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# A Systematic Review of Sleep in Pediatric Pain Populations

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## Abstract

**Objective—**The primary aim of this systematic review was to examine the evidence for a pain-sleep relationship in children with persistent pain by reviewing studies using single and mixed pediatric persistent pain samples.

**Method—**Electronic searches of Medline, PubMed, the Cochrane Database of Systematic Reviews, and PsycINFO were conducted to identify all relevant empirical studies. Studies were included in the review if the majority of participants were between 0-17 years and from one of the following pediatric pain populations: juvenile idiopathic arthritis, sickle cell disease, migraine/ headache, functional abdominal pain, juvenile fibromyalgia syndrome, chronic musculoskeletal pain, or mixed populations including the aforementioned conditions.

**Results—**Research from single and mixed sample studies support the hypothesis that children and adolescents with persistent pain suffer from sleep impairment. Literature addressing factors that may influence or mediate the pain-sleep relationship and the functional outcomes of the pain-sleep relationship was reviewed, and a model of the interrelationships with pain and sleep developed.

**Conclusion—**Findings from this review highlight the need to assess and treat sleep problems in children presenting with persistent pain. Healthcare providers should consider conducting routine sleep screenings, including a comprehensive description of sleep patterns and behaviors obtained through clinical interview, sleep diaries, and/or the use of standardized measures of sleep. Future research focusing on investigating the mechanisms associating sleep and pediatric persistent pain and on functional outcomes of poor sleep in pediatric pain populations is needed.

### Keywords

adolescent; child; persistent pain; sleep

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Persistent or recurring pain is common, affecting 25-40% of community samples of children and adolescents.[1] Persistent pain may be a symptom of an underlying chronic health condition, such as juvenile idiopathic arthritis (JIA) or sickle cell disease (SCD), or the problem itself, such as migraine headaches. A concerning and common comorbidity of pediatric persistent pain is poor sleep, which may be characterized by difficulty falling or staying asleep, poor subjective sleep quality, short sleep duration, poor sleep hygiene or habits, or disrupted sleep architecture. Sleep disturbances in pediatric persistent pain may be associated with underlying disease-related mechanisms (e.g. inflammation or hypoxemia), treatment regimens (e.g., medications that affect sleep, such as analgesics), or hospitalizations.[2-5] Poor sleep is associated with compromised emotional, cognitive, and behavioral functioning in healthy children[6-9] and has been related to reduced physical, social, and emotional function in adolescents with persistent pain,[10] above and beyond the effects of pain. Evidence indicates that good quality sleep promotes immune system function, while systemic inflammation due to immune system dysfunction has been related to increased pain.[11] Adult and animal studies indicate that insufficient sleep contributes to increased pain sensitivity and may initiate pain episodes.[12-13] Overall, research indicates that good quality sleep is important for children with persistent pain and understanding sleep disturbances is critical to optimize health outcomes.

Two publications reviewed literature on sleep-pain relationships in adult pain populations.[2-3] These reviews indicate pain is associated with insomnia (e.g, difficulty falling asleep, maintaining sleep, and reinitiating sleep;)[14], sleep disturbance (e.g., changes in the distribution of REM sleep, decreased sleep efficiency, and fragmented sleep), and daytime sleepiness. Results presented by Onen et al.[3] also indicated that not only does pain impact sleep, but poor sleep exacerbates pain, possibly by lowering pain thresholds. A conceptual review by Lewin and Dahl[4] addressing pain, sleep, pain management, and mood in pediatric pain populations, proposed that pain disrupts sleep, and poor sleep may promote a cascade of physiological and psychosocial consequences that exacerbate pain.

Since Lewin and Dahl's[4] publication, burgeoning sleep research in pediatric pain populations, including JIA[15-17] and SCD[18-20], offer the opportunity to summarize the emerging literature base. In addition, Lewin and Dahl's[4] discussion, though vital for establishing the groundwork for pediatric pain-sleep research, did not provide treatment recommendations. A recent review[21] focused on the reliability and validity of behavioral and physiological sleep assessments for pediatric persistent pain populations, but did not focus on investigating evidence for the pain-sleep relationship. Thus, the primary aim of this systematic review is to examine evidence for a pain-sleep relationship in children with persistent pain by reviewing studies using single and mixed pediatric pain samples. Secondary aims include development of: (1) a model describing interrelationships between pain and sleep, including factors that may influence or mediate pain-sleep relationships and functional outcomes, and (2) evidence-based recommendations for assessment and care of children with persistent pain.

