Reviewer Information Page

Number of tables: 4

Number of figures: 2

Abstract word count: 249

Word count: 3,731

Title Page

Title: Which objective sleep elements predict children's perceptions of good sleep quality? A preliminary investigation based on polysomnography and actigraphy

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Abstract

Objectives: Objective sleep elements that underlie child ratings of sleep quality are largely unknown and child-based sleep recommendations therefore typically focus on duration. An expert panel recently provided specific recommendations regarding objective sleep parameters that correspond with higher quality sleep, but child-based studies from which to draw conclusions were notably limited. The current study used actigraphy and polysomnography to explore sleep continuity and architectural variables that correspond with higher ratings of sleep quality in a sample of school-aged children.

Methods: Fifty-two healthy, pre-pubertal children (aged 7-11 years) completed one night of unattended ambulatory polysomnography at home with concurrent actigraphy and provided sleep quality ratings the following morning. Associations between sleep variables and subjective ratings were examined using polynomial regression models to examine potential linear and non-linear relationships.

Results: In contrast to findings among adults, total sleep time, sleep onset latency, and sleep efficiency values were unrelated to child ratings of sleep quality. Wake after sleep onset (WASO) showed a curvilinear (reversed j-shaped) relationship such that perceptions of sleep quality were high when WASO values were less than approximately 30 minutes. For sleep architecture, N1% showed a significant quadratic association with sleep quality such that N1% between 2-6% corresponded with high sleep quality ratings.

Conclusions: Our findings support expert recommendations regarding WASO values that predict high quality sleep in children, but also await replication. There is need for additional research aimed at understanding objective sleep elements and other influences of children's perceptions of sleep quality using linear and non-linear models.

Keywords: Sleep quality; pediatrics; children; age-based sleep recommendations; sleep architecture

Abbreviations list:

ADIS	Anxiety Disorders Interview Schedule
ICSD	International Classification of Sleep Disorders
NREM/N	non-rapid eye movement sleep
PSG	polysomnography
RCADS	Revised Children's Anxiety and Depression Scale
REM	rapid eye movement sleep
SE	sleep efficiency
SOL	sleep onset latency
SQ	sleep quality
SR	self-report
SWA	slow wave activity
SWS	slow wave sleep
TST	total sleep time
WASO	wake after sleep onset

Introduction

Use of the term ‘sleep quality’ is ubiquitous both in the scientific literature and popular media, where higher sleep quality routinely forecasts better physical and mental health outcomes.[1] Despite frequent usage of the term however, no consensus for its definition exists.[2] Although perceptions of sleep quality are ultimately subjective, various quantitative sleep parameters are commonly used to infer the presence of high sleep quality. In fact, based on a review of the scientific literature, an expert panel convened by the National Sleep Foundation (NSF) recently identified various objective sleep elements believed to correspond with higher quality sleep across all ages, including shorter sleep onset latency (i.e., SOL ≤ 45 min), fewer minutes spent awake after sleep onset (i.e., WASO ≤ 20 min), and higher sleep efficiency (SE ≥ 85%).[3] Consensus for architectural sleep variables that underlie higher sleep quality was far more limited however, given mixed findings in the literature. This was particularly true with regard to children due to the small number of available studies. As one objective of the panel was to provide specific recommendations to the public, there remains a need to understand objective sleep elements, beyond duration, that correspond with high sleep quality in children.

Compared to adults, assessment of sleep quality is more complex in younger persons. Current determinations rely largely on age-based recommendations for sleep duration[4] and/or parent-reports of sleep since understanding of sleep components that contribute to child-perceived high quality sleep is limited. The rapid changes in sleep duration and timing that characterize the first decade or so of life create additional challenges for understanding how sleep continuity measures contribute to quality sleep.[6,7] Changes in sleep architecture are also dramatic, including gradual decreases in the proportion of slow wave sleep (SWS) and underlying slow wave activity (SWA) during the early adolescent years; a marker of homeostatic sleep pressure and the sleep stage most closely associated with restoration.[6] These developmental considerations are reflected in recommendations provided by the expert NSF panel[3]. For example, compared to ≤ 5% of SWS for teenagers and adults, ≤ 11% of SWS is considered "inappropriate" for infants to school-aged children. Still, empirical data supporting these recommendations in youth remain limited.

