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Temporal daily associations among sleep and pain in treatment-seeking youth with acute musculoskeletal pain

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Abstract

Sleep is an important health risk factor. In the context of pediatric chronic pain, sleep is often impaired and temporal daily associations link sleep deficiency to subsequent increased pain. It is unknown whether similar temporal relationships exist for youth with acute pain. Thus, we characterized sleep in youth with acute musculoskeletal (MSK) pain to examine daily sleep-pain associations. Participants were 67 youth (10–17 years) with acute MSK pain (<1 month duration). Youth underwent eight nights of actigraphic sleep monitoring and completed twice daily pain diaries. Generalized linear models tested nighttime sleep as a predictor of morning pain, and evening pain as a predictor of nighttime sleep. Shorter sleep duration and poorer sleep quality predicted higher morning pain intensity. However, evening pain did not predict nighttime sleep, suggesting the strongest temporal association is in the direction of sleep deficiency impacting next-day pain, as has been found in prior research in youth with chronic pain.

Keywords

Sleep; Acute pain; Musculoskeletal; Actigraphy; Child; Adolescent

Introduction

Acute musculoskeletal (MSK) pain is common in childhood (Jordan et al., 2010; Mikkelsson et al., 1997) with pain prevalence increasing during adolescence (LeResche et al., 2005). When pain persists, youth may experience a range of negative consequences including activity limitations, impairments in quality of life, and depressive symptoms (Egger et al.,

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Compliance with ethical standards

Conflict of interest Amy Lewandowski Holley, Jennifer Rabbitts, Chuan Zhou, Lindsay Durkin, and Tonya M. Palermo declares that they have no conflict of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

1999; Kashikar-Zuck et al., 2001). Longitudinal epidemiologic data highlights the importance of sleep in the persistence of musculoskeletal pain complaints during adolescence (Paananen et al., 2010). Further, research in youth with chronic pain has revealed sleep can impact the daily pain experience, with poorer nighttime sleep predicting higher next day pain (Lewandowski et al., 2010). In youth with acute MSK pain complaints, these temporal associations among sleep and pain are not known.

The limited research investigating sleep in the context of acute pain has primarily involved adults. Presence of acute pain is associated with shorter sleep duration, greater sleep fragmentation, and less slow wave and rapid eye movement (REM) sleep (Roehrs & Roth, 2005). Adults experiencing acute pain are also less likely to report experiencing good or very good sleep (47 vs. 65%) (Foundation, 2015) than those without pain. Studies of adults with acute back pain have identified temporal sleep-pain associations. Specifically, poor sleep quality predicted next-day pain intensity in adults with new onset back pain (<6 week duration) (Alsaadi et al., 2014). In a combined sample of adults with acute and persistent back pain, number of pain days the preceding week predicted relative risk of sleep disturbance the following week (Axen, 2016).

Given this adult research highlighting the potentially bidirectional effects between sleep and acute MSK pain experiences and the unique developmental aspects of sleep in adolescence, a separate examination of day to day sleep-pain associations in youth with acute MSK pain is needed. The current study addresses this gap in the literature by using actigraphy and daily diaries to examine temporal daily associations among sleep and pain in youth experiencing acute MSK pain (less than 1 month duration). Our specific aims were: (1) to characterize subjective and objective reports of sleep in youth with acute MSK pain, and (2) to examine reciprocal daily associations between pain and sleep. We hypothesized bidirectional sleep-pain associations, and based on previous findings in a pediatric chronic pain sample (Lewandowski et al., 2010) anticipated the strongest relationship in the direction of sleep deficiency impacting next-day pain (controlling for relevant covariates).

