressive symptoms (*path a*: β = .37, t(340)= 6.90, p < .001), depressive symptoms was found to be significantly associated with pain interference *(path b*: β = .33, t(339)= 8.59, p < .001) and sleep disturbance was found to be significantly associated with pain interference (path c: β =.33, t(340) = 7.83, p < .001). Given that the *paths a* and *b* were statistically significant, the indirect effect was tested using the Bootstrapping method with bias-corrected confidence intervals, and the mediating role of depressive symptoms was confirmed (β = .12, CI = .08 to .17 at 95% confidence level, 5000 bootstrap resamples). The direct association between sleep disturbance and pain interference was still significant when controlling for the mediator (β = .20, t(340) = 5.08, p < .001). However, the β coefficient is lower than the β coefficient of the total effect (path c) consistent with the conclusion that the association between sleep disturbance and pain interference was partially mediated by depressive symptoms. A diagram of the model is presented in Figure 6.

[Insert Figure 6 about here]

Anxiety symptoms. A model in which anxiety mediated the association between sleep disturbance and pain interference was found to be significant. Sleep disturbance was found to be significantly associated with anxiety (*path a*: β = .29, t(340) = 5.08, p < .001), anxiety was found to be significantly associated with pain interference *(path b*: β = .32, t(339) = 8.88, p < .001) ,and sleep disturbance was found

to be significantly associated with pain interference (path c: β = .33, t(340) = 7.83, p < .001). Given that the *paths a* and *b* were statistically significant, the indirect effect was tested using the Bootstrapping method with bias-corrected confidence intervals, and the mediating role of anxiety was confirmed (β = .09, CI = .05 to .14 at 95% confidence level, 5000 bootstrap resamples). The direct association between sleep disturbance and pain interference was still significant when controlling for the mediator (β = .24, t(340) = 6.01, p < .001). However, the β coefficient is lower than the β coefficient of the total effect (path c), consistent with the conclusion that the association between sleep disturbance and pain interference is partially mediated by anxiety. A diagram of the model is presented in Figure 7.

[Insert Figure 7 about here]

Anger. We found evidence for a model in which anger mediated the association between sleep disturbance and pain interference. Sleep disturbance was found to be significantly associated with anger (*path a*: β= .45, t(340)= 6.74, p < .001), anger was found to be significantly associated with pain interference *(path b*: β= .26, t(339)= 8.57, p < .001) and sleep disturbance was found to be significantly associated with pain interference (path c: β =.33, t(340)= 7.83, p<0.001). Given that the *paths a* and *b* were statistically significant, the indirect effect was tested using the Bootstrapping method with bias corrected confidence intervals, and the mediating role of anger was confirmed (β = .12, CI = .08 to .17 at 95% confidence level, 5000 bootstrap resamples). The direct association between sleep disturbance and pain interference was still significant when controlling for mediator (β = .21, t(340) = 5.16, p < .001). However,

the β coefficient is lower than the β coefficient of the total effect (path c) which means that the association between sleep disturbance and pain interference was partially mediated by anger. A diagram of the model is presented in Figure 8.

[Insert Figure 8 about here]

DISCUSSION

Four keys findings emerged in this study with a sample of children with chronic pain from the community. First, as hypothesized, we found significant associations between sleep disturbance and both pain intensity and pain interference. These findings are consistent with the findings from previous studies that examined these associations in clinical samples of children with different chronic pain conditions [16,18,20,27,28], and extend these findings to children with chronic pain living in the community. Given the growing body of research showing consistent associations between sleep disturbance and key pain-related outcomes, an important next step is to more closely examine the causal associations between these variables. Indeed, Palermo and colleagues [56], in a 12-month longitudinal study with a sample of adolescents with and without chronic pain, found that insomnia persisted after one year, and that having chronic pain, poorer sleep hygiene, and more severe depressive symptoms were risk factors for insomnia over time. Additional longitudinal and longer follow-up studies are needed to confirm the validity of the findings reported by Palermo and colleagues in community samples from different cultural contexts and with different chronic pain conditions.