Also noteworthy is that fact that NSF recommendations regarding sleep continuity and architecture elements that serve to shape high sleep quality are suggestive of non-linear relationships. That is, more or less of any one sleep parameter is not necessarily expected to correspond with a meaningful change in the quality of one's sleep. Surprisingly however, a majority of studies to date have examined linear relationships between objective sleep elements and perceptions of sleep quality. Although most studies have explored these associations among adults, several recent investigations in youth underscore the presence of important non-linear associations between different elements of children's nighttime sleep and aspects of their daytime functioning.[8-10]

In light of the clinical significance of understanding factors that shape high quality sleep in children, the present study explored both linear and non-linear associations between objective sleep variables (derived from actigraphy and polysomnography) and Likert-type sleep quality ratings among healthy school-aged children. We specifically examined whether recommendations provided by the NSF expert panel[3] were observable in our sample, expecting longer sleep duration, higher sleep efficiency, shorter sleep onset latency, and fewer wake minutes after sleep onset would correspond with high sleep quality ratings. With regard to sleep architecture, we expected greater proportions of SWS would predict reports of higher sleep quality, whereas greater proportions of non-rapid eye movement sleep stages 1 (N1) and 2 (N2) would predict lower sleep quality ratings. Also following NSF recommendations for children[3] we expected these relationships to be non-linear (i.e., quadratic) and to align with specific child-based cut-off values provided in this report. Given evidence that affective symptoms can bias reports of sleep quality,[11] all analyses controlled for the presence of anxiety and depressive symptoms.

Method

Participants

The current sample of 55 pre-pubertal (Tanner stages 1 or 2) children, (*n* = 31 female; M_{age} = 9.11 ± 1.36) were recruited as part of a broader study focused on relationships between sleep and emotional health in children. To be included, children had to be between the ages of 7 to 11 years and speak fluent English (along with one parent). Additional child-focused exclusion criteria included (a) any psychiatric disorder based on the DSM-5;[12] (b) past or present suicidal ideation; (c) evidence of any sleep disorder based on the International Classification of Sleep Disorders (ISCD-2);[13] (d) IQ one standard deviation below average based on the Wechsler Abbreviated Scale of Intelligence;[14] (e) any chronic medical condition (e.g., atopic dermatitis, pain-related syndromes) and/or use of medication or non-prescription drug known to impact mood and/or sleep; and (f) typical sleep schedule of no less than 8.5 hours per night (confirmed with a week of at-home actigraphy monitoring). Three participants who did not provide a rating of sleep quality after at-home sleep monitoring were excluded, yielding a final sample size of 52 children.

The mean age of the present sample was approximately 9 years old, with 55.8% female. Children primarily identified as Caucasian (*n* = 31), followed by African American (*n* = 16), biracial/other (*n* = 3), and Asian American (*n* = 2). The majority of the sample identified as Non-

Hispanic/Latino (*n* = 36). The majority of parents who participated were married to their child's father/mother (*n* = 35). Yearly household income varied, but the median range was $60,000-80,000, slightly higher than the national median income $57,617.[15] Full sample characteristics can be found in Table 1.

Study Design

All procedures were approved by the Institutional Review Board at the University of Houston. Participants were recruited from local schools via direct mail, flyers in community centers, print advertisements, and local community events for families. Families who called or emailed expressing interest were given more information, screened using basic inclusion/exclusion criteria and invited to participate as appropriate.

Written informed consent/assent was obtained from parents/children prior to participation. Children and their parent arrived at the lab for an initial assessment, during which study eligibility was determined via child IQ testing and semi-structured clinical interviews with both the parent and child. Other information collected included parent-reported demographics and child sleep disturbance, and parent and child-reported anxiety/depressive symptoms. Within one week following the initial assessment, children underwent one night of at-home, unattended polysomnography (PSG) monitoring. One week of actigraphy monitoring also began on the PSG night. Actigraphy data were later examined to confirm a regular sleep schedule of at least 8.5 hours of sleep per night. Research staff prepared the children for PSG in their homes and children (with help from their parents) were provided instructions to go to bed at 9:00PM, and wake up by 7:00AM (i.e., 10 hours in bed). The following morning, children completed a self-report questionnaire about the quality of their sleep on the previous night.

Measures

Background/General Information

Parents reported family demographic information, including the child's age, sex, race/ethnicity, medication history, marital status, education level, and whether children were currently in school or on break/holiday. Demographic characteristics can be found in Table 1.

Self-Administered Rating Scale for Pubertal Development

All children completed the 5-item Self-Administered Rating Scale for Pubertal Development; scale ratings have been demonstrated to be strongly correlated to physician's examinations.[16] Items are rated on a 4-point scale ranging from 1 ("not yet begun") to 4 ("seems complete"), yielding an overall assessment of pubertal stage. All participants in the current study met criteria for Tanner stages 1 (pre-pubertal) or 2 (early pubertal).