Methods

This study was conducted at an academic medical center in the northwestern United States. All study procedures were approved by the Institutional Review Board, and all participants provided consent or assent prior to undergoing any study procedures. Child and adolescent participants were ages 10–17 years and enrolled in an ongoing longitudinal study of MSK pain. Participants in the current report included 67 youth presenting to the emergency department (n = 32) or orthopedic clinic (n = 35) for evaluation of a new MSK pain complaint (e.g., limb, back or neck pain) with pain duration *less than 1 month* at time of study enrollment. Both youth and their participating parent needed to be proficient in English (verbal and written) to participate. Participants were excluded if serious pathology (e.g., infection, disease process) was associated with the source of the pain complaint or if participants had a surgical procedure or fracture reduction at the pain site. Youth were also excluded if they had a current chronic pain condition (e.g., chronic headaches or recurrent abdominal pain) or a history of chronic pain or surgery at the location of the acute pain complaint. Previous manuscripts have reported on pain characteristics, psychological

functioning, and widespread pain in this sample (Lewandowski Holley et al., 2016; Rabbitts et al., 2016); this is the first paper to examine daily sleep-pain associations and to analyze actigraphic sleep data.

Procedures

Potential participants with acute MSK pain were identified from clinic schedules and invited to participate in the research study. Interested families underwent additional eligibility screening via phone. Eligible youth and their parents presented for an in-person study visit. At the completion of the study visit research assistants placed an Actiwatch on participants' non-dominant wrist and youth were instructed to wear the Actiwatch for the next 8 days and nights and to complete a diary twice a day (morning upon waking and evening prior to sleep). On the morning diary, participants rated their previous night's sleep quality (0–10 NRS), current pain intensity (0–10 NRS), time they went to bed the previous night and morning wake time. On the evening diary, participants reported daytime napping (yes/no), medications (type and dose), and current pain intensity (0–10 NRS). Youth were asked not to make any changes to their sleep, medications or other treatments during the monitoring period. Participants were provided with a postage-paid envelope to return all materials and youth received a gift card as compensation.

Measures

Demographics—Parents reported on family income as well as their child's age, sex, and race.

Actigraphic assessment of sleep—Wrist actigraphy (Actiwatch-2, Philips Respironics MiniMitter Company Inc., Bend, OR) was used to obtain an objective measurement of sleep patterns. Participants were instructed to wear the watch-like device for eight consecutive days/nights of monitoring in their home environment. Actual Actiwatch use varied from 4 to 12 nights (some youth removed the device early, others removed the device late); specifics on participant usage are described in the results section. Movement in the device was detected by an omni-directional mercury switch that remained open when there was no detectable movement and closed when movement above a threshold was detected. Each time the switch closed an activity count was generated and stored as a 1-min epoch. Participants were instructed to push a button on the side of the Actiwatch at bedtime and wake time to create an event marker in the data to aid scoring. Sleep intervals for each night of data were manually scored. The sleep onset and sleep offset were determined based on 10 min of contiguous sleep counts allowing for 1 min of wake set by the software and using the event marker and diary data for guidance. Sleep variables were computed using the Actiware 6.0.6 software package. Actigraphic sleep variables included: sleep duration, sleep efficiency, and amount of time awake after sleep onset (WASO). Sleep duration was calculated as the total time (in minutes) from initial sleep onset to sleep offset. Sleep efficiency was calculated as minutes scored as sleep from sleep onset to offset divided by sleep duration as a percentage. WASO was a total of the minutes awake from sleep onset to sleep offset. Validity of actigraphy has been demonstrated by agreement with polysomnography recordings (Meltzer et al., 2012); with 5–7 nights considered reliable estimates of total sleep time (Acebo et al., 1999).

Morning and evening diary

Sleep quality—Youth reported on their sleep quality the previous night in the morning diary entry using an 11-point numerical rating scale (NRS) with higher ratings indicating better sleep quality (0 = extremely poor sleep, 10 = extremely good sleep).

Pain intensity—Youth reported their pain intensity twice daily, in the morning and evening using an 11-point NRS with higher ratings representing more intense pain (0 = no pain, 10 = worst pain possible). Specific prompts were: “please rate your pain just before going to bed” (evening diary) and “please rate your pain at the time you woke up” (morning diary). The NRS is a valid and reliable tool for assessing pain intensity in children and adolescents (von Baeyer et al., 2009).