Second, and inconsistent with one of the study hypotheses, we found that the associations between measures of psychological dysfunction (i.e., depressive symptoms, anxiety symptoms, and anger) and pain intensity were weak and non-significant in our sample. These findings are inconsistent with the findings from previous studies that found measures of psychological dysfunction to be significantly associated with pain intensity [27,28,30]. One possible reason for the discrepant findings could be related to sample differences; that is, previous studies were conducted with children with chronic pain seen in clinical settings, while the current study was conducted with children with chronic pain living in the community. It is possible that psychological dysfunction may play a greater role in pain severity in clinical samples, who may have more pain intensity or distress than individuals in the community who are not necessarily seeking pain treatment. In fact, only 32% of children in our study sought treatment for their pain problem. Consistent with this idea, the samples in two of the previous studies examining these associations in children recruited from clinics reported pain intensity scores that were much higher than those in the sample studied here [28,30]. Research is needed to determine if this contextual factor (i.e., clinical *vs*. community setting) moderates the associations between psychological factors such as anger, anxiety, and depressive symptoms, and pain and function in children with chronic pain.

Third, we did not find support for a moderator role of the child's sex on the associations between sleep disturbance and psychological dysfunction and the two study outcome variables (i.e., pain intensity and interference). One possible reason for the discrepant findings across studies is how the variables are measured. For example,

sleep quality was measured using actigraphy in Bursztein and colleagues' study [32], whereas we used a self-report measure of sleep disturbance. Another potential reason for the inconsistent findings could be related to the characteristics of the different samples participating in the studies. For example, in the Kaczynski and colleagues' study [33], that showed sex moderated the association between pain interference and psychological dysfunction, the study sample were children with abdominal pain or headache only; whereas in this study participants had a much greater variety of pain conditions, including musculoskeletal pain. Moreover, as noted in the Introduction, findings with respect for the moderation effects of sex on the association between sleep disturbance and pain are inconsistent, with two studies showing stronger effects for boys [24,35], and other studies showing stronger effects for girls [32–34] . Additional research to evaluate the potential moderating role of sex on the associations between psychological function and pain outcomes differs as a function of different measures and the population being studied is warranted.

Finally, we found that none of the measures of psychological dysfunction (assessing depressive symptoms, anxiety, and anger) mediated the relationship between sleep disturbance and pain intensity. This finding is inconsistent with Valerie and colleagues' model [19] that hypothesizes such a mediation role. One possible reason for the null finding with respect to mediation is the use of a community sample with chronic pain, instead of clinical sample; as noted previously, other studies in this area have used samples recruited from clinical settings [28,57].

On the other hand, all of the measures of psychological dysfunction in the current study were found to mediate the association between sleep disturbance and

pain interference. This finding is consistent with Valrie and colleagues' model, and also with previous research [27,28]. This mediation effect can also be understood in light of the fear-avoidance model [58], which argues that psychological dysfunction (such as anxiety or depression symptoms) could enhance the fear and avoidance process, which then could result in a strengthening of the association between sleep disturbance and pain interference. Our findings also extend previous research by indicating that anger (a variable for which there was not previous evidence) also serves as a mediator. If these findings are replicated in future research, they would suggest that including anger management techniques in chronic pain programs could potentially help improve function in children with chronic pain who report poor sleep quality.

This study has some important limitations that should be considered when interpreting the results. First, we used a cross-sectional design, which makes it not possible to draw casual conclusions regarding the associations found [62]. Thus, we view the cross-sectional mediation analyses as an exploratory strategy that can be helpful to identify the associations that should be examined in future longitudinal studies. Second, all study variables were assessed using self-report measures. Thus, it is possible that some of the significant associations found could be due to shared method variance. Future research using objective measures of the variables under study (e.g., actigraphy to assess physical function and sleep quality) would help determine the role that shared method variance plays in the associations found. Third, because we used only a single measure of sleep quality (i.e., assessing sleep disturbance), the extent to which our findings generalize to the different more specific domains of sleep quality is not known. Thus, additional research that evaluates the

effects of different sleep quality domains on pain and pain interference is needed. Fourth, the participation rate in the study was low (38% of all schoolchildren invited), the majority of the participants (67%) were females, and the sample was from the community. Thus, the findings cannot be assumed to generalize to all schoolchildren with chronic pain. Future research with other samples, including more males and children seen in health care settings, is needed to help determine which of the study findings are reliable.

