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A Cross-sectional Study of Actigraphy-Measured Sleep Patterns among Children with Disabilities

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ABBREVIATIONS
ADHD-attention-deficit/hyperactivity disorder
ASD-autism spectrum disorder
CI-confidence interval
CPASS-Chile Pediatric and Adult Sleep and Stress Study
ICD-International Classification of Diseases
IQR-interquartile range
OR-odds ratio
SD-standard deviation
SE-standard error
WASO-wake after sleep onset

Abstract

Objectives: To characterize actigraphy-measured sleep patterns among children with disabilities and to examine whether caregivers' education is associated with sleep disturbances.

Design: Cross-sectional study.

Setting: A rehabilitation center in the Patagonia region, Chile.

Methods: This pilot study was conducted among 125 children aged 6-12 years with disabilities (boys: 55.2%) and caregivers in Chile. Children wore ActiSleep monitors for seven days. General linear models were fitted to generate least-square mean and standard error (SE) of sleep efficiency across caregivers' education levels adjusting for children's age, sex, disability type, caregiver-child relationship, and caregivers' age. Multivariable logistic regression analyses were conducted to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of longer sleep latency (≥30 minutes) and longer wake after sleep onset (WASO) (≥90 minutes) (a measure of sleep fragmentation) in relation to caregivers' educational attainment.

Results: Median sleep latency was 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours. Mean sleep efficiency was 80.0%. Caregivers' education was positively and significantly associated with children's sleep efficiency (P_{trend}=0.001). Adjusted mean sleep efficiency was 75.7% (SE=1.4) among children of caregivers <high school, and 81.9% (SE=1.0) among children of caregiver >high school. Compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep latency (OR=3.27; 95% CI=1.12-9.61) and longer WASO (OR=5.95; 95% CI=1.91-18.53). Associations were consistent across disability types.

Conclusions: Children with disabilities experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency). Among children with disabilities, lower caregiver education level is associated with more sleep disturbances.

KEY WORDS: child, disability, caregiver, education, sleep parameter, actigraph, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

Strengths and limitations of this study

- This pilot study is strengthened by its use of actigraphy which has been well validated for objective estimation of nighttime sleep parameters in the natural sleep environment.
- Our study was unique in being the first study to examine the associations between caregivers' education and actigraphy-measured sleep among children with disabilities.
- Its strength also lies in the statistical analysis that was performed using univariate and multivariable linear and logistic regression models.
- This is a cross-sectional, pilot study with a small sample size and high heterogeneity of disabilities included.

INTRODUCTION

Approximately 150 million children live with disabilities worldwide.[1] Sleep disturbances, particularly difficulty initiating and maintaining sleep, are commonly reported among children with a wide range of disabilities including attention-deficit/hyperactivity disorder (ADHD) and autism.[2-6] There are discrepancies between objective measures of sleep and those reported by parents of children with disabilities.[5] Parents may be, unaware of children's sleep disturbances, such as night awakenings, and tend to overestimate their children's sleep duration.[7] Inferences from prior studies are limited because investigators have relied on parental report of child sleep.[3] Although polysomnography is considered the gold standard for measuring sleep, it is burdensome and not easily amenable for use with children who have difficulties sleeping in unfamiliar surroundings. Actigraphy-based sleep offers opportunities to obtain objective measures of sleep in children's typical environment. Actigraphy has been validated for objective measures of sleep in clinical- and population-based studies.[8, 9]

Sleep disturbances have been related to sociodemographic, environmental, and behavioral factors.[10-13] Children's sleep disturbances have been connected with their home environment that may be influenced by caregivers' characteristics.[13, 14] Our recent qualitative study showed that while both caregivers and rehabilitation providers recognized the importance of sleep health, they differed in their understanding of how sleep practices influence sleep health.[13] Parental ability to provide support for healthy behaviors including sleep may be influenced by parental education, a known factor associated with child health measures.[12, 15-17] Magana et al reported that maternal education and knowledge about autism accounted for differences in the number of specialty services received by Latino children with autism spectrum disorder (ASD) as compared with White children in the US.[15] However, to our knowledge, little research has been conducted regarding the role of caregivers' education in objectively measured sleep among children with disabilities.

This pilot study aimed to characterize actigraphy-measured sleep patterns and to examine whether caregivers' education is associated with sleep disturbances among children with disabilities. Our hypotheses include that actigraphy-measured sleep disturbances including long sleep latency, long wake after sleep onset, short sleep, and poor sleep are common among children with disabilities. Caregivers' low levels of educational attainment are strongly associated with children's sleep disturbances. The use of actigraphy was intended to eliminate the influence of reporting errors in sleep patterns of children with disabilities.

METHODS

Participants

The Chile Pediatric and Adult Sleep and Stress Study (CPASS) was a cross-sectional, pilot study that was established in September 2012 at the Centro de Rehabilitacion Club de Leones Cruz del Sur in Punta Arenas, Chile.[13] The first wave of the CPASS (CPASS I) was conducted between September and December in 2012 among children aged 6-12 years who were receiving routine clinical care for disabilities (e.g., having impairments, activity limitations, participation restrictions) due to health conditions such as autism, Down's Syndrome, cerebral palsy at the center and their primary caregivers who were parents, grandparents, relatives, or other adults and were principally responsible for children's wellbeing and did not have developmental or intellectual disabilities. A total of 110 children and caregivers (one caregiver per child) were recruited in the CPASS I. Five children were excluded from this study due to incomplete actigraphy data: four children removed monitors after day one or day two of the study and/or without sleep log data; one child lost the monitor on day two. A total of 105 child-caregiver dyads (95.5% of enrolled families) completed the CPASS I study protocol. The second wave of the CPASS (CPASS II) was conducted among children with disabilities aged 10-21 years and their primary caregivers between April and July in 2013 at the center.[18, 19] Research personnel invited 129 caregivers of children with disabilities to participate. A total of 90 caregivers (72%) agreed to participate in the study. Twenty children were aged 10-12 years from the CPASS II. In total, 125 children aged 6-12 years were included in the study.

Written informed consents were obtained from primary caregivers of children with disabilities. This study was approved by the institutional review boards of the Centro de Rehabilitacion Club de Leones Cruz del Sur and Harvard T.H. Chan School of Public Health Office of Human Research Administration.

Study Procedures

A psychologist administered structured questionnaires to caregivers to collect information on sociodemographic and lifestyle factors of children and caregivers. Research staff instructed children to wear ActiSleep monitors (ActiLife, ActiGraph R&D, Florida, USA)[20] on their non-dominant wrists for seven consecutive days. Although the monitors are waterproof, children and their caregivers were instructed to remove them from their wrists before taking showers and before swimming. Caregivers were also instructed to keep sleep logs of time in bed and time out of bed for their children. Electronic medical records were reviewed by a physician to confirm children's disabilities defined by the World Health Organization.[21]

Sleep Parameters

Actigraphic sleep data were collected using the ActiSleep monitors and were analyzed using the ActiLife 6 data analysis software.[20] When worn during sleep episodes, the ActiSleep monitor can provide sleep measures including sleep onset, sleep latency, wake after sleep onset (WASO), number and length of awakenings, sleep duration, and sleep efficiency. Sleep latency is the length of time taken to fall asleep, calculated as the time of "lights off" to the first period of 3 minutes of consecutive epochs scored as sleep. WASO is the number of minutes awake between sleep onset and time of final waking. Sleep efficiency is defined as the proportion of the estimated sleep periods spent asleep. Actigraphy data were collected in 1-min epochs using the zero-crossing modes, and the "Sadeh" sleep algorithm was used for children.[22] The majority of children (98.4%) had complete 7-day actigraphic sleep data; two children had 6-day actigraphic data and one child had 3-day data available for study.

Sociodemographic Characteristics and Child Disabilities

Interviewer-administered questionnaires were used to collect information on children's age, sex, caregiver-child relationship (e.g., mother), caregivers' age, and education levels. Caregivers were asked to report the highest degree of education they had completed: less than 12th grade, high school graduate or equivalent, some college degree, or college graduate or above. According to the International Classification of Diseases (ICD-10),[23] children's disabilities were grouped as: 1) mental and behavioral disorders (e.g., autism, ADHD); 2) diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); 3) diseases of the nervous system (e.g., cerebral palsy); and 4) congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Statistical Analysis

Kolmogorov-Smirnov test was used to assess the normality of sleep parameters. Variables were described using means and standard deviations (SDs) for parametric variables and medians and interquartile ranges (IQRs) for nonparametric variables. Student's t-test was used for age, sleep efficiency, and number of awakening as parametric variables; Wilcoxon rank-sum test was used to test differences in nonparametric variables including sleep onset, sleep latency, WASO, awakening length, and sleep duration by child sex. Fisher's or χ^2 test was conducted to compare differences in sociodemographic factors and disability groups by child sex. Analysis of variance or Kruskal-Wallis test was conducted to evaluate differences in sleep parameters across children's disability groups and caregivers' education levels.

General linear model was fitted to generate least-square mean and standard error (SE) of sleep efficieny across caregivers' education levels with adjustment for children's age, sex, disability, caregiver-child relationship, and caregivers' age. Univariate and multivariable linear regression analyses were performed to examine the associations of caregivers' education level with sleep efficiency and the number of awakenings. Stratified analysis was conducted to evaluate whether associations between caregivers' education and children's sleep disturbances differed according to disability groups. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models to evaluate the associations of caregivers' educational attainment with children's long sleep latency (≥30 vs. <30 minutes), long WASO (≥90 vs. <90 minutes), and short sleep duration (<8 vs. ≥8 hours). These cut points were chosen based on the literature of sleep latency[24] and sleep duration,[25] as well as sleep data distributions in the study (WASO median=88 minutes, sleep duration median=8 hours; only 9.6% of children had sleep ≥9 hours). We also included a variable to represent study wave (I and II) in multivariable regression models and found similar results (data not shown). Statistical significance levels were set at P <0.05 for two-sided analyses. All tests were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

The mean age of children was 9.2 (SD=2.2) years. Most caregivers were mothers (88.0%); 21.6% of caregivers reported having <high school (**Table 1)**. There were no statistically significant differences in caregiver-child relationship, caregivers' age or education between boys and girls.

Median time for sleep onset was 22:39, sleep latency 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours (**Table 1**). Mean number of awakening was 22.1, sleep efficiency 80.0%. There were no statistically significant differences in sleep parameters between boys and girls (all P >0.05). Overall, 43.2% of children had sleep latency ≥30 minutes, 51.2% had short sleep <8 hours, and 77.6% had low sleep efficiency <85%.