Medication use—Data on daily medication use was collected to account for potential effects on sleep-pain associations. In their evening diary participants were asked to report (yes or no) whether they had taken any medications that day. Those who responded “yes” were instructed to list all medications taken. A research assistant coded the medications into nine classes: over-the-counter pain medication, opioid, antidepressant, antiepileptic, sleep, benzodiazepine, other pain medication, antihistamine, other medication (e.g., birth control pills). Similar to prior research (Rabbitts et al., 2014), the number of medication classes that youth took each day were included as a covariate in analyses.

Daytime naps—On the evening diary participants responded (yes/no) if they took a nap that day. This variable was included as a covariate in all models to account for impact of daytime sleep on nighttime sleep or pain.

Statistical analyses

Demographic and sleep characteristics of the participants were summarized using descriptive statistics. Generalized linear models were used to examine temporal daily associations among sleep and pain. Generalized estimating equations (GEEs) were used for parameter estimation and inference to account for the correlations in the data due to repeated assessments across days within individuals. Specifically four models tested evening pain intensity as a predictor of subsequent nighttime sleep (duration, efficiency, WASO, quality), and an additional four models tested nighttime sleep (duration, efficiency, WASO, quality) as a predictor of pain intensity the next day. Based on previous literature, we decided a priori to include age, sex, medication use, fracture status and napping as covariates in all models which allows for examination of their potential association with dependent variables. Results of models without covariates were also tested. Our choice of GEE approach allows for the examination of temporal associations among variables while taking into account the correlations among outcome measurements within individuals. Furthermore, GEE is a semi-parametric approach and relies less on explicit distributional assumptions. For our analyses, robust standard errors estimates were used for all inferences (Burton et al., 1998). Data analyses were conducted using the STATA command “xtgee” (STATA version 12.1 SE, StataCorp, Texas, USA) and the Statistical Package for the Social Sciences Version 22.0 (SPSS 22.0). Significance levels were set at $p < .05$.

Results

Descriptives

Demographic characteristics of the sample are presented in Table 1. The 67 participating youth had a mean age of 13.9 years, were 62.7% female, and predominantly Caucasian (61.2%). Youth had sought evaluation for their pain complaint at either the emergency department (n = 32) or orthopedic clinic (n = 35). Primary pain locations were leg/foot, hand/arm, and back. The majority of youth reported their pain was due to a sports injury and approximately one-third (28.4%) sustained a fracture.

Summary of subjective and objective reports of sleep from diary and actigraphy data

Data from a total of 471 diary days (87.9% completion) were used in the analyses. Participants completed an average of 6.8 (SD = 1.4) morning entries and 6.8 (SD = 1.3) evening entries during the data collection period. Daily morning and evening pain reports varied from 0 to 10 on the NRS. Evening pain (NRS >0) was present on 52.9% of diary days and morning pain (NRS >0) was present on 52.4% of diary days. When present, average pain before sleep was M = 3.1 (SD = 1.9) and average pain in the morning was M = 2.8 (SD = 1.8). A paired *t* test comparing differences between average evening and morning pain revealed pain in the evening was significantly higher, $t(67) = -4.06$, $p < .001$.

Data from 543 nights of actigraphy were used in the analysis with an average of 8.1 nights per child. Available nights ranged from 4 to 12; specifically one teen (1.5%) had four nights, 21 (31.3%) had seven nights, 28 (41.8%) had eight nights, 9 (13.4%) had nine nights, and 8 (11.7%) had 10–12 nights. We retained all available data for inclusion in analyses. Average sleep duration (mean over the 8 day monitoring period) for all participants was 7.2 h (SD = .84), with 22.4% of youth experiencing extremely short sleep duration (average of less than 6.5 h of sleep). Mean sleep efficiency over the monitoring period was 87.1% (SD = 4.1), with 17.9% of youth having poor sleep efficiency (defined as less than 85%). Average WASO was M = 54.5 min (SD = 18.8). A large subset of youth (32.8%) had WASO that averaged greater than 1 h per night. A modest number of youth (39.8%) reported taking a nap during the 8 day study period, however naps were infrequent (M = .23, SD = .17 naps per day, per participant).