## METHOD

Electronic searches of Medline, PubMed, the Cochrane Database of Systematic Reviews, and PsycINFO since inception to December 2011 were conducted to identify all relevant empirical studies. Search terms included sleep, pain, and a third term including one of the following: pediatric, juvenile, adolescent, child, children, or youth. Search terms were chosen to provide the widest range of citations related to sleep in pediatric pain populations. Each list was screened for relevant titles and abstracts of all marginally relevant titles were examined. Next, two reviewers examined the reference lists and PubMed "related links" citations for each reviewed article to identify additional articles. No attempt was made to

locate unpublished studies. The reviewers extracted data consisting of age range, pain populations, and findings related to sleep characteristics and pain-sleep relations from all relevant articles.

Articles in this review detailed empirical studies that included sleep assessments of participants between 0-17 years diagnosed with a pediatric persistent pain condition: JIA, SCD, migraine/headache, functional abdominal pain, juvenile fibromyalgia syndrome, chronic musculoskeletal pain, complex regional pain syndrome, or mixed populations including the aforementioned conditions. Excluded articles utilized community samples, examined fatigue only, or were not available in English. Because studies measured a variety of sleep aspects (e.g., sleep quality, duration, architecture), outcome data pooling was not viable. Therefore, results were synthesized and described systematically based upon review aims.

## RESULTS

A total of 56 articles utilizing 46 independent samples met criteria and were included in the review (see Figure 1). The studies were published 1982-2011, with the majority (47/56) published after 2000. Table 1 provides an overview of the studies reviewed including presence of controls, type of sleep assessments (e.g., behavioral or physiological), and a summary of key findings.

### Findings from Studies conducted in a Single Pediatric Pain Population

**JIA—**JIA is a rheumatic disease characterized by flares of joint stiffness, inflammation, and pain, which affects approximately 300,000 children in the United States under the age of 16.[22] Many children with arthritis report mild pain most days and severe pain on 30% of days.[23] Seven sleep studies used behavioral measures; five used polysomnography (PSG[24]; Table 1).

Behavioral measures found significantly more sleep problems in children with JIA than healthy controls. Two studies using the Children's Sleep Habits Questionnaire[25] (CSHQ) in children with JIA aged 6-12[26-27], found parents reported more sleep-related anxiety, night wakings, parasomnias, sleep disordered breathing (SDB), and daytime sleepiness in their children with JIA than parents of healthy children. One study also found parents reported more delayed sleep onset.[27] Studies using PSG in children with JIA found significantly lower sleep efficiency, higher arousal indexes, more leg movements related to arousals, less time in slow wave sleep, and more alpha/delta activity during non-REM sleep compared to healthy controls.[28-29] Overall, findings from behavioral measures and PSG indicate that children with JIA experience significantly more sleep disturbances than healthy children.

**Sickle Cell Disease—**SCD is a family of genetic blood disorders affecting about 1 in 600 African Americans.[30] Approximately 70% of individuals with SCD experience pain,[30] with recurrent vaso-occlusive pain episodes occurring 10-13 times a year during childhood and adolescence.[31] Eight studies utilized behavioral measures; 3 used PSG, but did not include healthy comparisons (Table 1).

Behavioral measures indicate children with SCD experience significant sleep problems.[18,32-33] Prospectively, 8-12 year old children with SCD[18] reported night awakenings, difficulty falling asleep, and daytime sleepiness on more than 30% of daily diary days. On the CSHQ, parents of children aged 4-10 years with SCD reported significantly more night awakenings and SDB symptoms in their children than parents of healthy controls.[33] PSG studies in SCD largely focus on SDB, a significant concern in this population, and often fail to report other sleep characteristics. In PSG studies, 36% of

children with SCD have SDB,[34] and up to 40% experience nocturnal desaturation,[35] which is associated with short sleep duration, high sleep fragmentation and movement, high latency to REM sleep, and short REM sleep duration.[36] However, findings from one study suggest that other sleep characteristics do not differ between children with SCD with and without SDB.[37] In another PSG study of 64 children with SCD aged 2-18[38], 23% were diagnosed with periodic limb movement disorder (PLM), identifying an important area for future research and clinical assessment in this population. In summary, physiological sleep research in pediatric SCD has largely focused on SDB, but findings suggest other sleep disruptions in SCD warrant further investigation.