Revised Children's Anxiety and Depression Scale—Child and Parent versions (RCADS-C/P)

The Revised Children's Anxiety and Depression Scale—Child and Parent versions (RCADS-C/P)[16] is a 47-item, self-report measure that assesses anxiety and depressive symptoms corresponding to several anxiety disorders from the DSM-IV and is a reliable and valid measure of anxiety and depressive symptoms in children and adolescents.[17,18] RCADS items are scored using a 4-point scale (0 = Never, 1 = Sometimes, 2 = Often, 3 = Always). Items are summed to generate subscale scores (i.e., separation anxiety, generalized anxiety, social phobia, panic disorder, obsessive-compulsive, and major depression), total anxiety and depression scores, and an overall RCADS score. RCADS items showed excellent internal consistency for child report (α = .95) and good internal consistency for parental report (α = .89). In the current study, raw scores were calculated from mean anxiety and depression scores and converted to a corresponding T-score. As is common practice in the child mental health literature[19,20] we aggregated child and parent scores for inclusion in regression analyses since combined scores yield less measurement error than single informant responses.[21]

Polysomnography

One night of ambulatory PSG was recorded for each participant using Embletta MPR and ST Proxy units (Embla Systems, Kanata, Canada) with RemLogic software (version 3.4.1; Natus, Pleasanton, CA, USA). Electroencephalogram (EEG; frontal, central and occipital regions), electrooculogram (EOG), electromyogram (EMG, submental, right/left tibial), electrocardiogram (ECG), nasal pressure, thoracic and abdominal respiratory effort, and oximetry was collected for all participants. Data were scored in 30-second epochs in accordance with American Academy of Sleep Medicine criteria, by registered polysomnographic sleep technicians (RPSGT) experienced in scoring pediatric sleep records. Variables derived from PSG for the current study included percentage of the sleep period spent in REM sleep (REM%) as well as non-REM sleep stages 1-3 (N1%, N2% and N3% respectively).

Actigraphy

Actigraphy was measured simultaneously with PSG using the Micro Motionlogger Sleep Watch (Ambulatory Monitoring, Inc., Ardsley, NY, USA). This watch is an accelerometer-based monitor that can record movement for up to one month. Participants were instructed to wear the watch continuously concurrently with the PSG night and to push the event marker button on the watch to indicate when they got into bed at night and when they got out of bed the following morning. Data were recorded in one-minute epochs, and scored with the validated Sadeh algorithm to determine sleep-wake periods.[22] Actigraphy variables examined in the present paper included sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO), and sleep efficiency (SE). SOL was calculated as the number of minutes between the event marker and the first epoch of sleep. TST was calculated as the total number of minutes scored as "sleep" during the time-in-bed period. WASO was calculated as the total number of minutes scored as "wake" following the onset of sleep. Finally, SE was calculated as the proportion of TST to the proportion of time-in-bed and is indicated as a percentage.

Subjective Sleep Quality

Participants provided ratings of their sleep quality on the morning following PSG and actigraphy monitoring with a self-report measure created for the current study. Global sleep quality was assessed with the question *"How well did you sleep last night?"* rated on a 0 to 10 Likert-type scale, with anchors of 0 ="poorly", 5 ="okay", and 10 ="great/excellent". For the current study, ratings ≥ 6 were considered to reflect good/high quality sleep.

Statistical Analysis

All analyses were conducted using SPSS (Version 25; SPSS Inc., Chicago, IL). Preliminary analyses assessed for potential sleep-based differences based on demographic variables (i.e., age, gender, race, ethnicity, parent marital status, household income). Partial correlations among all continuous variables were also examined to identify significant relationships. To examine potential linear and non-linear effects, separate polynomial regression models were run for each sleep-based predictor (i.e., N1%, N2%, N3%, REM%, TST, SOL, WASO, and SE) to examine relationships with subjective sleep quality. Models that did not include total sleep time as a predictor controlled for this variable. Linear effects were represented by mean-centered sleep variables and quadratic terms were created by squaring the mean-centered sleep variables. When both the linear and quadratic effect was significant in a model, only the quadratic effect was interpreted. To examine specific expert panel recommendations[3] values were plotted using predicted values for outcome variables. All analyses controlled for child-reported anxiety and depressive symptoms.