There were no significant differences in sleep parameters across disability groups (**Supplementary Figure 1**), except for the number of nocturnal awakening (**Supplementary Table 1**). Children with diseases of musculoskeletal system and connective tissue, skin and subcutaneous tissue appeared to have more awakenings, reflecting more fragmented sleep, than children with other disabilities.

Children whose caregivers had <high school had longer sleep latency, longer WASO, longer awakening length, and lower sleep efficiency compared to children whose caregivers had >high school (**Figure 1, Table 2)**. Although children of caregivers with <high school tended to have later sleep onset, higher number of awakenings, and shorter sleep duration when compared to children of caregivers with higher education, these differences did not reach statistical significance.

After adjustment for child age, sex, disability group, caregiver-child relationship, and caregiver age, mean sleep efficiency was the lowest among children of caregivers with <high school (75.7% [SE=1.4]), followed by children of caregivers with high school (80.4% [SE=1.0]) and >high school (81.9% [SE=1.0]).

Linear regression analyses showed no significant associations between caregivers' education levels and children's awakening number. However, compared to children whose caregivers had >high school, children of caregivers with <high school had significantly lower sleep efficiency (adjusted beta=-6.3, SE=1.7; P=0.001) (**Table 3**). Caregivers' educational attainment was significantly and positively associated with children's sleep efficiency (P_{trend}=0.001).

As shown in **Table 4,** compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep latency ≥30 minutes (adjusted

OR=3.27; 95% CI=1.12-9.61) and longer WASO ≥90 minutes (OR=5.95; 95% CI=1.91-18.53). Caregivers' education levels were significantly and inversely associated with children's sleep latency and WASO (both P_{trend}<0.05). Children's short sleep duration (<8 hours) was not associated with caregivers' low educational level (OR=0.78; 95% CI=0.28-2.18).

The associations between caregivers' education and children's sleep efficiency varied little according to disability groups. For example, among children with mental and behavioral disorders, children of caregivers with <high school had lower sleep efficiency (beta=-6.2, SE=2.2; P=0.006), after adjustment for children's age, sex, caregiver-child relationship, and caregivers' age.

DISCUSSION

In this cross-sectional, pilot study, we assessed sleep patterns using wrist ActiSleep monitors over seven consecutive days among Chilean children with disabilities. We found that actigraphy-measured sleep disturbances including long sleep latency (median=27 minutes), long WASO (median=88 minutes), short sleep duration (median=8 hours), high number of nocturnal awakenings (mean=22), and low sleep efficiency (mean=80%) were common among children. These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency), maintaining sleep (long WASO, low sleep efficiency), and sleep fragmentation (increased nocturnal awakenings). These indices are common in insomnia, which may occur secondary to chronic health conditions, and for many conditions, is associated with poor quality of life and increased disease-specific health burden including behavioral and cognitive problems.[26, 27] We also found strong associations between caregivers' low educational attainment and sleep disturbances (e.g., low sleep efficiency) independent of children's disability and other covariates from children and caregivers. To our knowledge, this is the first study to specifically quantify actigraphy-measured sleep patterns and strong associations of caregivers' low education levels with children's sleep disturbances.

Children with a wide range of disabilities have been reported to have sleep disturbances, including prolonged sleep latency, increased WASO, and decreased sleep efficiency.[4-6, 28, 29] In a study of 8 UK children with mucopolysaccharidosis aged 2-15 years, median actigraphy-measured sleep latency was 35.4 minutes, WASO 83.4 minutes, and sleep efficiency was 75.6%.[29] Allik et al reported that children aged 8-12 years with Asperger syndrome and high-functioning autism in Sweden had actigraphy-measured longer sleep latency (mean=32 minutes) and lower sleep efficiency (mean=87%) than controls.[6] In a study of children aged 5-11 years with ADHD in Denmark, average sleep latency was 26 minutes, 31% of children had sleep latency >30 minutes.[5] A case-control study using 5-night actigraphy for 15 school-aged children with traumatic brain injury and 15 school-aged sibling in UK reported that brain injury was significantly associated with children's longer sleep latency (mean=50 minutes), longer WASO (mean=65 minutes), and lower sleep efficiency (mean=80%).[28] Gibbs et al reported that among 8 children aged 4-15 years with Prader-Willi syndrome in New Zealand, median 7-night actigraphy-measured WASO was 95 minutes.[30] Corkum et al reported the average of awakenings was 15 among Canadian children with ADHD (age: 7-11 years).[4] In this study, we found a high prevalence of actigraphy-measured sleep disturbances among Chilean children with disabilities: 43% of children had sleep latency ≥30 minutes, and 78% had sleep efficiency <85%. Our study along with previous research suggests that children with disabilities have difficulties initiating and maintaining sleep.

Several researchers have reported that children with disabilities have late sleep onset.[31, 32] A study of US children aged 2-5 years with autism and other developmental disabilities reported that the mean of 7-day actigraphy-measured sleep onset was 21:32.[31] In this study, we found that median sleep onset was 22:39 among Chilean children with autism and other disabilities. Unique climate (e.g., late sunset) and lifestyle characteristics (e.g., late mealtime) in the Patagonia region may have partly contributed to children's late sleep time.[13, 33] Our findings of late sleep onset are generally consistent with literature for children in this age range. For example, a cross-sectional study of 96 healthy Chilean children aged 10 years found that the mean of overnight polysomnography-measured sleep onset was 23:10 for children with normal weight and 23:20 for children with overweight and obesity.[34] Another study of 58 US healthy children aged 11-13 years showed that the mean of 4-day actigraphy-measured sleep onset was 23:27.[35] In the Cleveland Children's Sleep and Health Study, 14.8% of US children aged 8-11 years had bedtime 23:00 or later.[14] Future research is warranted to examine how to improve sleep onset time among children, especially among those with disabilities.

It has been reported that children whose caregivers have low education levels are more likely to have adverse health outcomes, such as greater body weight[16] and lower quality of life.[17] McDonald et al found that lower maternal education was independently associated with parent-reported shorter sleep (<11 hours/night) among young children.[12] Although several studies have reported that parental education is associated with child health,[12, 15] we are unaware of published reports that have investigated whether and how caregivers' education levels are related to objectively measured sleep patterns among children with disabilities. In our study, caregivers' education in relation to children's sleep disturbances was substantiated through statistically significant association as shown in univariate and multivariable linear and logistic regression models. For example, after adjustment for children's age, sex, disability, caregiver-child relationship, and caregivers' age, children of caregivers with <high school had 6.3% lower sleep efficiency than children whose caregivers had >high school. Children of caregivers with <high school were 2.27 times more likely to have sleep latency ≥30 minutes and were 4.95 times more likely to have WASO ≥90 minutes when compared with children whose caregivers had >high school. These findings suggest the importance of tailoring sleep education for caregivers with lower educational attainment to improve children's sleep health. It may be important to provide education and support that include sleep hygiene education and strategies to ensure necessary social support for the less well-educated parents and families of children with disabilities.

Lack of knowledge of healthy sleep behaviors among caregivers has been associated with an increased risk of having unhealthy sleep behaviors for their children.[36] Although sleep disturbances have been noted to be common in children with neurological conditions (e.g., cerebral palsy), there are no interventions specifically designed to improve sleep in these children.[37] Several small studies of children with ASD have reported that parent-based sleep education appears effective in improving child sleep health.[32, 38] A study of 20 children with ASD showed that parent-based sleep education workshops improved sleep latency from 62.2 minutes to 45.6 minutes.[38] Malow et al reported that sleep education to parents of 80 children with ASD (aged 2-10 years) significantly improved children's sleep onset from 58.2 to 39.6

minutes.[32] Our prior qualitative study indicated that parental knowledge gaps regarding healthy sleep behaviors in children support the need for increased sleep health education among targeted caregivers.[13] Pediatricians and family physicians can provide adequate advice and educational messages (e.g., sleep health) to pediatric patients and their families.[39]

Our study has several limitations. First, as this was a cross-sectional, pilot study, we did not have a control group of children without disabilities. Second, this study was limited by its small sample size and the heterogeneity of disabilities represented among children studied. As such, we were not able to report associations specific to any single disability category (e.g., autism). Third, we did not collect information pertaining to caregivers' sleep hygiene and other factors such as co-sleeping. Hence we were not able to quantify the influence of these factors on children's sleep patterns. Our findings also focused on caregivers (majority were mothers) of children with disabilities in Chile, and may not be generalizable to other populations/groups. Although characterized as an objective measure of sleep-wake cycle, actigraphy has its limitations. For example, periods of quiet wakefulness may be interpreted by the device as sleep, and periods of restless sleep may be interpreted by the device as wakefulness.[8, 40] Despite this, actigraphy has been well validated for objective estimation of nighttime sleep parameters across age groups in the natural sleep environment.[9]

CONCLUSIONS

These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency), maintaining sleep (long WASO, low sleep efficiency), and sleep fragmentation (increased nocturnal awakenings). Among children with disabilities, lower levels of caregivers' educational attainment are strongly and independently associated with children's sleep disturbances. Parental support and education programs directed to families with low education levels may be of particular importance for sleep behavior intervention among children with disabilities. Larger studies are warranted to confirm our findings. Future research is also needed regarding the effects of sleep education intervention as well as social support to low educational families of children with disabilities on sleep health, with taking into account of different cultural backgrounds.

Contributors' Statement

All of the authors have agreed to the content of this manuscript. XC conceptualized and designed the study, supervised data collection, carried the initial analyses, and drafted the initial manuscript. JCV and CB carried out the field survey, supervised data collection, and critically reviewed and revised the manuscript. MP carried out the field survey, coordinated data collection at the study site, and reviewed the manuscript. BG helped develop the study protocol, and critically reviewed and revised the manuscript. SR critically reviewed and revised the manuscript. MAW provided funding support to the study, supervised the study, conceptualized and designed the study, and critically reviewed and revised the manuscript.

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Ethics Approval: This study was approved by the institutional review boards of the Centro de Rehabilitacion Club de Leones Cruz del Sur and Harvard T.H. Chan School of Public Health Office of Human Research Administration.

Data Sharing Statement: No additional data are available.