**Headache—**Approximately 70-90% of youth suffer from headaches[39-40] with 5% of children and adolescents aged 10-18 years reporting daily headaches.[41] The majority (15) of identified sleep studies in clinical pediatric headache samples employed behavioral measures (Table 1); 2 used actigraphy[42] and 1 PSG (without a healthy comparison group).

Behavioral measures identify significantly more sleep problems in children and adolescents with headache versus healthy controls.[43-49] In a study of 69 adolescents with headache,[45] insufficient sleep, daytime sleepiness, difficulty falling asleep, and night awakenings were identified as frequent problems on the School Sleep Habits Questionnaire.[46] Using the CSHQ,[50] parents rated 6-18 year old children with migraine as having longer sleep durations, more daytime sleepiness, and longer sleep onset delays than healthy siblings. Findings from studies using actigraphy, wrist-watch size computers that monitor movement to identify sleep and wake patterns,[42] were mixed. One study found no group differences in sleep patterns of 8-12 year olds with and without headaches,[51] while another study found that children with headache rose earlier than healthy children.[52] The only PSG study in children with headache is a chart review[53] of 90 headache patients aged 5-19 years who screened positive for behavioral signs of a sleep disorder. Children with chronic migraine had significantly less total sleep time, longer sleep latencies, and greater arousal indexes than children with less frequent migraines and other types of headaches. SDB was detected in 49% of the total sample, identifying an important aspect of sleep for research and clinical assessment in children with headache. Overall, behavioral and PSG findings indicate that children with headaches experience significant sleep problems; however, actigraphy findings are equivocal.

## Mixed Pediatric Pain Samples

Twenty-two studies were identified that included mixed samples of children with musculoskeletal pain, complex regional pain syndrome, functional abdominal pain, juvenile fibromyalgia syndrome, or at least two different pediatric pain conditions, (e.g., JIA, SCD, headache). The majority of studies (19) utilized behavioral measures, six used actigraphy, and 2 used PSG (Table 1).

Behavioral assessments consistently found that children with persistent pain experience poor sleep,[54-56] particularly in comparison to healthy controls.[57-60] In a study of 59 adolescents with persistent pain and 56 healthy controls[59] using the Adolescent Sleep Wake Scale,[61] sleep hygiene, and pre-sleep arousal questionnaires there was an association between persistent pain and insomnia; adolescents with chronic pain also reported higher levels of pre-sleep arousal. In a study of 100 children with persistent pain (headache, JIA, or SCD),[60] 53% of the pain sample scored at or above the clinical cutoff for total sleep problems versus 23% of the normative community sample for the CSHQ. A few studies with mixed samples used actigraphy, but with inconclusive findings.[62-65] In an age and sex matched sample, adolescents with persistent pain experienced lower sleep efficiency, more night awakenings, and shorter total sleep times on actigraphy than healthy peers.[63] However, two larger studies

conducted by the same investigative team[64-65] found that adolescents with persistent pain reported poorer subjective sleep quality on daily diaries, but there were no between-group differences on actigraphic variables. Two studies that used PSG in children and adolescents with juvenile fibromyalgia syndrome [66-67] found that the sleep architecture of children and adolescents with juvenile fibromyalgia syndrome differed significantly from healthy controls.

Overall, behavioral assessments and PSG consistently identified more sleep disturbances in children and adolescents with persistent pain compared to healthy children; actigraphy results were equivocal. Also, consistent with studies using a single pediatric pain population, the majority of studies were cross-sectional and did not address whether differences in sleep disturbances change over time.

## A Model of the Pain-Sleep Relationship in Pediatric Persistent Pain Populations

Understanding the pain-sleep relationship in pediatric persistent pain populations within a broader biopsychosocial context is needed to develop appropriate research and clinical recommendations. Thus, the following model (see Figure 2) was developed to reflect complex bidirectional relationships between sleep, pain, physiology/biology, mood, developmental stage, sex, race/ethnicity/culture, socio-contextual factors, and functional outcomes in pediatric pain populations. In the proposed model, pain perception and sleep quality have a bidirectional relationship and interact with physiology/biology and mood to influence functional outcomes, including health-related quality of life (HRQoL), health care use, and functional disability. In addition, though not fully explored in current research, developmental stage, sex, race/ethnicity/culture, and socio-contextual factors are proposed to influence the interaction between pain, sleep, physiology, and mood, and to modify their influence on functional outcomes. The following sections review supporting evidence for the relationships proposed in the model.