Results

Preliminary Analyses

Children of Hispanic/Latinx ethnicity reported significantly lower sleep quality ratings (t[22.88] = 2.19, p = .04), exhibited less TST (t[50] = 2.24, p = .02), and greater WASO (t[50] = -2.51, p = .02) based on actigraphy than non-Hispanic/Latinx children. Actigraphy-based TST (F[3, 48] = 3.13, p = .03) also differed as a function of race such that African-American children had the longest TST, while biracial/other children had the shortest TST. PSG-derived N2% differed significantly based on parent marital status (F[4, 47] = 3.28, p = .02) such that children with single parents exhibited greater N2% than children with married parents (either to the child's other parent or to another partner). After controlling for relevant demographic variables, age and actigraphic TST were negatively correlated (r = -.34, p < .05). Sleep variables did not differ based on participation timing (i.e., during school year versus spring/summer break), or any other demographic variable. Partial correlations (controlling for child race, child ethnicity, and parent marital status) are reported in Table 3.

In order to examine whether sleep timing on the PSG night differed significantly from children's typical sleep patterns, we conducted paired-samples t-tests to compare mean sleep onset and offset times from the actigraphy week (when no sleep times were prescribed) to the PSG night. No significant differences in sleep onset (t[50] = -1.63, p = .11) or sleep offset (t[50] = -.63, p = .53) times were observed. Similarly, no significant differences between the PSG night and the actigraphy week were observed in terms of SOL (t[50] = -.01, p = .99), TST (t[51] = 1.45, p = .15, or WASO (t[51] = 1.60, p = .12).

Sleep Characteristics and Ratings of Sleep Quality

Objective sleep characteristics and sleep quality ratings on the night of sleep monitoring are presented in Table 2. On average, children slept for 508.97 minutes (*SD* = 72.79) and reported good subjective sleep quality (*M*=6.15, *SD* = 2.77) on the PSG night. Descriptive statistics for self-reported variables can be found in Table 2, and correlations among subjective and objective variables are included in Table 3.

Sleep Continuity Variables as Predictors of Sleep Quality Ratings

Separate polynomial regression models examined the contribution of each sleep continuity variable in predicting subjective ratings of sleep quality (see Table 4). For all models, relevant demographic variables (e.g., child race/ethnicity and parent marital status) and affective symptoms were entered as first- and second-step covariates, respectively. Affective symptoms did not contribute significantly to any of the models. TST was included as a covariate as appropriate. Neither linear nor quadratic effects of TST, SOL or SE were statistically significant in predicting next-morning ratings of sleep quality, all with small effect sizes (Cohen's $f^2 \leq .09$; see Table 4). For WASO, the linear effect was non-significant (ΔR^2 = .02, p = .34) while the quadratic effect was marginal, based on a small effect size (ΔR^2 = .07, p = .05, Cohen's f^2 = *.10*). Plotted predicted values indicated that ratings of high sleep quality were predicted when WASO was approximately ≤ 30 minutes. (see Figure 1).