CONCLUSIONS

Despite the study's limitations, the results provide important new information regarding the role of sleep disturbance and psychological dysfunction in relation to pain intensity and function in children with chronic pain in the community. In particular, sleep disturbance was shown to be significantly associated with pain. Moreover, psychological dysfunction domains was supported as a mediator between sleep disturbance and pain interference. The findings indicate that research testing the beneficial effects of sleep management strategies to enhance psychological function as a part of pain treatment in children with chronic pain is warranted.

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FIGURE Titles and Legends

Figure 1. Moderation models for pain intensity

Figure 2. Moderation models for pain interference

Figure 3. Mediation model for pain intensity (depressive symptoms as mediator)

** p<.001
a = effect predictor on mediator; *b* = effect mediator on outcome; *c* = total effect outcome; *c'*= direct effect predictor on outcome (controlled for indirect effect)

Figure 4. Mediation model for pain intensity (anxiety symptoms as mediator)

** p<.001
a = effect predictor on mediator; *b* = effect mediator on outcome; *c* = total effect outcome; *c'*= direct effect predictor on outcome (controlled for indirect effect)

Figure 5. Mediation model for pain intensity (anger as mediator)

** p<.001
a = effect predictor on mediator; *b* = effect mediator on outcome; *c* = total effect outcome; *c'*= direct effect predictor on outcome (controlled for indirect effect)

Figure 6. Mediation model for pain interference (depressive symptoms as mediator)

** p<.001
a = effect predictor on mediator; *b* = effect mediator on outcome; *c* = total effect outcome; *c'*= direct effect predictor on outcome (controlled for indirect effect)

Figure 7. Mediation model for pain interference (anxiety symptoms as mediator)

** p<.001
a = effect predictor on mediator; *b* = effect mediator on outcome; *c* = total effect outcome; *c'*= direct effect predictor on outcome (controlled for indirect effect)

Figure 8. Mediation model for pain interference (anger as mediator)

** p<.001
a = effect predictor on mediator; *b* = effect mediator on outcome; *c* = total effect outcome; *c'*= direct effect predictor on outcome (controlled for indirect effect)

Table 1. Sample characteristics

Sex (N, %)	**N/Mean**	**SD/%**
Girls	223	65
Boys	119	35
Age (Mean, SD)	12.84	2.52
School Level (N, %)		
Primary school	113	33
Secondary school	229	67
Highest last 7 days usual pain intensity (Mean, SD)	5.82	2.30
Location of pain (N, %) *		
Head	138	40
Neck	70	21
Chest/breast	30	9
Shoulders	52	15
Back	126	37
Hands	31	9
Arms	35	10
Bottom/hips	14	4
Belly/pelvis	67	20
Legs	83	24
Feet	78	23
Other locations	33	10
Number of pain locations (N, %)		
1 pain location	145	42
2 pain locations	88	26
3 pain locations	56	16
4 pain locations	27	8
5 pain locations	9	3
6 pain locations	8	2
7 pain locations	8	2
11 pain locations	1	0
Children that visited a clinician for their pain	109	32
Pain intensity (Mean, SD)	5.82	2.30
Pain interference, T-score (Mean, SD)	53.71	8.73
Sleep disturbance, T-score (Mean, SD)	52.46	10.42
Depressive symtoms, T-score (Mean, SD)	54.99	11.01

Anxiety symtoms, T-score (Mean, SD)	55.74	11.45
Anger, T-score (Mean, SD)	53.86	13.64

Note: *Children could report more than one pain site.