## Evidence for a Bi-directional Relationship between Sleep and Pain Intensity

Studies using behavioral assessments[26,45,50,68-70], and PSG[16,53,66] in pediatric pain samples generally detected a relationship between high pain and disrupted sleep. In addition, most reviewed studies indicate that even after controlling for other factors, high pain is predictive of disrupted sleep patterns. In a study of children with SCD that controlled for age, sex, and SCD genotype,[18] high pain predicted poor self-reported sleep quality. A study of 118 children with headache[71] found that longer headache duration predicted higher sleep anxiety and more bedtime resistance on the CSHQ after controlling for age, sex, and race/ethnicity. Also, more frequent headaches predicted symptoms of parasomnia, sleep walking, and bruxism (e.g., clenching or grinding teeth during sleep). In a study of 86 adolescents with headache, JIA, or SCD,[10] higher pain intensity and frequency predicted more sleep problems after controlling for socioeconomic status and illness group.

Mounting evidence shows that poorer sleep is predictive of higher pain in pediatric pain populations. A diary study of 20 children with SCD aged 8-12 years[19] found that high pain intensity predicted poor sleep quality and poor sleep quality predicted high pain the following day. Similarly, diary studies of children with JIA aged 8-16[15] and adolescents with persistent pain[65] found that though pain intensity did not predict sleep quality, poor sleep quality predicted high pain intensity the following day. Findings from studies of headache,[72-73] musculoskeletal pain,[74] and mixed pain samples[75] also suggest that children with persistent pain may use sleep for pain coping. However, a prospective diary study of 25 children with headache aged 8-17 years[76] found that although 68% of the sample endorsed lack of sleep as a headache trigger, shorter sleep duration, increased number of night awakenings, and feeling unrested in the morning did not predict subsequent headache

occurrence. These findings support complex, bidirectional associations between pain characteristics and sleep quality in children with persistent pain.

Lastly, a few small uncontrolled intervention studies targeting pain appeared to impact sleep outcomes and vice versa.[77-79] In a small, uncontrolled trial of cognitive behavioral therapy for youth with juvenile fibromyalgia syndrome[78], incorporating pain and sleep treatment components, youth displayed significant improvement in pain, sleep, fatigue, and psychological and functional ability. In addition, Bruni and colleagues[79] randomly assigned 70 children with headache to either a parent implemented sleep hygiene intervention or maintenance of current sleep routines. The intervention group reported significant reductions in headache frequency compared to the control group at three and six months. Clearly, additional intervention studies are needed in pediatric pain populations to better assess the impact of pain and sleep management techniques on improving health outcomes.

## Factors Influencing and Mediating the Pain-Sleep Relationship

**Mood—**Research has consistently linked mood to both pain and sleep. Studies of children with persistent pain report that increased depressive symptoms and poorer negative mood regulation are predictive of high pain intensity.[80-81] In addition, higher pain predicted more depressive symptoms and greater negative mood in children with persistent pain.[20,82] There is also a body of literature linking mood fluctuations to poor sleep.[83] A study of adolescents with persistent pain and healthy controls[65] found that more depressive symptoms predicted poorer sleep quality. In a daily diary study of children with SCD[20], negative mood partially mediated the influence of poor sleep quality on high pain intensity the following day and of high pain intensity and poor sleep quality that night. This is consistent with a recent review exploring the pain-emotion relationship in adult persistent pain populations indicating that poor sleep may strengthen the association between high pain and emotional distress.[84] Additionally, there is evidence that positive emotions act as a protective factor in the pain-sleep relationship. Studies in SCD[20] and JIA[15] found that the influence of poor sleep on high pain the following day was weakened at increasing levels of positive mood. Unfortunately, most studies do not utilize mood assessments that separately assess negative and positive mood.