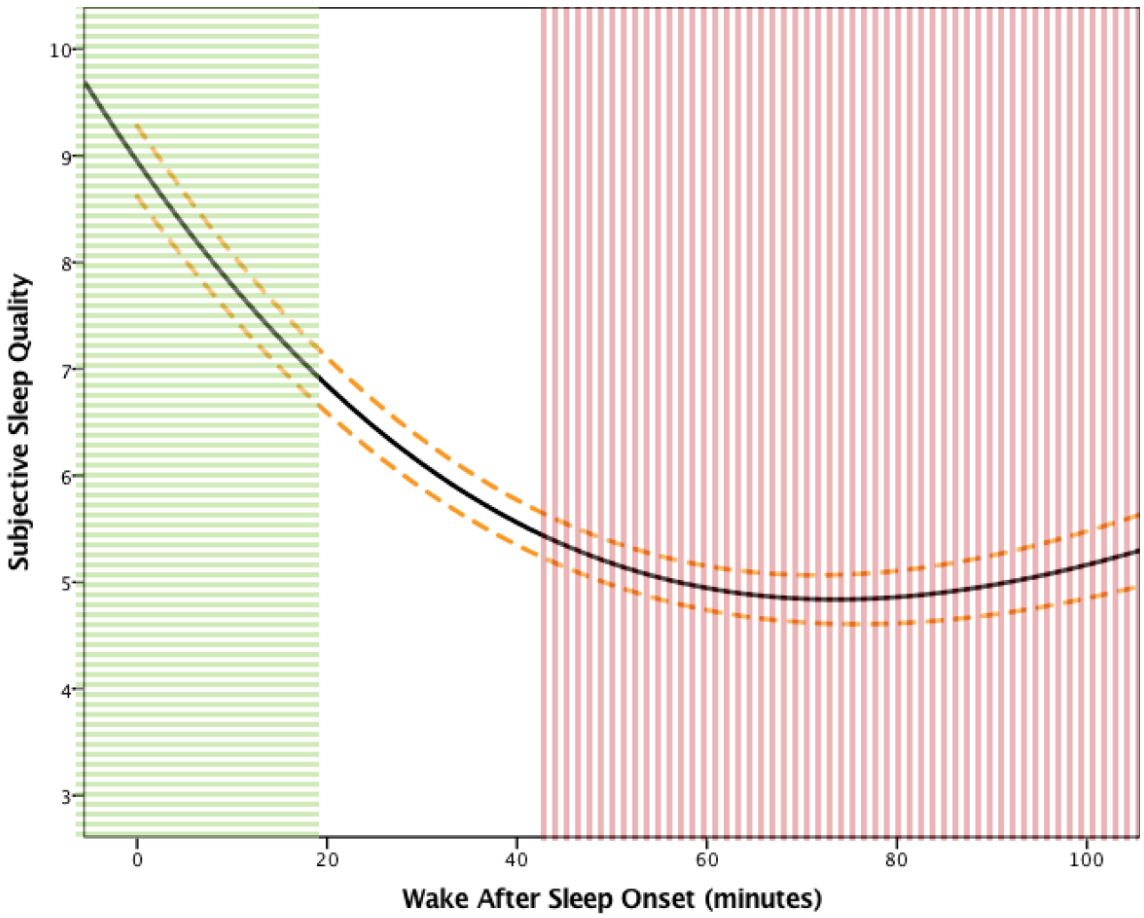

Figure 1. Quadratic effect for wake after sleep onset (WASO) in minutes predicting subjective sleep quality ratings. Orange dashed lines indicate 95% confidence interval. Green shaded area indicates the National Sleep Foundation (NSF)'s recommendation for "good quality sleep". Red shaded area indicates NSF's recommendation for "poor quality sleep".

Sleep Architecture Variables as Predictors of Sleep Quality Ratings

Separate polynomial regression models were also used to examine the contribution of sleep architecture variables in predicting child reports of sleep quality (Table 4). Again, relevant demographic variables and affective symptoms were entered as first- and second-step covariates, respectively, and TST in minutes was also entered as a covariate in all models. Again, affective symptoms did not contribute significantly to these models. Both linear and quadratic effects of N2%, N3%, and REM% on ratings of sleep quality were non-significant with small effect sizes (Cohen's $f^2 \leq .03$; see Table 4). For N1%, the linear effect on sleep quality ratings was non-significant ($\Delta R^2 = .002$, $p = .72$), while the quadratic effect was significant based on a medium effect size ($\Delta R^2 = .13$, $p = .007$, Cohen's $f^2 = .17$). Plotted predicted values indicated that high ratings of sleep quality were predicted when N1 occupied approximately 2% to 6% of the nighttime sleep period. See Figure 2.