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Figure Legends

FIGURE 1 Children's Sleep Parameters, by Caregiver Education Levels

TABLE 1 Characteristics of Children with Disabilities and Their Primary Caregivers

	Total (n=125)	Boys (n=69)	Girls (n=56)	P value
Child characteristics				
Age (years), mean (SD)	9.2 (2.2)	8.8 (2.1)	9.8 (2.3)	0.015
Type of disability diagnosis, %				
Mental and behavioral disorders	48.0	59.4	33.9	0.004
Diseases of musculoskeletal system	16.8	10.1	25.0	
Diseases of the nervous system	27.2	27.5	26.8	
Congenital/chromosomal abnormalities	8.0	2.9	14.3	
Sleep parameters				
Sleep onset, median (IQR)	22:39 (22:06, 23:08)	22:44 (22:24, 23:08)	22:32 (21:53, 23:09)	0.183
Sleep latency, median (IQR), minutes	27.3 (15.0, 38.9)	27.1 (14.4, 41.7)	27.4 (15.4, 38.2)	0.512
WASO, median (IQR), minutes	88.1 (65.6, 111.1)	92.4 (64.4, 112.4)	81.9 (66.2, 107.0)	0.411
Number of awakening, mean (SD)[a]	22.1 (6.7)	22.5 (6.5)	21.6 (6.9)	0.441

Awakening length, median (IQR), minutes	5.1 (4.2, 7.1)	5.1 (4.2, 7.0)	5.1 (4.2, 7.1)	0.923
Sleep duration, median (IQR), hours	8.0 (7.5, 8.2)	8.0 (7.3, 8.2)	8.0 (7.5, 8.3)	0.459
Sleep efficiency, mean (SD), %[a]	80.0 (7.2)	79.0 (8.1)	81.2 (5.8)	0.072
Caregiver characteristics				
Age (years), mean (SD)	38.0 (7.8)	38.5 (7.8)	38.0 (7.8)	0.690
Caregiver-child relationship, %				
Mother	88.0	88.4	87.5	0.877
Other	12.0	11.6	12.5	
Education level, %				
<High school	21.6	24.6	17.9	0.088
High school	37.6	29.0	48.2	
>High school	40.8	46.4	33.9	

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Of these sleep parameters, only number of awakening and sleep efficiency were normally distributed (Kolmogorov-Smirnov test: P > 0.05). While Student's t-test was used for number of awakening and sleep efficiency, Wilcoxon rank-sum test was used for the other sleep parameters.

TABLE 2 Children's Sleep Parameters, By Caregivers' Education Levels

Sleep parameters	<High school (n=27)	High school (n=47)	>High school (n=51)	P value
Sleep onset, median (IQR)	23:05 (22:17, 23:23)	22:31 (21:55, 23:04)	22:39 (22:24, 23:02)	0.098
Sleep latency, median (IQR), minutes	35.6 (17.3, 53.7)	27.1 (17.4, 38.4)	23.6 (11.1, 35.9)	0.031
WASO, median (IQR), minutes	99.1 (88.1, 121.0)	77.1 (63.4, 103.4)	77.0 (57.6, 106.0)	0.006
Number of awakening, mean (SD)[a]	23.1 (5.7)	21.2 (6.3)	22.4 (7.5)	0.470
Awakening length, median (IQR), minutes	6.9 (5.0, 9.5)	5.2 (4.2, 7.2)	4.7 (3.9, 5.7)	0.001
Sleep duration, median (IQR), hours	7.9 (7.3, 8.4)	8.0 (7.6, 8.2)	8.0 (7.4, 8.2)	0.852
Sleep efficiency (%), mean (SD)[a]	75.9 (7.0)	80.5 (7.3)	81.8 (6.5)	0.002

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Sleep efficiency and number of awakening were normally distributed in this study.

TABLE 3 Linear Regression Models for Associations between Caregiver Education and Child Sleep Parameters

	Number of awakening		Sleep efficiency (%)	
	Beta (SE)	P value	Beta (SE)	P value
Univariate model				
Caregiver education (ref: >high school)				
High school	-1.2 (1.3)	0.384	-1.3 (1.4)	0.357
<High school	0.7 (1.6)	0.662	-5.9 (1.7)	<0.001
P value for trend test		*0.838*		*0.001*
Multivariable model[a]				
Caregiver education (ref: >high school)				
High school	-0.6 (1.4)	0.674	-1.6 (1.4)	0.269
<High school	1.9 (1.7)	0.245	-6.3 (1.7)	0.001
P value for trend test		*0.364*		*<0.001*

Abbreviation: SE, standard error.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

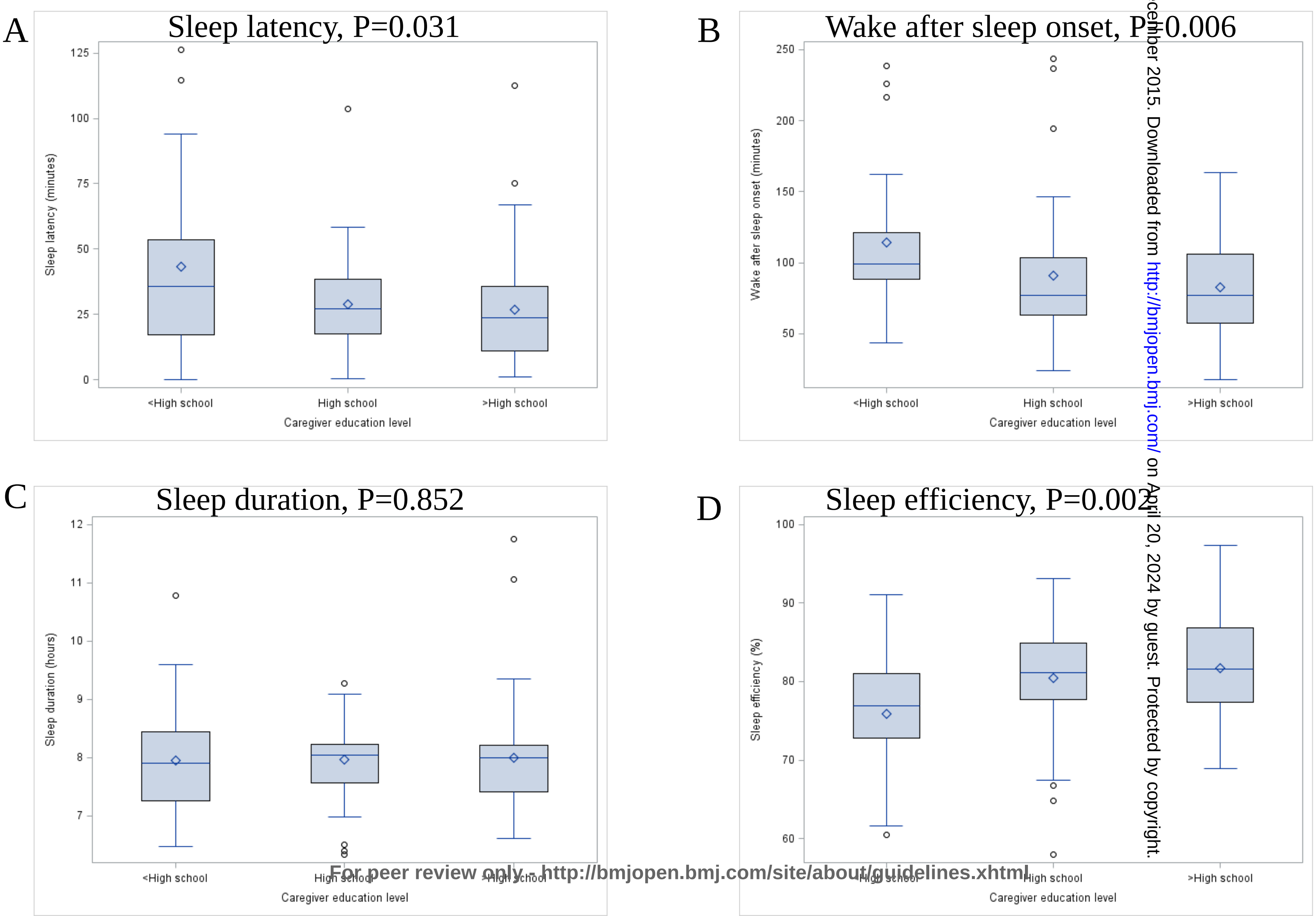
TABLE 4 Logistic Regression Models for Associations between Caregiver Education and Child Sleep Disturbances

	Sleep latency ≥30 vs. <30 minutes		Long WASO ≥90 vs. <90 minutes		Sleep duration <8 vs. ≥8 hours	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Univariate model						
Caregiver education (ref: >high school)						
High school	0.95 (0.42, 2.17)	0.911	1.36 (0.61, 3.04)	0.449	0.72 (0.33, 1.60)	0.424
<High school	3.37 (1.26, 8.98)	0.015	4.43 (1.58, 12.38)	0.005	0.89 (0.35, 2.25)	0.797
P value for trend test		*0.029*		*0.006*		*0.689*
Multivariable model						
Caregiver education (ref: >high school)[a]						
High school	1.02 (0.42, 2.45)	0.966	1.38 (0.58, 3.30)	0.468	0.70 (0.30, 1.64)	0.408
<High school	3.27 (1.12, 9.61)	0.031	5.95 (1.91, 18.53)	0.002	0.78 (0.28, 2.18)	0.629
P value for trend test		*0.056*		*0.004*		*0.526*

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio; WASO, wake after sleep onset.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