**Developmental Stage—**Studies indicate that adolescents are more prone to sleep problems than school age children,[85] that these differences are probably linked to pubertal and psychosocial changes across development,[86] and that persistent pain prevalence steadily increases, peaking during adolescence.[1,87-88] However, the majority of studies included in this review report broad age ranges and fail to investigate the possible influence of developmental stage, or the role of pubertal status, which may also contribute to age and sex-specific differences. The few studies using child or adolescent only samples consistently indicate that both children and adolescents with persistent pain experience sleep problems.

**Sex—**Findings concerning the role of sex on sleep in pediatric pain populations are limited and equivocal, likely due to the higher prevalence of females in pain samples, making examination of sex differences more difficult.[18,71,89] Results from daily diaries and actigraphy in 28 children with headache[52] indicated that sex may moderate the relationship between headache and sleep. However, these findings should be interpreted cautiously as they are based upon a small sample of children with headache further subdivided by sex.

**Race/Ethnicity/Culture and Socio-Contextual Factors—**Race, ethnicity, culture, and socio-contextual factors (e.g., socio-economic status, neighborhood disadvantage, and family environment) are seen as interconnected factors often studied as a cluster. A recent review[90] highlights how cultural and socio-contextual factors can predispose chronically ill

children to poor sleep patterns, but also underscores vast limitations in the evidence base. This is similar in the literature on pediatric persistent pain as only one study on the pain-sleep association examined these factors,[91] finding that minority children with persistent pain reported sleeping less than Caucasian children with persistent pain. Of note, while SCD is seen primarily in minority populations, most other pediatric pain conditions are more common in Caucasians, complicating research on the influence of race/ethnicity/culture and socio-contextual factors in pediatric pain.

### The Impact of Pain and Sleep on Functional Outcomes

Studies have linked sleep problems in pediatric pain populations to a range of functional outcomes. A series of investigations[27,92] support the relationship between sleep and executive functioning in children with JIA aged 6-11 years. Higher mean number of night awakenings predicted poorer rapid visual processing, higher apnea severity scores predicted longer reaction times, and higher total sleep disturbances on the CSHQ predicted slower reaction times for all children; however, group membership (JIA versus comparison) did not predict slower reaction times. Studies of children with persistent pain[6068,89] also related behavioral reports of poorer sleep to poorer HRQoL. Lower sleep efficiency and less sleep per night were related to a high number of daytime naps in adolescent girls with persistent pain[93] and higher pain frequency and lower sleep efficiency predicted activity limitations in 40 adolescents with and without persistent pain.[94]

## DISCUSSION

Overall, research supports that children and adolescents with persistent pain suffer from sleep impairment. Behavioral sleep assessments indicate that children, adolescents, and their parents report poorer subjective sleep quality as evidenced by more night awakenings and daytime sleepiness versus healthy controls. Findings from PSG studies in pediatric rheumatology populations also indicate that children and adolescents with persistent pain experience more disrupted sleep, including lower sleep efficiency, more alpha/delta activity, and the presence of more physiological sleep disorders (e.g., PLM and SDB), compared to healthy peers. Additional investigation is needed into the epidemiology of sleep disorders in pediatric pain populations.

Sleep actigraphy, on the other hand, has been less frequently used with pediatric pain populations than behavioral questionnaires or PSG. When used, sleep actigraphy has indicated less sleep pattern differences between children with persistent pain and healthy controls. Given high concordance rates previously observed between sleep actigraphy and PSG,[42] these inconsistencies warrant further investigation. A lack of standardized sleep actigraphy scoring may impact researchers' ability to detect between-group differences and small sample sizes may also contribute to equivocal findings. In addition, specific aspects of sleep assessed via actigraphy versus those assessed using behavioral reports or PSG may have different relationships with pain and related factors. Lastly, the reviewed studies demonstrate that sleep difficulties in children with persistent pain are strongly predictive of function, including impaired executive dysfunction and poorer HRQoL. These findings highlight the critical need to consider assessment and management of sleep problems in the care of pediatric pain populations.