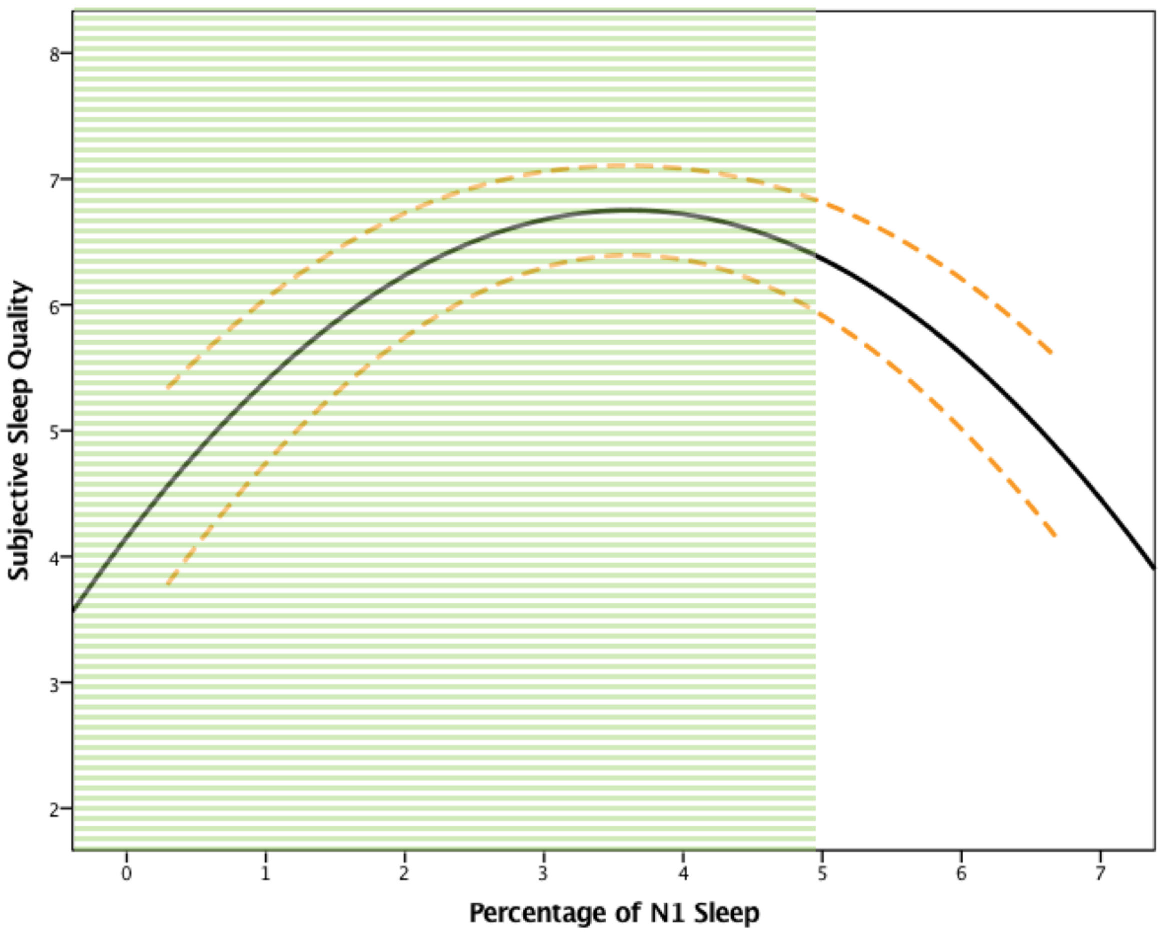

Figure 2. Quadratic effect for percentage of stage 1 sleep (N1) predicting subjective sleep quality. Orange dashed lines indicate 95% confidence interval. Green shaded area indicates the National Sleep Foundation (NSF)'s recommendation for "good quality sleep".

Discussion

Despite agreement for the importance of high quality sleep in youth, the relative contribution of objective sleep elements to perceptions of good quality sleep in school-aged children is generally and surprisingly unknown. We therefore examined linear and nonlinear associations between objective sleep parameters and reports of sleep quality among a sample of healthy children after a night of sleep monitoring in the home. Contrary to hypotheses and previous reports, TST, SOL and SE did not predict child ratings of sleep quality. However, we did observe a marginal effect for WASO, where values of approximately ≤ 30 minutes corresponded with high sleep quality. This finding generally aligns with NSF expert recommendation for good sleep quality that WASO not exceed 20 minutes for all age groups. Importantly, this relationship was curvilinear such that it diminished when WASO values surpassed approximately 40 minutes, also consistent with NSF recommendation[3] that ≥ 41 minutes WASO is associated with the poorest quality sleep. Thus, WASO may contribute meaningfully to children's perceived sleep quality at lower levels but less so at higher levels. It is important to note that WASO values on the PSG night were similar to those observed during the actigraphy week as well as values reported in other studies of school-aged children,[23,24] adding supporting to these findings. Nonetheless, replication studies in larger samples are needed to confirm these results.

For sleep architecture variables, percentages of N2, N3 and REM sleep were non-predictive of child-rated sleep quality, contrary to our hypotheses. Because SWS is generally recognized as the most restorative sleep stage, reflective of sleep depth/intensity,[25] this finding in particular was surprising. Although greater SWS has often been associated with higher ratings of sleep quality in adults,[26] the greater duration and intensity of this sleep stage and associated slow wave activity (SWA) during the pre-adolescent years may have relevance for our findings.[27] Specifically, a stable and abundant proportion of SWS between the ages 6 to 11 years,[27] together with our inclusion of healthy children without psychiatric, medical or sleep disorders, may have results in a restricted range of SWS in our study that reduced our ability to detect a relationship with sleep quality. This developmentally-focused question remains to be precisely examined.

We did however find a non-linear effect of N1% on sleep quality ratings whereby high ratings of quality sleep were endorsed when N1 occupied 2% to 6% of the total sleep period. This finding is more nuanced as compared to NSF recommendation that N1 ≤ 5% corresponds with good quality sleep.[3] Because N1 sleep reflects the lightest stage of sleep, occurs during the transition from wakefulness,[28] and is associated with greater sleep fragmentation and next-day sleepiness,[29] greater N1% would be expected to coincide with lower subjective sleep quality. Conversely, minimal N1 sleep may result from acute or an accumulated sleep debt[30] (i.e., as a consequence of increased sleep pressure and SWS) and correspond with lower ratings of sleep quality.