FIGURE 1 Children's Sleep Parameters, by Caregiver Education Levels

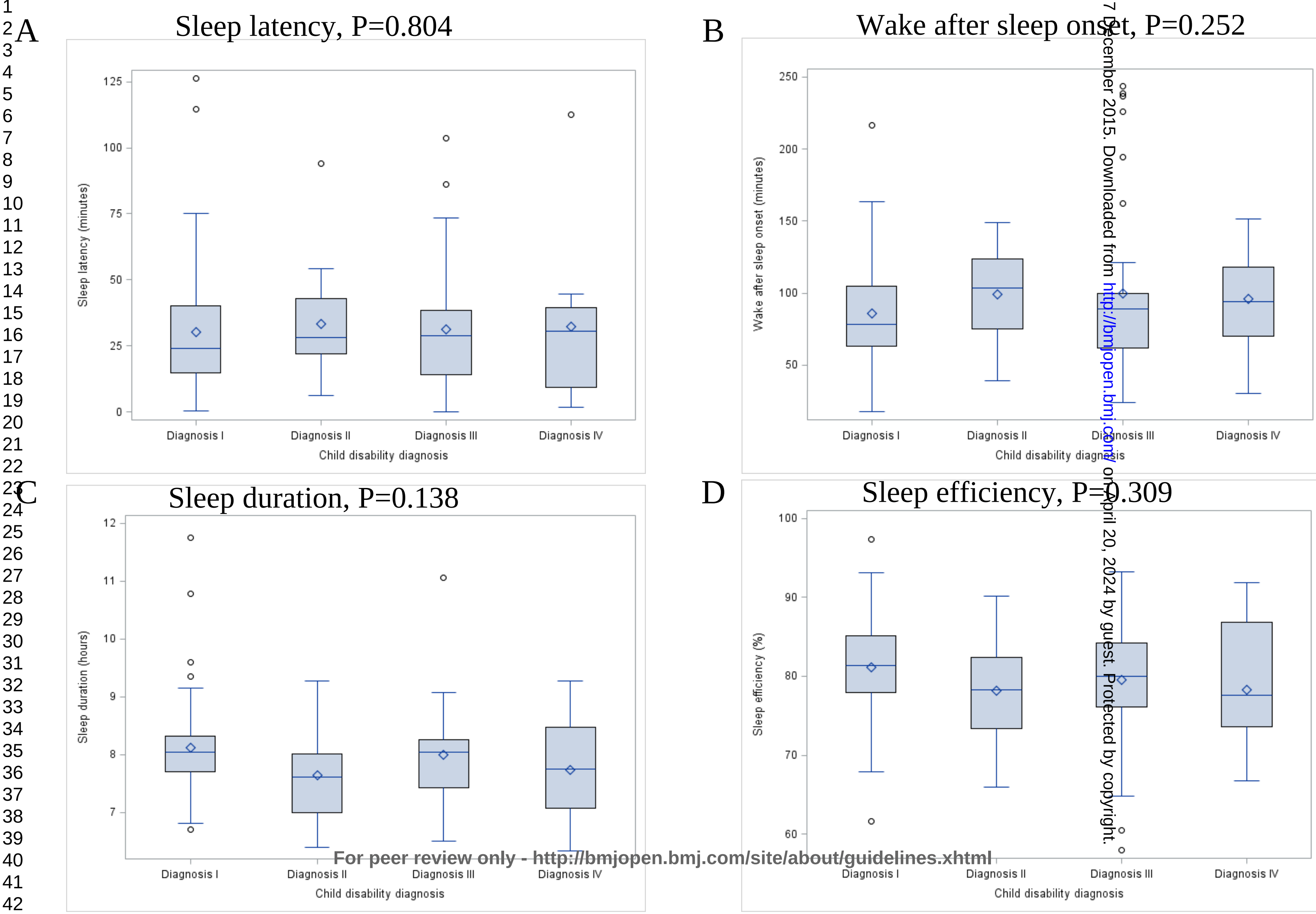


Supplementary Table 1 Children's Sleep Parameters, By Types of Disability Diagnosis

Sleep parameters	Diagnosis I (n=60)	Diagnosis II (n=21)	Diagnosis III (n=34)	Diagnosis IV (n=10)	P value
Sleep onset, median (IQR)	22:35 (22:04, 23:03)	23:05 (22:25, 23:22)	22:37 (22:19, 23:05)	22:35 (21:45, 23:03)	0.187
Sleep latency, median (IQR), minutes	24.1 (14.7, 40.1)	28.1 (22.1, 43.0)	28.8 (14.1, 38.4)	30.5 (9.1, 39.4)	0.804
WASO, median (IQR), minutes	78.4 (63.5, 104.9)	103.3 (75.0, 123.7)	89.1 (61.7, 100.0)	94.0 (69.9, 117.9)	0.252
Number of awakening, mean (SD)[a]	22.4 (6.6)	25.1 (5.1)	19.3 (6.5)	23.6 (7.6)	0.011
Sleep duration, median (IQR), hours	8.0 (7.7, 8.3)	7.6 (7.0, 8.0)	8.0 (7.4, 8.3)	7.8 (7.1, 8.5)	0.138
Sleep efficiency, mean (SD), %[a]	81.2 (6.5)	78.2 (6.2)	79.5 (8.6)	78.3 (8.2)	0.309

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.
Only sleep efficiency (%) and number of awakening were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$).
[a]Analysis of variance was used for sleep efficiency and number of awakening (normally distributed), while Kruskal-Wallis test was used for other sleep parameters.
Diagnosis I: mental and behavioral disorders (e.g., autism, ADHD, mental retardation); Diagnosis II: diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); Diagnosis III: diseases of the nervous system (e.g., cerebral palsy); Diagnosis IV: congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

SUPPLEMENTARY FIGURE 1 Children's Sleep Parameters, by Disability Group



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).
Bias	9	
Study size	10	This is a cross-sectional, pilot study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
Results		
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Outcome data	15	
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study.

A Cross-sectional Study of Actigraphy-Measured Sleep Patterns among Children with Disabilities

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A Cross-sectional Study of Actigraphy-Measured Sleep Patterns among Children with Disabilities

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SHORT TITLE: Sleep patterns among children with disabilities

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Supplementary figure: 1

KEY WORDS
Child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

ABBREVIATIONS
ADHD: attention-deficit/hyperactivity disorder
ASD: autism spectrum disorder
CI: confidence interval
CPASS: Chile Pediatric and Adult Sleep and Stress Study
ICD: International Classification of Diseases
ICF-CY: International Classification of Functioning, Disability and Health for Children and Youth

IQR: interquartile range
OR: odds ratio
SD: standard deviation
SE: standard error
WASO: wake after sleep onset

Abstract

Objectives: To characterize actigraphy-measured sleep patterns among children with disabilities and to examine whether caregivers' education is associated with sleep disturbances.

Design: Cross-sectional study.

Setting: A rehabilitation center in the Patagonia region, Chile.

Methods: This pilot and feasibility study was conducted among 125 children aged 6-12 years with disabilities (boys: 55.2%) and caregivers in Chile. Children wore ActiSleep monitors for seven days. General linear models were fitted to generate least-square means and standard errors (SEs) of sleep efficiency (proportion of the sleep period spent sleeping) across caregivers' education levels adjusting for children's age, sex, disability type, caregiver-child relationship, and caregivers' age. Multivariable logistic regression analyses were conducted to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of longer sleep latency (≥30 minutes) and longer wake after sleep onset (WASO) (≥90 minutes) (a measure of sleep fragmentation) in relation to caregivers' educational attainment.

Results: Median sleep latency was 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours. Mean sleep efficiency was 80.0%. Caregivers' education was positively and significantly associated with children's sleep efficiency (P_{trend}=0.001). Adjusted mean sleep efficiency was 75.7% (SE=1.4) among children of caregivers <high school, and 81.9% (SE=1.0) among children of caregiver >high school. Compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep latency (OR=3.27; 95%

CI=1.12-9.61) and longer WASO (OR=5.95; 95% CI=1.91-18.53). Associations were consistent across disability types.

Conclusions: Children with disabilities experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency). Among children with disabilities, lower caregiver education level is associated with more sleep disturbances.

KEY WORDS: child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

Strengths and limitations of this study

- This cross-sectional pilot and feasibility study is strengthened by its use of actigraphy which has been well validated for objective estimation of nighttime sleep parameters in the natural sleep environment.
- Our study was unique in being the first study to examine the associations between caregivers' education and actigraphy-measured sleep among children with disabilities.
- Its strength also lies in the statistical analysis that was performed using univariate and multivariable linear and logistic regression models.
- This is a cross-sectional, pilot study with a small sample size and high heterogeneity of disabilities included.

INTRODUCTION

Approximately 150 million children live with disabilities worldwide.[1] Sleep disturbances, particularly difficulty initiating and maintaining sleep, are commonly reported among children with a wide range of disabilities including Down syndrome, attention-deficit/hyperactivity disorder (ADHD), and autism.[2-6] There are discrepancies between objective measures of sleep and those reported by parents of children with disabilities.[5] Parents may be unaware of children's sleep disturbances, such as night awakenings, and tend to overestimate their children's sleep duration.[7] Inferences from prior studies are limited because investigators have relied on parental report of child sleep.[3] Although polysomnography is considered the gold standard for measuring sleep, it is burdensome and not easily amenable for use with children who have difficulties sleeping in unfamiliar surroundings. Actigraphy-based sleep offers opportunities to obtain objective measures of sleep in children's typical environment. Actigraphy has been validated for objective measures of sleep in clinical- and population-based studies.[8, 9]

Sleep disturbances have been related to sociodemographic, environmental, and behavioral factors.[10-13] Children's sleep disturbances have been connected with their home environment that may be influenced by caregivers' characteristics.[13, 14] Our recent qualitative study showed that while Chilean caregivers and rehabilitation providers recognized the importance of sleep health, they differed in their understanding of how sleep practices influence sleep health.[13] Parental ability to provide support for healthy behaviors including sleep may be influenced by parental education, a known factor associated with child health measures.[12, 15-17] Magana et al reported that maternal education and knowledge about autism accounted for differences in the number of specialty services received by Latino children with autism spectrum disorder (ASD) as compared with White children in the US.[15] However, to our knowledge, little research has been conducted regarding the role of caregivers' education in objectively measured sleep among children with disabilities, particularly among Patagonian Chilean children, an understudied population with documented high burden of obesity and related chronic disorders.[18]

This cross-sectional pilot and feasibility study aimed to characterize actigraphy-measured sleep patterns and to examine whether caregivers' education is associated with sleep disturbances among children with disabilities, conducted to inform future research in this population. We sought to estimate the prevalence of actigraphy-measured sleep disturbances including long sleep latency, long wake after sleep onset (WASO), short sleep duration, and poor sleep quality (low sleep efficiency) among Chilean children with disabilities. Further, following up on results from a previous qualitative study,[13] we sought to determine the extent to which, if at all, caregivers' low levels of educational attainment are associated with children's sleep disturbances and overall poor sleep quality.

METHODS

Participants

The Chile Pediatric and Adult Sleep and Stress Study (CPASS) was a cross-sectional pilot and feasibility study that was established in September 2012 at the Centro de Rehabilitacion Club de

Leones Cruz del Sur in Punta Arenas, Chile.[13] The first wave of the CPASS (CPASS I) was conducted between September and December in 2012 among children aged 6-12 years who were receiving routine clinical care for disabilities at the center and their primary caregivers who were parents, grandparents, relatives, or other adults and were principally responsible for children's well-being and did not have developmental or intellectual disabilities. Children with disabilities in this study were those who had impairments, activity limitations, participation restrictions due to health conditions such as autism, Down's Syndrome, and cerebral palsy, according to the World Health Organization, the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY).[19] All the children were diagnosed by a clinical care team composed by a pediatric neurologist, a pediatrician with extensive experience in developmental disabilities, and a rehabilitation medicine specialist using diagnostic criteria and/or standardized tests with the input of families and teachers. The trained research staff talked with caregivers to determine if they could complete the interviewer-administered questionnaire survey. In addition, a physician helped confirm that caregivers had no developmental or intellectual disabilities. Of 153 children whose families were contacted via telephone by research staff, 110 adult caregivers (72%) consented to participate in this study. A total of 110 children and caregivers (one caregiver per child) were recruited in the CPASS I. Five children were excluded from this study due to fewer than 3 days of actigraphy data: four children removed monitors after day one or day two of the study and/or without sleep log data; one child lost the monitor on day two. A total of 105 child-caregiver dyads (95.5% of enrolled families) completed the CPASS I study protocol.