A limitation of the current literature is the cross sectional design of most studies describing sleep patterns in children with persistent pain. The lack of longitudinal study designs does not allow researchers to elucidate the nature of sleep disturbances in this population over time, to discern how changes over time compare to normal developmental sleep changes, or to detect associations with variations in disease activity. Another key limitation of the literature is the lack of focus on mechanisms by which children with persistent pain

experience disrupted sleep. It has been proposed that sleep disturbances in children with persistent pain are associated with underlying disease-related mechanisms, treatment regimens, or hospitalizations.[2-5] Additionally, the influence of mood, developmental stage, sex, race/ethnicity/culture, and socio-contextual factors may be important, but the influence of these factors on sleep in pediatric pain populations has not been extensively researched. There is also a critical need for further investigation into the functional consequences of poor sleep in pediatric pain populations. For example, the lack of information on the possible influences of pain and sleep on pain management behaviors, and on the interactive influences of pain and sleep on functional outcomes, hinder the ability of clinicians to develop standardized approaches to treatment.

## Clinical Implications

Findings from this systematic review underline the need to assess and manage sleep problems in children with persistent pain. Clinical assessment of the nature of a child's sleep disruptions is critical for individualizing interventions. One useful screening tool available to pediatricians is the BEARS,[95] a brief interview designed for pediatric clinical settings, assessing **B**edtime problems, **E**xcessive sleepiness, **A**wakenings, **R**egularity of sleeping, and **S**leep-disordered breathing. Though not a comprehensive research assessment, the BEARS is a developmentally appropriate screening tool.

Children with evidence of excessive daytime sleepiness, poor quality sleep, and heavy snoring, gasping, or long pauses in breathing, may require formal evaluation by a sleep medicine specialist for SDB. However, other sleep problems necessitate thorough assessment of sleep patterns and behaviors (e.g., sleep schedule, routines, habits, behaviors during the night) via clinical interview, diaries, and/or standardized pediatric sleep measures (reviewed by Lewandowski, et al.[96]). Following assessment, behavioral interventions may target sleep habits or sleep hygiene; improving habits that interfere with sleep onset or maintenance (e.g., restricting evening caffeine intake, eliminating naps, creating a sleep routine/schedule, restricted use of electronic devices at night). A thorough sleep assessment for youth with persistent pain includes a detailed review of medications, including doses and timing. Many commonly used medications for persistent pain effect sleep staging.[96] Onen and colleagues[3] have recently reviewed the medical management of sleep problems in adult pain populations.

Following assessment by the pediatrician, children with persistent sleep problems should be referred to a sleep medicine specialist for additional evaluation, including a 1 to 2 night sleep study (overnight PSG) and the multiple sleep latency test,[97] an indicator of excessive daytime sleepiness. Some sleep disorders, such as SDB and PLM, may require medical interventions (e.g., continuous positive airway pressure), and sleep medicine management, overseen by a sleep medicine specialist. Children with inadequate sleep, insomnia, or delayed sleep phase, may benefit from cognitive behavioral therapy with a behavioral sleep specialist. Cognitive behavioral therapy has been recommended by the American Academy of Sleep Medicine for the treatment of adult insomnia based on a large evidence base in diverse adult patient populations.[98] There is evidence that cognitive behavioral therapy leads to reduction of insomnia symptoms and pain in older adults with persistent pain.[99]

In conclusion, children with persistent pain commonly suffer from disturbed sleep, which puts them at risk for poor functional outcomes. Pediatricians who treat children with persistent pain can optimize care by integrating the assessment and management of sleep problems into routine practice, focusing on the interactions between pain, sleep, and moderating biopsychosocial factors. Embedding medical and behavioral interventions to enhance sleep into existing pain management interventions for children with persistent pain

will improve health outcomes. However, more systematic research investigating the mechanisms associating sleep and pediatric persistent pain is warranted.