The role of development is central to the current set of findings. The period of late childhood and the transition from childhood to adolescence is routinely underscored as a period of high risk.[31,32] Sleep patterns and timing undergo rapid changes around the time of sexual maturation, including decreases in SWS and REM sleep and increases in the percentage of N1, N2, and WASO.[7] These collective changes reflect progressively lighter sleep with potential implications for perceptions of sleep quality. Longitudinal studies demonstrate that subjectively-reported sleep disturbance emerging during this developmental window uniquely forecast persistent sleep, emotional, and behavioral problems.[32,33] Middle to late childhood also constitutes a period of rapid cognitive development wherein children are able to reflect upon and report their internal experiences. Still, the reliability of child ratings of sleep quality remains unknown, partly because factors that directly shape their perceptions of ‘good sleep quality’ have not been explored. Future studies might incorporate parent reports of sleep and daytime sleepiness to better estimate the reliability of child reports. Notably however, even when more easily quantifiable sleep variables are compared based on parent and child reports (e.g. total sleep time), agreement is often low.[34,35] Overall, relationships observed in the present study await replication and expansion but stand to inform both public health as well as intervention efforts.

Limitations and Strengths

Our study has several strengths, including the examination of objective sleep variables derived from both actigraphy and PSG and a well-screened, healthy sample of children studied in the home environment. At the same time, several limitations are noteworthy. Our sample size likely limited our ability detect relationships among some study variables. The use of only one PSG night creates the possibility of first-night effects.[36] Further, although TST, SOL and WASO were similar on the PSG night compaerd to the actigraphy week, the use of prescribed sleep times during PSG assessment may have impacted specific findings. The inclusion of healthy children who slept at least 8.5 hours per night also needs to be considered, as this limits the generalizability of our findings to other pediatric populations. Other limitations include the use of a single question to assess subjective sleep quality and our relatively arbitrary categorization of good sleep quality. Future studies should incorporate validated measures of child-reported sleep and multiple nights of sleep monitoring. It is also possible that other factors not examined in our study may influence reports of sleep quality in youth. For example, physical activity,[37] electronic media use,[38] and sleep hygiene[39] have all been associated with sleep quality. Although we observed no differences in sleep timing between the PSG night and week of actigraphy, controlled studies that account for individual sleep timing and seasonal variations are needed.

Conclusions

Specific elements of sleep that most robustly influence children's reports of sleep quality are generally unknown. This study contributes knowledge by investigating these associations in healthy pre-pubertal children using various forms of sleep assessment. Both N1 sleep and WASO showed curvilinear associations with child-reported sleep quality, whereas TST, SE, SOL and SWS were not associated with sleep quality. These findings await replication in larger and more diverse samples of children.

Acknowledgements

We would like to acknowledge and thank the families who participated in this study.

Funding Source: This project was funded by grant #R21 MH099351 from the National Institutes of Mental Health awarded to the corresponding author. There are no other disclosures.

Conflict of Interest: The authors have no conflict of interest.

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Tables

Table 1

Demographic Characteristics of Study Sample

N	52
Age: *M (SD)*	9.15 (1.35)
Female: *n* (%)	29 (55.8%)
Race: *n* (%)	
Caucasian	31 (59.6%)
African-American	16 (30.8%)
Asian-American	2 (3.8%)
Biracial/Other	3 (5.8%)
Ethnicity: *n* (%)	
Non-Hispanic/Latino	36 (69.2%)
Hispanic/Latino	16 (30.8%)
Body Mass Index: *M (SD)*	18.58 (3.46)
Pubertal Development Scale: *M (SD)*	2.05 (.77)
Parent Relation to Child: *n* (%)	
Mother	43 (83%)
Father	9 (17%)
Parent Marital Status: *n* (%)	
Married to child’s father/mother	35 (67.3%)
Married to another partner	3 (5.8%)
Single	9 (17.3%)
Divorced	4 (7.7%)
Widowed	1 (1.9%)
Yearly Household Income: *n* (%)	
<$20,000	3 (5.8%)
$20,000-$40,000	9 (17.3%)
$40,000-$60,000	10 (19.2%)
$60,000-$80,000	9 (17.3%)
$80,000-$100,000	7 (13.5%)
>$100,000	14 (26.9%)
Holiday Status during participation: *n* (%)	
No (Participated during school year)	38 (73.1%)
Yes (Participated during school holiday)	14 (26.9%)

Note. M = Mean; SD = Standard deviation.