The second wave of the CPASS (CPASS II) was conducted among children with disabilities aged 10-21 years and their primary caregivers between April and July in 2013 at the center.[20, 21] Research personnel invited 129 caregivers of children with disabilities to participate. A total of 90 caregivers (72%) agreed to participate in the study. Twenty children were aged 10-12 years from the CPASS II. As these two studies (CPASS I and CPASS II) were conducted between September 2012 and July 2013 at the same rehabilitation center in Chile, with the same staff and with identical study protocols used for assessing sleep traits, we combined the results from the two studies in order to have a larger sample size with increased statistical power in the present analysis. In total, 125 children aged 6-12 years were included in the current study.

Written informed consents were obtained from primary caregivers of children with disabilities. This study was approved by the institutional review boards of the Centro de Rehabilitacion Club de Leones Cruz del Sur and Harvard T.H. Chan School of Public Health Office of Human Research Administration.

Study Procedures

A psychologist administered structured questionnaires to caregivers to collect information on sociodemographic and lifestyle factors of children and caregivers. Research staff instructed children to wear ActiSleep monitors (ActiLife, ActiGraph R&D, Florida, USA)[22] on their non-dominant wrists for seven consecutive days. Although the monitors are waterproof, children were instructed to remove them from their wrists before taking showers and before swimming.

Caregivers were also instructed to keep sleep logs of time in bed and time out of bed for their children. Electronic medical records were reviewed by a physician in order to extract children's diagnoses defined by the International Classification of Diseases (ICD-10).[23]

Sleep Parameters

Actigraphic sleep data were collected using the ActiSleep monitors and were analyzed using the ActiLife 6 data analysis software.[22] When worn during sleep episodes, the ActiSleep monitor can provide estimates of sleep onset, sleep latency, WASO, number and length of awakenings, sleep duration, and sleep efficiency. Sleep latency is the length of time taken to fall asleep, calculated as the time between "lights off" to the first period of 3 minutes of consecutive epochs scored as sleep. WASO is the number of minutes awake between sleep onset and time of final waking. Sleep efficiency is defined as the proportion of the estimated sleep periods spent asleep. Actigraphy data were collected in 1-min epochs using the zero-crossing modes, and the "Sadeh" sleep algorithm was used for children.[24] The majority of children (n=122, 97.6 %) had complete 7-day actigraphic sleep data; two children had 6-day actigraphic data and one child had 3-day data available for study. The averages of sleep parameters were calculated for children who had 3, 6, or 7 days of actigraphic data. There were no missing sleep log data for children included in this study. Caregivers were asked to record their children's sleep logs each morning up awakening and checked their sleep logs when caregivers returned with ActiSleep monitors. Information from sleep logs were not used to substitute missing actigraphy data.

Sociodemographic Characteristics and Children's Disabilities

Interviewer-administered questionnaires were used to collect information on children's age, sex, daytime napping, medication use, caregiver-child relationship (e.g., mother), caregivers' age, employment status, and education level. Caregivers were asked to report the highest degree of education they had completed: less than 12th grade, high school graduate or equivalent, some college degree, or college graduate or above. According to the ICD-10,[23] children's disabilities were grouped as: 1) mental and behavioral disorders (e.g., autism, ADHD); 2) diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); 3) diseases of the nervous system (e.g., cerebral palsy); and 4) congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Statistical Analysis

Kolmogorov-Smirnov test was used to assess the normality of sleep parameters. Variables were described using means and standard deviations (SDs) for parametric variables and medians and interquartile ranges (IQRs) for nonparametric variables. Student's t-test was used for age, sleep efficiency, and number of awakening as parametric variables by child sex; Wilcoxon rank-sum test was used to test differences in nonparametric variables including sleep onset, sleep latency, WASO, awakening length, and sleep duration by child sex. Fisher's or χ^2 test was conducted to compare differences in sociodemographic factors, daytime napping, medication use, and disability groups by child sex. Analysis of variance or Kruskal-Wallis test was conducted to evaluate differences in sleep parameters across children's disability groups and caregivers' education levels.

A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficieny across caregivers' education levels with adjustment for children's age, sex, disability, caregiver-child relationship, and caregivers' age. Univariate and multivariable linear regression analyses were performed to examine the associations of caregivers' education level with sleep efficiency and the number of awakenings. Stratified analysis was conducted to evaluate whether associations between caregivers' education and children's sleep disturbances differed according to children's disability groups. As sleep latency, WASO, and sleep duration were not normally distributed and given that we aimed to examine whether children whose caregivers had lower education level were more likely to have sleep disturbances (e.g., long sleep latency, long WASO) and to enhance interpretability, we created categorical variables for these sleep parameters and used in logistic regression models. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models to evaluate the associations of caregivers' educational attainment with children's long sleep latency (≥30 vs. <30 minutes), long WASO (≥90 vs. <90 minutes), and short sleep duration (<8 vs. ≥8 hours). These cut points were chosen based on the literature of sleep latency[25] and sleep duration,[26] as well as sleep data distributions in the study (WASO median=88 minutes, sleep duration median=8 hours; only 9.6% of children had sleep ≥9 hours). We also included a variable to represent study wave (I and II) in multivariable regression models and found similar results (data not shown). We conducted sensitivity analysis by including medication use and daytime napping in the models and did not find that they had an impact on our results in this study (data not shown). Statistical significance levels were set at P <0.05 for two-sided analyses. P values were not corrected for multiple testing. All tests were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

The mean age of children with disabilities was 9.2 (SD=2.2; range 6-12) years. Most caregivers were mothers (88.0%); 21.6% of caregivers reported having <high school education level (**Table 1)**. There were no statistically significant differences in medication use, daytime napping, caregiver-child relationship, caregivers' age, employment status, or education level between boys and girls.

Median time for sleep onset was 22:39, sleep latency 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours (**Table 1**). Mean number of awakening was 22.1, sleep efficiency 80.0%. There were no statistically significant differences in sleep parameters between boys and girls (all P >0.05). Overall, 43.2% of children had sleep latency ≥30 minutes, 51.2% had short sleep <8 hours, and 77.6% had low sleep efficiency <85%.

There were no significant differences in sleep parameters across disability groups (**Supplementary Figure 1**), except for the number of nocturnal awakening (**Supplementary**

Table 1). Children with diseases of musculoskeletal system and connective tissue, skin and subcutaneous tissue appeared to have more awakenings, reflecting more fragmented sleep, than children with other disabilities.

Children whose caregivers had <high school had longer sleep latency, longer WASO, longer awakening length, and lower sleep efficiency compared to children whose caregivers had >high school (**Figure 1, Table 2)**. Although children of caregivers with <high school tended to have later sleep onset, higher number of awakenings, and shorter sleep duration when compared to children of caregivers with higher education, these differences did not reach statistical significance.

After adjustment for child age, sex, disability group, caregiver-child relationship, and caregiver age, mean sleep efficiency was the lowest among children of caregivers with <high school (75.7% [SE=1.4]), followed by children of caregivers with high school (80.4% [SE=1.0]) and >high school (81.9% [SE=1.0]). Linear regression analyses showed no significant associations between caregivers' education levels and children's awakening number. However, compared to children whose caregivers had >high school, children of caregivers with <high school had significantly lower sleep efficiency (adjusted beta=-6.3, SE=1.7; P=0.001) (**Table 3**). Caregivers' educational attainment was significantly and positively associated with children's sleep efficiency (P_{trend}=0.001).

As shown in **Table 4,** compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep latency ≥30 minutes (adjusted OR=3.27; 95% CI=1.12-9.61) and longer WASO ≥90 minutes (OR=5.95; 95% CI=1.91-18.53). Caregivers' education levels were significantly and inversely associated with children's sleep latency and WASO (both P_{trend}<0.05). Children's short sleep duration (<8 hours) was not associated with caregivers' low educational level (OR=0.78; 95% CI=0.28-2.18).

The associations between caregivers' education and children's sleep efficiency varied little according to disability groups (data not shown in tables). For example, among children with mental and behavioral disorders, children of caregivers with <high school had lower sleep efficiency (beta=-6.2, SE=2.2; P=0.006), after adjustment for children's age, sex, caregiver-child relationship, and caregivers' age. Similar results were found for children with other disabilities.

DISCUSSION

In this cross-sectional pilot and feasibility study, we assessed sleep patterns using wrist actigraphy over seven consecutive days among Chilean children with disabilities. We found that actigraphy-measured sleep disturbances including long sleep latency (median=27 minutes), long WASO (median=88 minutes), short sleep duration (median=8 hours), high number of nocturnal awakenings (mean=22), and low sleep efficiency (mean=80%) were common among children. These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency), and have increased sleep fragmentation (increased nocturnal awakenings). These indices are common in insomnia, which may occur secondary to chronic health conditions, and for many conditions, is associated with poor quality of life and increased disease-specific health burden including behavioral and cognitive problems.[27, 28] We also found strong associations between caregivers' low educational attainment and children's sleep disturbances (e.g., low sleep efficiency) independent of children's disability and other covariates from both children and caregivers. To our knowledge, this is the first study to specifically quantify actigraphy-measured sleep patterns with caregivers' low education levels with children with disabilities. Furthermore, we address these questions among Patagonian Chilean children with disabilities, an understudied population in South America.

Children with a wide range of disabilities have been reported to have sleep disturbances, including prolonged sleep latency, increased WASO, short sleep duration, and decreased sleep efficiency in Europe and other developed countries including Canada and New Zealand.[4-6, 29, 30] For example, in a small study of 8 UK children with mucopolysaccharidosis aged 2-15 years, median actigraphy-measured sleep latency was 35.4 minutes, WASO 83.4 minutes, and sleep efficiency was 75.6%.[30] Allik et al reported that children aged 8-12 years with Asperger syndrome and high-functioning autism in Sweden had actigraphy-measured longer sleep latency (mean=32 minutes) and lower sleep efficiency (mean=87%) than controls.[6] In a study of children aged 5-11 years with ADHD in Denmark, average sleep latency was 26 minutes and 31% of children had sleep latency >30 minutes.[5] A case-control study using 5-night actigraphy for 15 school-aged children with traumatic brain injury and 15 school-aged sibling in UK reported that brain injury was significantly associated with children's longer sleep latency (mean=50 minutes), longer WASO (mean=65 minutes), and lower sleep efficiency (mean=80%).[29] To our knowledge, no research has been conducted on objectively measured sleep parameters in South American (e.g., Chile) among children with disabilities, an understudied sample. In our study of Chilean children with autism and other disabilities, the median of actigraphy-measured sleep latency was 27 minutes, WASO was 88 minutes, and the mean of sleep efficiency was 80%, which were similar to several previous research findings.[5, 29, 30] We also found that a high proportion of Chilean children with disabilities experience actigraphy-measured sleep disturbances: 43% of children had sleep latency ≥30 minutes, 51% had short sleep <8 hours (90% of children had sleep duration <9 hours), and 78% had sleep efficiency <85%. Although the recommendations are for school-aged children to have at least 9 hours of sleep,[26, 31] in our study, only 10% of Chilean children with disabilities had sleep duration ≥9 hours. Gibbs et al reported that among 8 children aged 4-15 years with Prader-Willi syndrome in New Zealand, median 7-night actigraphy-measured WASO was 95 minutes.[32] Corkum et al reported the average of awakenings was 15 among Canadian children with ADHD (age: 7-11 years).[4] In our current study, the average of nocturnal awakenings was 22 among Chilean children with ADHD and other disabilities. Our study along with previous research suggests that children with disabilities have difficulties initiating and maintaining good sleep.