Table 2. Results of the linear regression analysis for pain intensity in the last 7 days

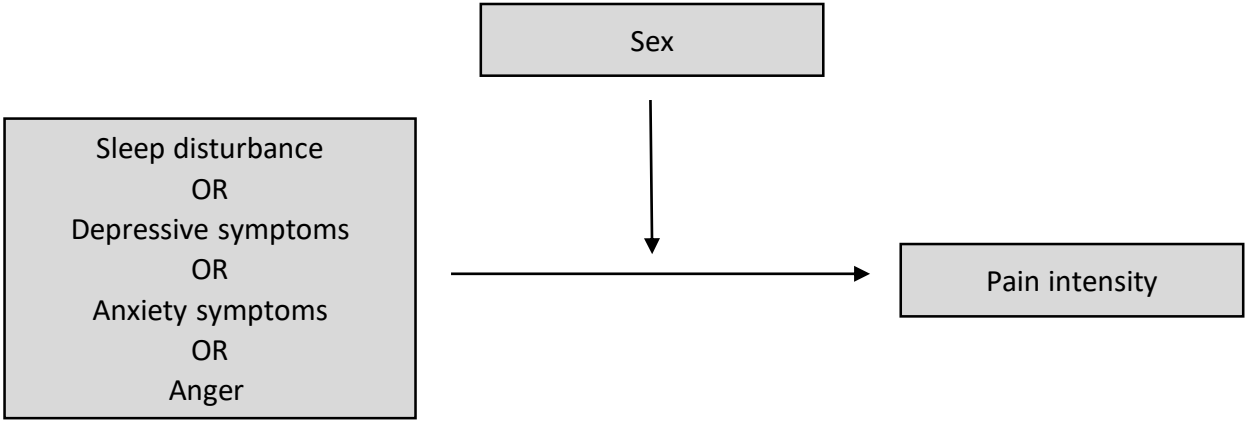
Step and variable	Total R^2	R^2change	F change	$Sd\ \beta$
Step 1	.002	.002	.63	
Sex				.04
Step 2	.06	.06	5.37**	
Sleep disturbance				.23**
Depressive symptoms				-.05
Anxiety				-.04
Anger				.09
Step 3: Interactions	.07	.01	.74	
Sex x Sleep Disturbance				.29
Sex x Depressive Symptoms				.35
Sex x Anxiety				.13
Sex x Anger				-.19