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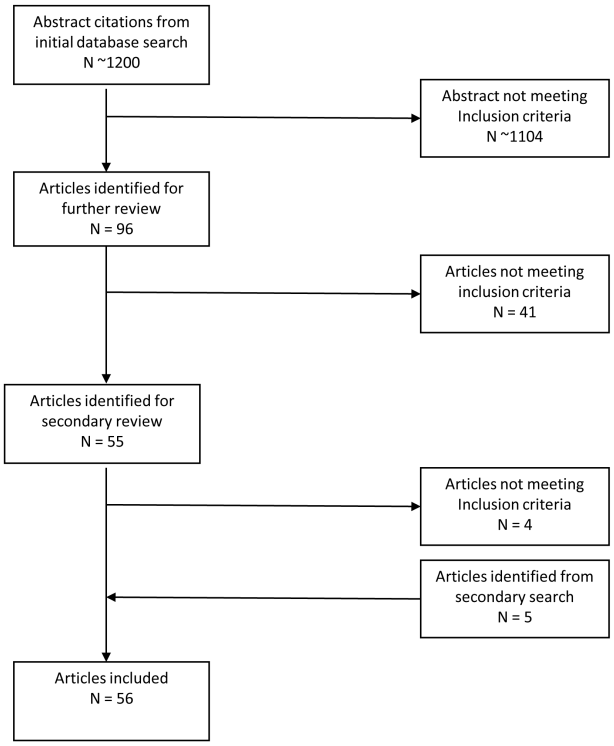


**Figure 1.**
Flow Diagram of Studies Reviewed for Inclusion

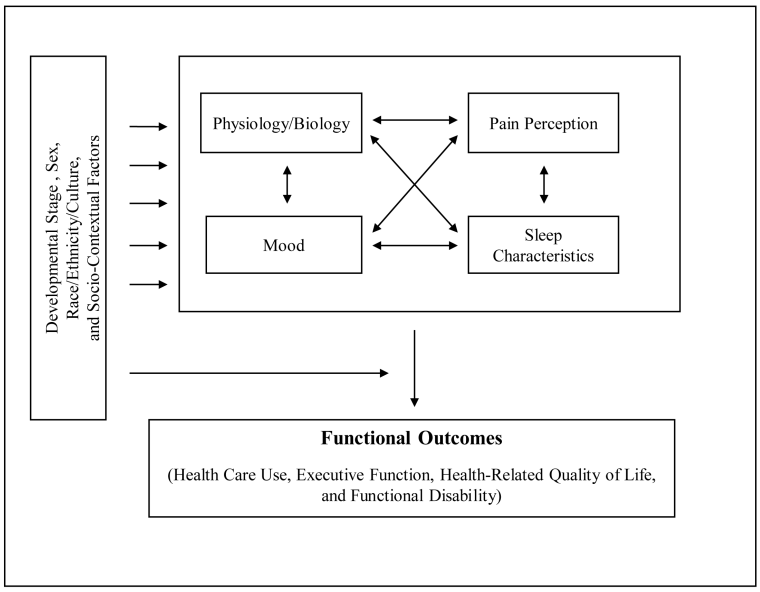


**Figure 2.**
A Model of the Pain-Sleep Relationship in Pediatric Persistent Pain Populations

## Table 1

Summary of Studies Reviewed by Pain Population and Assessment Type

| Pain Condition | # of Studies* (Combined N) | Behavioral Assessment Findings | Physiological Assessment Findings | Articles Reviewed |
|---|---|---|---|---|
| Juvenile Idiopathic Arthritis | 9 (N = 310) | 7 Behavioral Studies<br>JIA > HC for behavioral sleep problems | 5 PSG Studies<br>JIA > HC for sleep disturbances | 15-17, 26-29, 68, 92 |
| Sickle Cell Disease | 10 (N = 360) | 8 Behavioral Studies<br>SCD > HC for behavioral sleep problems | 3 PSG Studies<br>Findings: No HC groups | 18-20, 32-34, 37-38, 69-70 |
| Headache | 15 (N = 1753) | 14 Behavioral Studies<br>HA > HC for behavioral sleep problems | 2 Actigraphy Studies<br>Mixed Findings<br>1 PSG Study<br>No HC group | 43-45, 47-53, 71-73, 76, 79 |
| Mixed Pain Sample | 22 (N = 1579) | 19 Behavioral Studies<br>MPS > HC for behavioral sleep problems | 6 Actigraphy Studies<br>Mixed Findings<br>2 PSG Studies<br>MPS > HC for sleep disturbances | 10, 54-60, 62-67,74-75, 77-78, 89, 91, 93-94 |

Note: HC = Healthy controls; HA= Headache; JIA= Juvenile idiopathic arthritis; SCD = Sickle cell disease; MPS=Mixed Pain Sample; PSG=Polysomnography

*This is the total number of studies. The number of studies using behavioral assessments and objective assessments are not mutually exclusive, as about half of the studies (11/19) using objective assessments also used behavioral assessments.