Table 2

Descriptive Statistics for Study Variables:	*M (SD)*	Range
RCADS Anxiety T-Scores	41.20 (6.46)	25.54
RCADS Depression T-Scores	43.15 (5.24)	23.69
Actigraphy SOL (minutes)	20.84 (15.92)	68.00
Actigraphy TST (minutes)	508.97 (72.79)	457.00
Actigraphy WASO (minutes)	52.02 (40.96)	168.00
Actigraphy SE (%)	85.69 (8.78)	25.91
PSG %N1	3.59 (2.08)	6.40
PSG %N2	57.95 (6.92)	29.40
PSG %N3	22.20 (6.98)	32.30
PSG %REM	16.10 (5.17)	23.70
Next Morning Self-Reported Sleep Quality (0-10)	6.15 (2.77)	10.00

Note. M = Mean; SD = Standard deviation; RCADS = Revised child anxiety and depression scale (average of parent and child report); SOL = Sleep onset latency; TST = Total sleep time; WASO = Wake after sleep onset; SE = Sleep efficiency; N = Non-rapid eye movement; REM = Rapid eye movement.

Table 3

Partial Correlations among Continuous Study Variables

	1	2	3	4	5	6	7	8	9	10	11
1. Age											
2. Depression	-.41**										
3. Anxiety	-.14	.57**									
4. Act-SOL	.01	.06	.08								
5. Act-TST	-.34*	.05	.05	-.34*							
6. Act-WASO	.25	-.25	-.24	.09	-.66**						
7. Act-SE	-.07	-.05	.07	-.33*	.73**	-.84**					
8. PSG-%N1	.21	-.21	-.11	-.28*	.19	-.28	.39**				
9. PSG-%N2	-.15	.23	.08	-.001	-.002	.11	-.22	-.23			
10. PSG-%N3	.05	-.22	-.16	-.12	-.27	.32*	-.31*	.03	-.66**		
11. PSG-%REM	-.05	.03	.07	.17	.31	-.45**	.43**	.06	-.34*	-.33*	
12. SR-SQ	.07	-.07	.26	-.14	.13	-.20	.45**	.06	-.03	-.18	.18

Note. Controlled for race, ethnicity, and parent marital status. Act = Actigraphy; PSG = Polysomnography; SR = Next morning self-report; SOL = Sleep onset latency; TST = Total sleep time; WASO = Wake after sleep onset; SE = Sleep efficiency; N = Non-rapid eye movement; REM = Rapid eye movement; SQ = Sleep quality.
*$p < .05$. **$p < .01$.

Table 4

Objective Sleep Variables Predicting Subjective Sleep Quality

Predictor:	ΔR^2	**β**	*b*	SE	95% CI
Act-SOL					
Linear	.001	.00	-.002	.03	[-.06, .06]
Quadratic	.03	.27	.002	.001	[-.001, .004]
Act-TST					
Linear	.003	.06	.002	.006	[-.01, .01]
Quadratic	.01	-.11	< .001	.00	[.00, .00]
Act-WASO					
Linear	.02	-.18	-.01	.01	[-.04, .01]
Quadratic	.07*	.36	.00*	.00	[.00, .001]
Act-SE					
Linear	.07	.49	.16	.08	[-.01, .33]
Quadratic	.04	.27	.005	.003	[-.002, .01]
% N1					
Linear	.002	.05	.08	.22	[-.37, .52]
Quadratic	.13***	-.40	-.33***	.12	[-.56, -.09]
% N2					
Linear	.003	-.06	-.02	.06	[-.14, .09]
Quadratic	.03	-.18	-.008	.006	[-.02, .005]
% N3					
Linear	.01	-.12	-.05	.06	[-.16, .07]
Quadratic	.01	.12	.004	.005	[-.007, .01]
% REM					
Linear	.05	.23	.12	.08	[-.03, .27]
Quadratic	.00	.02	.001	.01	[-.02, .02]

Note. For all models, relevant demographic variables (child age, child race/ethnicity, parent marital status) and affective symptoms were entered as first-step covariates. TST was entered as a second-step covariate as appropriate. Predictor variables were first mean-centered. Act = Actigraphy; PSG = Polysomnography; SOL = Sleep onset latency; TST = Total sleep time; WASO = Wake after sleep onset; SE = Sleep efficiency; N = Non-rapid eye movement; REM = Rapid eye movement.

* $p = .05$

** $p < .05$

*** $p < .01$