Approximately half of participants (n = 38, 56.7%) reported using a medication from one or more of the medication classes during the study period. The most commonly used medications were: NSAIDs/acetaminophen (14.9% of study days), antidepressants (7.1% of study days), and antihistamines (6.3% of study days). Opioids and sleep medications were rarely used (.9% and .4% of study days respectively). Of those youth who reported using medication on their daily diary, average use was less than one medication per day (M = .79, SD = .50). No youth reported using anticonvulsant or benzodiazepine medications during the 8 day monitoring period. Number of medication classes was controlled for in the models.

Temporal associations among pain and sleep

Nighttime sleep as a predictor of morning pain—Four generalized linear models evaluated nighttime sleep (sleep quality, sleep duration, sleep efficiency, and wake after

sleep onset) as a predictor of pain the next morning controlling for age, sex, fracture status, medication use, and naps. As hypothesized, two of the models showed significant temporal associations between sleep and pain. Specifically, shorter actigraphic sleep duration ($\beta = -.003$, $p = .003$) and poorer subjective sleep quality ($\beta = -.12$, $p = .006$) were associated with higher reports of pain intensity the next morning (complete model). For every additional hour of sleep, participants reported a .18 reduction in pain intensity, and for every point improvement in sleep quality participants reported a .12 reduction in pain. Results were consistent in models that included and excluded covariates (see Table 2). Contrary to our hypotheses, neither actigraphic sleep efficiency nor WASO predicted next day pain. No covariates were significant in any of the four models indicating no effect of age, sex, daytime napping, medication use, or fracture status on the temporal sleep-pain associations.

Evening pain as a predictor of nighttime sleep—Four mixed linear models evaluated evening pain as a predictor of nighttime sleep. Separate models examined sleep quality, sleep duration, sleep efficiency and wake after sleep onset, adjusting for age, sex, medication use, and naps. Contrary to our hypotheses, pain did not predict any sleep variable (p's >.05), suggesting that pain before bed had little impact on objective or subjective sleep that night.

Discussion

To our knowledge this is the first study to explore daily bidirectional relationships between acute MSK pain and sleep in youth using a multimethod approach (daily diaries, actigraphy). Poorer subjective sleep quality (assessed via daily diaries) and shorter sleep duration (assessed via actigraphy) predicted higher morning pain intensity the next day, indicating that sleep influences subsequent pain. None of the covariates examined (e.g., demographics, daily medications, naps) influenced this relationship. Our findings are consistent with previous research showing the influence of poor sleep on next-day pain in adults with acute MSK pain (Alsaadi et al., 2014), extending this research to pediatric samples with acute MSK pain. The present findings also extend our prior work in pediatric samples with established chronic pain conditions (Lewandowski et al., 2010), by finding similar relationships between sleep and acute pain. Contrary to hypotheses, within our sample evening pain did not predict subsequent sleep patterns or sleep quality. This lack of significant association among evening pain and subsequent nighttime sleep in youth with acute pain deserves further investigation as pain may influence sleep continuity and duration (Finan et al., 2013).

While findings were statistically significant it is important to recognize that the strength of daily sleep-pain associations was small. For every additional hour of sleep, participants reported a .18 reduction in pain intensity, and for every point improvement in sleep quality participants reported a .12 reduction in pain. This highlights that while sleep plays a role in the daily pain experiences of youth with acute MSK pain, other factors not examined in this study (e.g., activity limitations, daily stressors, interactions with parents or peers) also likely influence youth's pain experience and should be examined. Future research should also include youth with more severe acute pain (e.g., burn patients) to understand whether similar daily sleep-pain associations are present in the context of higher daily pain intensity.

Another key finding of this study was that youth with acute MSK pain complaints had significant sleep deficiency. In particular, a large percentage of youth (32.8%) had 1 h or more of time awake after sleep onset and 17.9% had poor sleep efficiency. Moreover, participants were receiving an average of only 7.2 h of sleep per night (with 22.4% with short sleep duration of less than 6.5 h of sleep). Getting sufficient sleep may be particularly important for recovery in the acute pain period, making these data particularly striking.