Several researchers have reported that children with disabilities have late sleep onset.[33, 34] A study of US children aged 2-5 years with autism and other developmental disabilities reported that the mean of 7-day actigraphy-measured sleep onset time was 21:32.[33] In this study, we found that median sleep onset time was 22:39 among Chilean children with autism and other disabilities. Unique climate (e.g., late sunset) and lifestyle characteristics (e.g., late mealtime) in the Patagonia region may have partly contributed to children's late sleep time.[13,18] Our findings of late sleep onset are generally consistent with literature for children in this age range. For example, a cross-sectional study of 96 healthy Chilean children aged 10 years found that the mean of overnight polysomnography-measured sleep onset time was 23:10 for children with normal weight and 23:20 for children with overweight and obesity.[35] Another study of 58 US healthy children aged 11-13 years showed that the mean of 4-day actigraphy-measured sleep onset time was 23:27.[36] In the Cleveland Children's Sleep and Health Study, 14.8% of US children aged 8-11 years had bedtime 23:00 or later.[14] Future research is warranted to examine potential risk factors of late bedtime such as daytime napping and how to improve sleep onset time among children, especially among those with disabilities.

It has been reported that children whose caregivers have low education levels are more likely to have adverse health outcomes, such as greater body weight[16] and lower quality of life.[17] McDonald et al found that lower maternal education was independently associated with parent-reported shorter sleep (<11 hours/night) among young children.[12] Although several studies have reported that parental education is associated with child health,[12, 15] we are unaware of published reports that have investigated whether and how caregivers' education levels are related to objectively measured sleep problems among children with disabilities. In our study, caregivers' education level in relation to children's sleep disturbances was substantiated through statistically significant association as shown in univariate and multivariable linear and logistic regression models. Our study suggests the importance of tailoring sleep education for caregivers with lower educational attainment to improve children's sleep health. We considered low educational attainment a proxy for low socioeconomic status (SES). It has been reported that educational levels and SES are highly correlated.[37] Low SES, as well as low education, has been related to high risks for cardiovascular disease, cancer, and mortality.[38] Parental SES has been reported to be inversely associated with child health consequences including cardiovascular disease and mortality.[39, 40] Some of the burden from low parental education level may be attributable to relatively lower health literacy, particularly sleep health literacy, which is pertinent to our pilot observations in the focus group study[13] and also in this pilot epidemiologic study.

Parents with low education levels may lack knowledge and resources about children's sleep practices and disabilities, resulting in adverse parenting practices known to affect sleep hygiene such as less limit setting, more variability in routines important to establish regular sleep patterns, suboptimal configuration of bedrooms to optimize sleep, and inappropriate use of electronic devices, and meal timing in relationship to sleep. Better educated parents can have more access to information about sleep and disabilities possibly through the internet or group membership with other parents of children diagnosed with disabilities. Future research should consider the impact of providing education and support such as sleep hygiene education, as well as initiatives to provide social support for parents and families of children with disabilities. Although our data suggest that these efforts may especially benefit less well-educated parents, all parents may have difficulties in navigating all of the controversies and different claims on the internet and may benefit from improved education and support. Our findings of the associations documented in our study population, if replicated, could help motivate the development and implementation of training programs to increase the parental health literacy (especially sleep health literacy). Parents of children with disabilities could benefit from sleep education workshops. Social support from families of children with disabilities as well as health care providers including occupational and physiotherapists and nurses could also be important in helping parents handle with their children's sleep problems.

Lack of knowledge of healthy sleep behaviors among caregivers has been associated with an increased risk of having unhealthy sleep behaviors for their children.[41] Although sleep disturbances have been noted to be common in children with neurological conditions (e.g., cerebral palsy), there are no interventions specifically designed to improve sleep in these children.[42] Several small studies of children with ASD have reported that parent-based sleep education appears effective in improving child sleep health.[34, 43] For example, a study of 20 children with ASD showed that parent-based sleep education workshops improved sleep latency from 62.2 minutes to 45.6 minutes.[43] Malow et al reported that sleep education to parents of 80 children with ASD (aged 2-10 years) significantly decreased children's sleep latency from 58.2

to 39.6 minutes.[34] Our prior qualitative study in Chile indicated that parental knowledge gaps regarding healthy sleep behaviors in children support the need for increased sleep health education among targeted caregivers.[13] Pediatricians and family physicians can be trained to provide adequate advice and educational messages (e.g., sleep health) to pediatric patients and their families.[44]

Our study has several limitations. First, as this was a cross-sectional pilot and feasibility study, we did not have a control group of children without disabilities. Second, this study was limited by its modest sample size and the heterogeneity of disabilities represented among children studied. As such, the confidence intervals were wider for some groups (e.g., the less than high school education group) and we were not able to report associations specific to any single disability category (e.g., autism). Third, we did not collect information pertaining to some aspects of sleep which may be associated with low education levels such as caregivers' shift work, sleep hygiene and other factors such as co-sleeping, lack of knowledge about sleep health, or inability to obtain medications to treat sleep or conditions in this study. Hence we were not able to quantify the influence of these factors on children's sleep patterns. Our findings also focused on caregivers (majority were mothers) of children with disabilities in Chile, and may not be generalizable to other populations/groups. Although accepted to provide an objective measure of sleep-wake cycle, actigraphy has its limitations. For example, periods of quiet wakefulness may be interpreted by the device as sleep, and periods of restless sleep may be interpreted by the device as wakefulness.[8, 45] Recent literature has indicated limitations of actigraphy for accurately capturing children's awakenings.[46] Our study has indicated that children with diseases of the musculoskeletal system and connective, skin, and subcutaneous tissue have more awakenings because their restless sleep may be represented by actigraphy as awakenings, and/or due to medication use or body pain. Despite this, actigraphy has been well validated for objective estimation of nighttime sleep parameters across age groups in the natural sleep environment.[9] As this was an exploratory study aimed to examine whether parental education was associated with children's sleep disturbances, we did not adjust for multiple comparisons in this study. In addition, the simple adjustments for multiple comparisons might be overly conservative because many sleep problems (e.g., long WASO and low sleep efficiency) were correlated.

CONCLUSIONS

These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency), maintaining sleep (long WASO, low sleep efficiency), and sleep fragmentation (increased nocturnal awakenings). Among children with disabilities, lower levels of caregivers' educational attainment are strongly associated with children's sleep disturbances and these associations appear to be independent of children's age, sex, disability group, caregiver-child relationship, and caregiver age. Parental support and education programs directed to families with low education levels may be of particular importance for sleep behavior intervention among children with disabilities. Larger studies are warranted to confirm our findings. Future research is also needed regarding the effects of sleep education intervention as well as social support to low educational families of children with disabilities on sleep health, with taking into account of different cultural backgrounds.

Contributors' Statement

All of the authors have agreed to the content of this manuscript. XC conceptualized and designed the study, supervised data collection, carried the initial analyses, and drafted the initial manuscript. JCV and CB carried out the field survey, supervised data collection, and critically reviewed and revised the manuscript. MP carried out the field survey, coordinated data collection at the study site, and reviewed the manuscript. BG helped develop the study protocol, and critically reviewed and revised the manuscript. SR critically reviewed and revised the manuscript. MAW provided funding support to the study, supervised the study, conceptualized and designed the study, and critically reviewed and revised the manuscript.

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Figure Legends

FIGURE 1 Children's Sleep Parameters, by Caregiver Education Levels

TABLE 1 Characteristics of Children with Disabilities and Their Primary Caregivers

	Total (n=125)	Boys (n=69)	Girls (n=56)	P value
Child characteristics				
Age (years), mean (SD)	9.2 (2.2)	8.8 (2.1)	9.8 (2.3)	0.015
Type of disability diagnosis, %				
Mental and behavioral disorders	48.0	59.4	33.9	0.004
Diseases of musculoskeletal system	16.8	10.1	25.0	
Diseases of the nervous system	27.2	27.5	26.8	
Congenital/chromosomal abnormalities	8.0	2.9	14.3	
Daytime napping	16.8	14.5	19.6	0.444
Medication use	44.0	42.0	46.4	0.622
Sleep parameters				
Sleep onset, median (IQR)	22:39 (22:06, 23:08)	22:44 (22:24, 23:08)	22:33 (21:54, 23:09)	0.183
Sleep latency, median (IQR), minutes	27.3 (15.0, 38.9)	27.1 (14.4, 41.7)	27.4 (15.4, 38.2)	0.511
WASO, median (IQR), minutes	88.1 (65.6, 111.1)	92.4 (64.4, 112.4)	81.9 (66.2, 107.0)	0.411

Number of awakening, mean (SD)[a]	22.1 (6.7)	22.5 (6.5)	21.6 (6.9)	0.441
Awakening length, median (IQR), minutes	5.1 (4.2, 7.1)	5.1 (4.2, 7.0)	5.1 (4.2, 7.1)	0.923
Sleep duration, median (IQR), hours	8.0 (7.5, 8.2)	8.0 (7.3, 8.2)	8.0 (7.5, 8.3)	0.459
Sleep efficiency, mean (SD), %[a]	80.0 (7.2)	79.0 (8.1)	81.2 (5.8)	0.072
Caregiver characteristics				
Age (years), mean (SD)	38.3 (7.8)	38.5 (7.8)	38.0 (7.8)	0.690
Caregiver-child relationship, %				
Mother	88.0	88.4	87.5	0.877
Other	12.0	11.6	12.5	
Employed/self-employed	60.0	62.3	57.1	0.557
Education level, %				
<High school	21.6	24.6	17.9	0.088
High school	37.6	29.0	48.2	
>High school	40.8	46.4	33.9	

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Of these sleep parameters, only number of awakening and sleep efficiency were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$). While Student's t-test was used for number of awakening and sleep efficiency, Wilcoxon rank-sum test was used for the other sleep parameters.