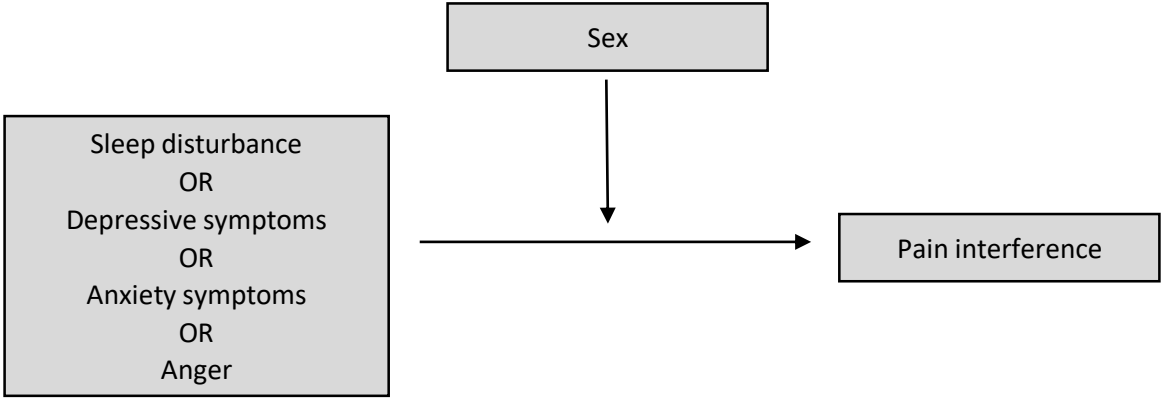
**p < .001

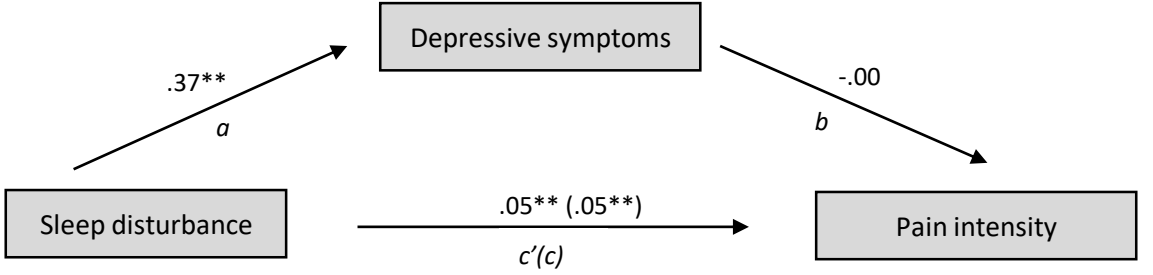
Table 3. Results of the linear regression analysis for pain interference in the last 7 days

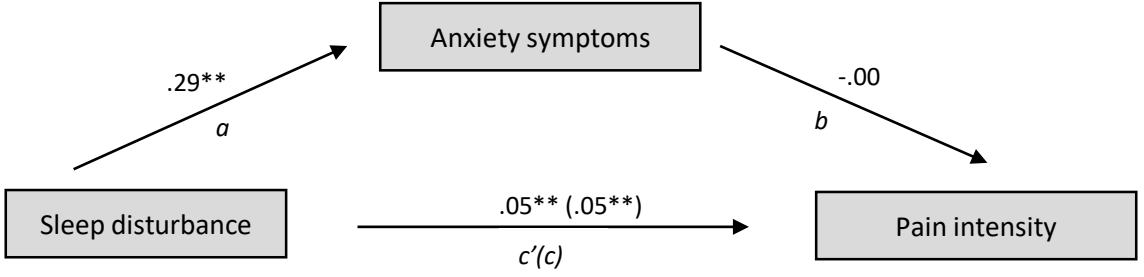
Step and variable	Total R^2	R^2change	*F* change	*Sd β*
Step 1	.06	.06	11.00**	
Sex				.15*
Pain intensity				.19**
Step 2	.41	.35	50.53**	
Sleep disturbance				.18**
Depressive symptoms				.17*
Anxiety				.23**
Anger				.22**
Step 4: Interactions	.42	.004	.51	
Sex x Sleep Disturbance				.07
Sex x Depressive Symptoms				.20
Sex x Anxiety				.06
Sex x Anger				-.33