This study has several limitations, which should be taken into account when interpreting the findings. First, sleep was assessed after onset of the acute MSK pain complaint. We do not know if youth had preexisting sleep disturbances that could have influenced the results. Second youth started actigraphic sleep monitoring after pain had been present for 1 month. Future studies could recruit and enroll participants in the clinic setting and begin actigraphic monitoring immediately after their initial evaluation to study sleep-pain associations closer to time of pain onset. Third, youth completed a paper diary making it impossible to confirm timing of pain reports and prevent back-filling. Follow-up studies should utilize electronic diaries, which may have a higher level of accuracy, to replicate findings on daily sleep-pain associations. In addition, while all youth had acute MSK pain complaints, the sample was diverse in terms of pain etiology and body site. While analyses controlled for fractures (yes/no) in sleep-pain associations, the sample is not large enough to determine if sleep-pain associations differed by pain site. Finally, the sample was predominantly middle class, potentially impacting generalizability of findings.

In summary, findings highlight the association between sleep and pain in youth experiencing acute MSK pain, and suggest assessment of sleep disturbances may be potentially relevant early on in the course of recovery. Further, sleep disturbances during the acute period can potentially be viewed as one of many important modifiable factors for clinicians to target in treatment. Future research should identify whether targeting interventions to youth with sleep disturbances in the immediate post-injury period can impact pain intensity and have a positive impact on recovery trajectories.

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Table 1

Demographic characteristics of the sample (N = 67)

Age (years; M(SD), range 10–17 years)	13.9	1.9
Gender (n, %)		
Male	25	37.6
Female	42	62.7
Race and ethnicity (n, %)		
Hispanic/latino	9	13.4
White non-hispanic/latino	52	77.6
Unknown/not reported	6	9.0
BMI percentile (age corrected; n, %)	73.2	26.6
Referral source (n, %)		
Emergency department	32	47.8
Orthopedics	35	52.2
Fracture (n, %)		
Yes	19	28.4
No	48	71.6
Primary pain complaint (n, %)		
Leg/foot	36	53.7
Arm/hand	17	25.4
Back	7	10.4
Shoulder	3	4.5
Hip	3	4.5
Chest	1	1.5
Income (n, %)		
≤$29,999	6	9.0
$30,000–39,999	8	11.9
$40,000–69,999	7	10.4
$70,000–89,999	6	9.0
>$90,000	39	58.2
Missing	1	1.5

Table 2

Summary of linear mixed models examining nighttime sleep as a predictor of morning pain intensity (N = 67)

Number of observations	Complete model		Trimmed model	
	Predictor variables	**β (SE)**	**Predictor variables**	**β (SE)**
412	Sleep duration	−.003 (.001)**	Sleep duration	−.003 (.001)**
	Sex	−.30 (.44)		
	Age	.11 (.11)		
	Medication category	.38 (.22)		
	Nap (yes/no)	−.30 (.30)		
	Fracture (yes/no)	.46 (.53)		
452	Sleep quality	−.12 (.05)**	Sleep quality	−.13 (.04)**
	Sex	−.35 (.44)		
	Age	.15 (.11)		
	Medication category	.35 (.22)		
	Nap (yes/no)	−.15 (.38)		
	Fracture (yes/no)	.17 (.52)		
412	Sleep efficiency	−.02 (.01)	Sleep efficiency	−.01 (.01)
	Sex	−.33 (.44)		
	Age	.13 (.11)		
	Medication category	.39 (.22)		
	Nap (yes/no)	−.25 (.31)		
	Fracture (yes/no)	.38 (.53)		
412	WASO	−.002 (.002)	WASO	−.002 (.002)
	Sex	−.31 (.45)		
	Age	.14 (.12)		
	Medication category	.38 (.23)		
	Nap (yes/no)	−.28 (.31)		
	Fracture (yes/no)	.36 (.54)		

** $p < .01$