TABLE 2 Children's Sleep Parameters, By Caregivers' Education Levels

Sleep parameters	<High school (n=27)	High school (n=47)	>High school (n=51)	P value
Sleep onset, median (IQR)	23:05 (22:17, 23:23)	22:31 (21:55, 23:04)	22:39 (22:24, 23:02)	0.098
Sleep latency, median (IQR), minutes	35.6 (17.3, 53.7)	27.1 (17.4, 38.4)	23.6 (11.1, 35.9)	0.031
WASO, median (IQR), minutes	99.1 (88.1, 121.0)	77.1 (63.4, 103.4)	77.0 (57.6, 106.0)	0.006
Number of awakening, mean (SD)[a]	23.1 (5.7)	21.2 (6.3)	22.4 (7.5)	0.470
Awakening length, median (IQR), minutes	6.9 (5.0, 9.5)	5.2 (4.2, 7.2)	4.7 (3.9, 5.7)	0.001
Sleep duration, median (IQR), hours	7.9 (7.3, 8.4)	8.0 (7.6, 8.2)	8.0 (7.4, 8.2)	0.852
Sleep efficiency (%), mean (SD)[a]	75.9 (7.0)	80.5 (7.3)	81.8 (6.5)	0.002

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Sleep efficiency and number of awakening were normally distributed in this study.

TABLE 3 Linear Regression Models for Associations between Caregiver Education and Child Sleep Parameters

	Number of awakening		Sleep efficiency (%)	
	Beta (SE)	P value	Beta (SE)	P value
Univariate model				
Caregiver education (ref: >high school)				
High school	-1.2 (1.3)	0.384	-1.3 (1.4)	0.357
<High school	0.7 (1.6)	0.662	-5.9 (1.7)	<0.001
P value for trend test		*0.838*		*0.001*
Multivariable model[a]				
Caregiver education (ref: >high school)				
High school	-0.6 (1.4)	0.674	-1.6 (1.4)	0.269
<High school	1.9 (1.7)	0.245	-6.3 (1.7)	0.001
P value for trend test		*0.364*		*<0.001*

Abbreviation: SE, standard error.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

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[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

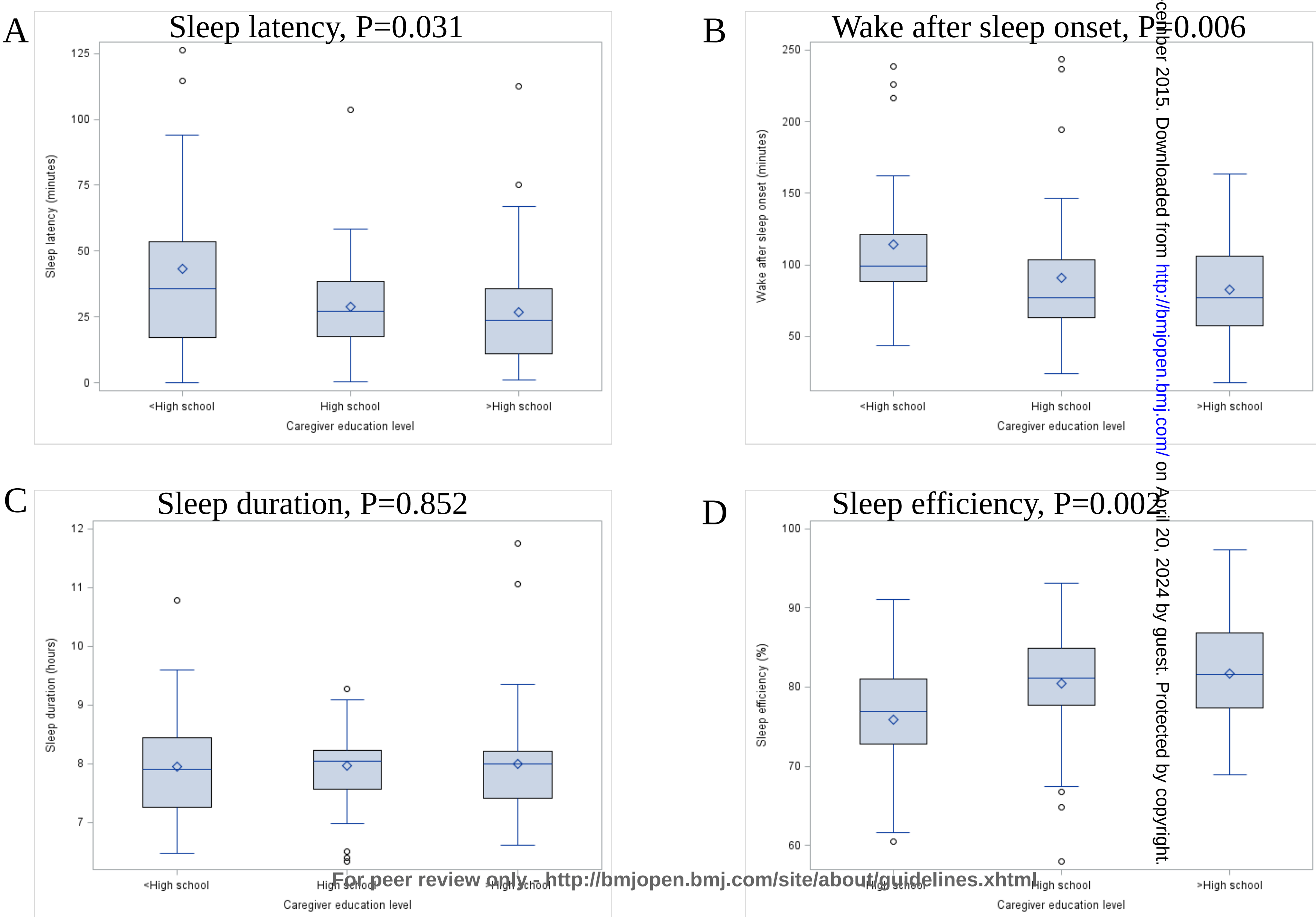
TABLE 4 Logistic Regression Models for Associations between Caregiver Education and Child Sleep Disturbances

	Sleep latency ≥30 vs. <30 minutes		Long WASO ≥90 vs. <90 minutes		Sleep duration <8 vs. ≥8 hours	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Univariate model						
Caregiver education (ref: >high school)						
High school	0.95 (0.42, 2.17)	0.911	1.36 (0.61, 3.04)	0.449	0.72 (0.33, 1.60)	0.424
<High school	3.37 (1.26, 8.98)	0.015	4.43 (1.58, 12.38)	0.005	0.89 (0.35, 2.25)	0.797
P value for trend test		*0.029*		*0.006*		*0.689*
Multivariable model						
Caregiver education (ref: >high school)[a]						
High school	1.02 (0.42, 2.45)	0.966	1.38 (0.58, 3.30)	0.468	0.70 (0.30, 1.64)	0.408
<High school	3.27 (1.12, 9.61)	0.031	5.95 (1.91, 18.53)	0.002	0.78 (0.28, 2.18)	0.629
P value for trend test		*0.056*		*0.004*		*0.526*

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio; WASO, wake after sleep onset.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

FIGURE 1 Children's Sleep Parameters, by Caregiver Education Levels



Supplementary Table 1 Children's Sleep Parameters, By Types of Disability Diagnosis

Sleep parameters	Diagnosis I (n=60)	Diagnosis II (n=21)	Diagnosis III (n=34)	Diagnosis IV (n=10)	P value
Sleep onset, median (IQR)	22:35 (22:04, 23:03)	23:05 (22:25, 23:22)	22:37 (22:19, 23:05)	22:35 (21:45, 23:03)	0.187
Sleep latency, median (IQR), minutes	24.1 (14.7, 40.1)	28.1 (22.1, 43.0)	28.8 (14.1, 38.4)	30.5 (9.1, 39.4)	0.804
WASO, median (IQR), minutes	78.4 (63.5, 104.9)	103.3 (75.0, 123.7)	89.1 (61.7, 100.0)	94.0 (69.9, 117.9)	0.252
Number of awakening, mean (SD)[a]	22.4 (6.6)	25.1 (5.1)	19.3 (6.5)	23.6 (7.6)	0.011
Sleep duration, median (IQR), hours	8.0 (7.7, 8.3)	7.6 (7.0, 8.0)	8.0 (7.4, 8.3)	7.8 (7.1, 8.5)	0.138
Sleep efficiency, mean (SD), %[a]	81.2 (6.5)	78.2 (6.2)	79.5 (8.6)	78.3 (8.2)	0.309

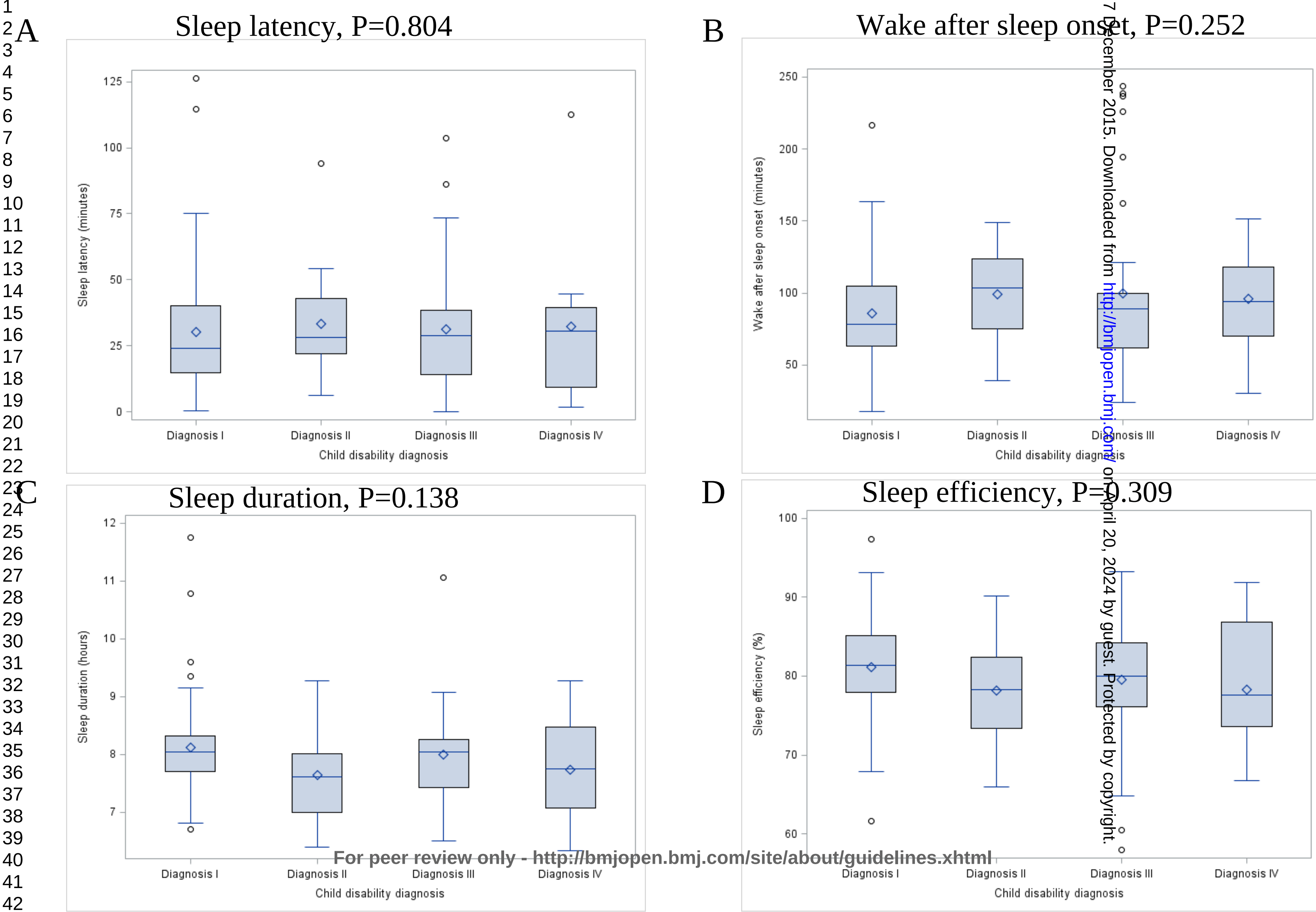
Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