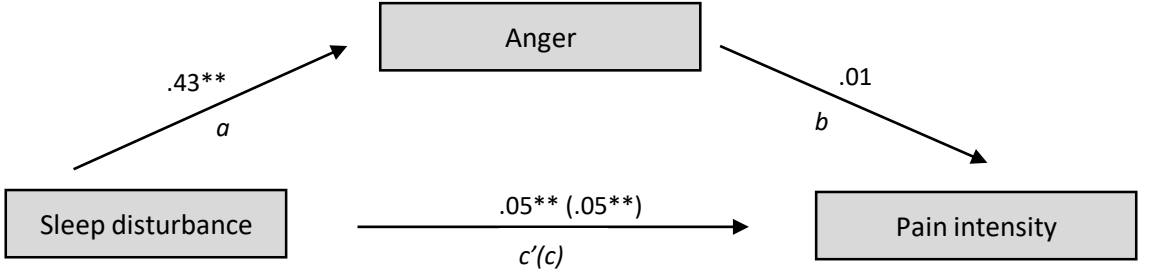
*p < .01 **p< .001

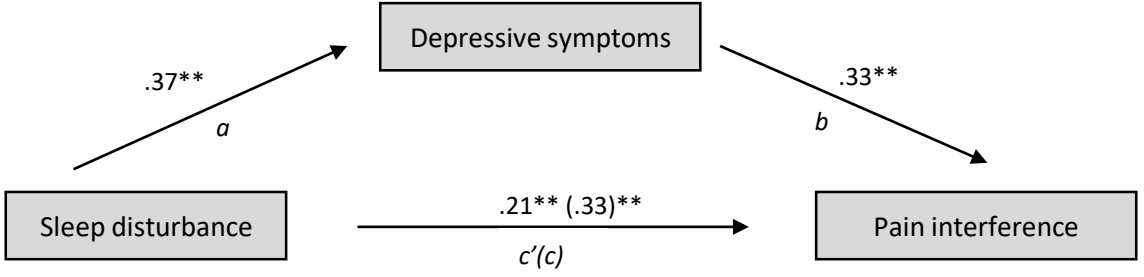

Sex
Sleep disturbance
OR
Depressive symptoms
OR
Anxiety symptoms
OR
Anger
Pain intensity

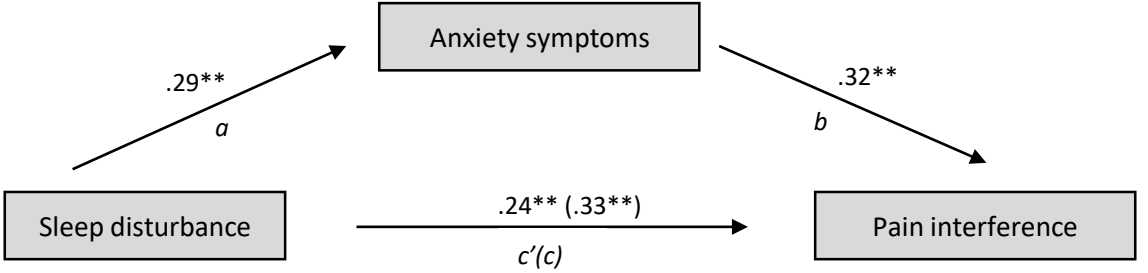

Sex
Sleep disturbance
OR
Depressive symptoms
OR
Anxiety symptoms
OR
Anger
Pain interference

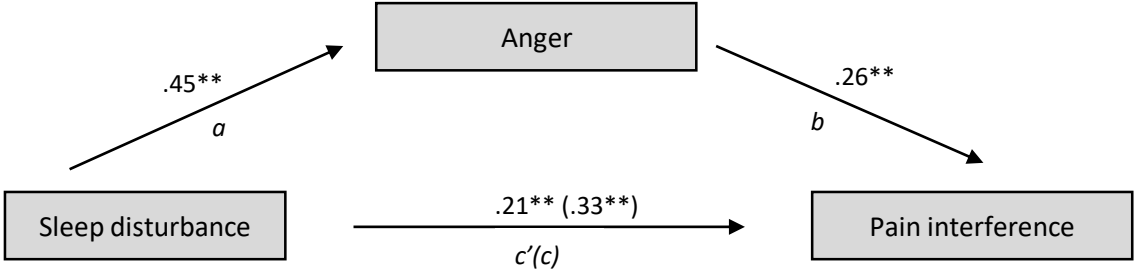

Depressive symptoms
.37**
a
-.00
b
Sleep disturbance
.05** (.05**)
c'(c)
Pain intensity


Anxiety symptoms
.29**
a
-.00
b
Sleep disturbance
.05** (.05**)
c'(c)
Pain intensity


Anger
.43**
a
.01
b
Sleep disturbance
.05** (.05**)
c'(c)
Pain intensity


Depressive symptoms
.37**
a
.33**
b
Sleep disturbance
.21** (.33)**
c'(c)
Pain interference


Anxiety symptoms
.29**
a
.32**
b
Sleep disturbance
.24** (.33**)
c'(c)
Pain interference


Anger
.45**
a
.26**
b
Sleep disturbance
.21** (.33**)
c'(c)
Pain interference