Only sleep efficiency (%) and number of awakening were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$).

[a]Analysis of variance was used for sleep efficiency and number of awakening (normally distributed), while Kruskal-Wallis test was used for other sleep parameters.

Diagnosis I: mental and behavioral disorders (e.g., autism, ADHD, mental retardation); Diagnosis II: diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); Diagnosis III: diseases of the nervous system (e.g., cerebral palsy); Diagnosis IV: congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

SUPPLEMENTARY FIGURE 1 Children's Sleep Parameters, by Disability Group



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).
Bias	9	
Study size	10	This is a cross-sectional, pilot study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
Results		
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Outcome data	15	
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study.

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A Cross-sectional Study of Actigraphy-Measured Sleep Patterns among Children with Disabilities: The Importance of Caregivers' Educational Attainment Levels

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A Cross-sectional Study of Actigraphy-Measured Sleep Patterns among Children with Disabilities: The Importance of Caregivers' Educational Attainment Levels

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Supplementary figure: 1

KEY WORDS
Child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

ABBREVIATIONS
ADHD: attention-deficit/hyperactivity disorder
ASD: autism spectrum disorder
CI: confidence interval
CPASS: Chile Pediatric and Adult Sleep and Stress Study
ICD: International Classification of Diseases
ICF-CY: International Classification of Functioning, Disability and Health for Children and Youth

IQR: interquartile range
OR: odds ratio
SD: standard deviation
SE: standard error
WASO: wake after sleep onset

Abstract

Objectives: To characterize actigraphy-measured sleep patterns among children with disabilities and to examine whether caregivers' education is associated with sleep disturbances.

Design: Cross-sectional study.

Setting: A rehabilitation center in the Patagonia region, Chile.

Methods: This study was conducted among 125 children aged 6-12 years with disabilities (boys: 55.2%) and their primary caregivers in Chile. Children wore ActiSleep monitors for seven days. A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficiency (proportion of the sleep period spent asleep) across caregivers' education levels adjusting for children's age, sex, disability type, caregiver-child relationship, and caregivers' age. Multivariable logistic regression analyses were conducted to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of longer sleep latency (≥30 minutes) and longer wake after sleep onset (WASO) (≥90 minutes) (a measure of sleep fragmentation) in relation to caregivers' educational attainment.

Results: Median sleep latency was 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours. Mean sleep efficiency was 80.0%. Caregivers' education was positively and significantly associated with children's sleep efficiency (P_{trend}<0.001). Adjusted mean sleep efficiency was 75.7% (SE=1.4) among children of caregivers <high school education, and 81.9% (SE=1.0) among children of caregivers >high school education. Compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep

latency (OR=3.27; 95% CI=1.12-9.61) and longer WASO (OR=5.95; 95% CI=1.91-18.53). Associations were consistent across disability types.

Conclusions: Children with disabilities experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency). Among children with disabilities, lower level of caregivers' education is associated with more sleep disturbances.

KEY WORDS: child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

Strengths and limitations of this study

- This cross-sectional pilot study is strengthened by its use of actigraphy which has been well validated for objective estimation of nighttime sleep parameters in the natural sleep environment.
- Our study was unique in being the first study to examine the associations between caregivers' education and actigraphy-measured sleep among children with disabilities.
- Its strength also lies in the statistical analysis that was performed using univariate and multivariable linear and logistic regression models.
- This is a cross-sectional, pilot study with a small sample size and high heterogeneity of disabilities included.

INTRODUCTION

Approximately 150 million children live with disabilities worldwide.[1] Sleep disturbances, particularly difficulty initiating and maintaining sleep, are commonly reported among children with a wide range of disabilities including Down syndrome, attention-deficit/hyperactivity disorder (ADHD), and autism.[2-6] There are discrepancies between objective measures of sleep and those reported by parents of children with disabilities.[5] Parents may be unaware of children's sleep disturbances, such as night awakenings, and tend to overestimate their children's sleep duration.[7] Inferences from prior studies are limited because investigators have relied on parental report of child sleep.[3] Although polysomnography is considered the gold standard for measuring sleep, it is burdensome and not easily amenable for use with children who have difficulties sleeping in unfamiliar surroundings. Actigraphy-based sleep offers opportunities to obtain objective measures of sleep in children's typical environment. Actigraphy has been validated for objective measures of sleep in clinical- and population-based studies.[8, 9]

Sleep disturbances have been related to sociodemographic, environmental, and behavioral factors.[10-13] Children's sleep disturbances have been connected with their home environment that may be influenced by caregivers' characteristics.[13, 14] Our recent qualitative study showed that while Chilean caregivers and rehabilitation providers recognized the importance of sleep health, they differed in their understanding of how sleep practices influence children's sleep health.[13] Parental ability to provide support for healthy behaviors including sleep may be influenced by parental education, a known factor associated with child health measures.[12, 15-17] Magana et al

reported that maternal education and knowledge about autism accounted for differences in the number of specialty services received by Latino children with autism spectrum disorder (ASD) as compared with White children in the US.[15] However, to our knowledge, little research has been conducted regarding the role of caregivers' education in objectively measured sleep among children with disabilities, particularly among Patagonian Chilean children, an understudied population with documented high burden of obesity and related chronic disorders.[18]

This cross-sectional pilot study aimed to characterize actigraphy-measured sleep patterns and to examine whether caregivers' education level is associated with sleep disturbances among children with disabilities. We sought to estimate the prevalence of actigraphy-measured sleep disturbances including long sleep latency, long wake after sleep onset (WASO), short sleep duration, and poor sleep quality (low sleep efficiency) among Chilean children with disabilities. Further, following up on results from a previous qualitative study,[13] we sought to determine the extent to which, if at all, caregivers' low levels of educational attainment are associated with children's sleep disturbances and overall poor sleep quality.

METHODS

Participants

The Chile Pediatric and Adult Sleep and Stress Study (CPASS) was a cross-sectional pilot study that was established in September 2012 at the Centro de Rehabilitacion Club de Leones Cruz del Sur in Punta Arenas, Chile.[13] The first wave of the CPASS (CPASS I) was conducted between

September and December in 2012 among children aged 6-12 years who were receiving routine clinical care for disabilities at the center and their primary caregivers. Children with disabilities in this study were those who had impairments, activity limitations, and participation restrictions due to health conditions such as autism, Down syndrome, and cerebral palsy, according to the World Health Organization, the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY).[19] All children were diagnosed by a clinical care team composed of a pediatric neurologist, a pediatrician with extensive experience in developmental disabilities, and a rehabilitation medicine specialist using diagnostic criteria and/or standardized tests with the input of families and teachers. Primary caregivers were parents, grandparents, relatives, or other adults and were principally responsible for children's well-being and did not have developmental or intellectual disabilities. Research staff talked with caregivers to determine if they could complete the interviewer-administered questionnaire survey. In addition, a physician helped confirm that caregivers had no developmental or intellectual disabilities. Of 153 children whose families were contacted via telephone by research staff, 110 adult caregivers (71.9%) consented to participate in this study. A total of 110 children and caregivers (one caregiver per child) were recruited in the CPASS I. Five children were excluded from this study due to fewer than 3 days of actigraphy data: four children removed monitors after day one or day two of the study; one child lost the monitor on day two. These children had no sleep log data. A total of 105 child-caregiver dyads (95.5% of enrolled families) completed the CPASS I study protocol.

The second wave of the CPASS (CPASS II) was conducted among children with disabilities aged 10-21 years and their primary caregivers between April and July in 2013 at the center.[20, 21] Research personnel invited 129 caregivers of children with disabilities to participate. A total of 90 caregivers (69.8%) agreed to participate in the study. Twenty children were aged 10-12 years from the CPASS II. As these two studies (CPASS I and CPASS II) were conducted between September 2012 and July 2013 at the same rehabilitation center in Chile, with the same staff and with identical study protocols used for assessing sleep traits, we combined the results from the two studies in order to have a larger sample size with increased statistical power in the present analysis. In total, 125 children aged 6-12 years were included in the current study.

Written informed consents were obtained from primary caregivers of children with disabilities. This study was approved by the institutional review boards of the Centro de Rehabilitacion Club de Leones Cruz del Sur and Harvard T.H. Chan School of Public Health Office of Human Research Administration.

Study Procedures

A psychologist administered structured questionnaires to caregivers to collect information on sociodemographic and lifestyle factors of both children and caregivers. Research staff instructed children to wear ActiSleep monitors (ActiLife, ActiGraph R&D, Florida, USA)[22] on their non-dominant wrists for seven consecutive days. Although the monitors are waterproof, children were instructed to remove them from their wrists before taking showers and/or before swimming.

Caregivers were also instructed to keep sleep logs of time in bed and time out of bed for their children. Electronic medical records were reviewed by a physician in order to extract children's diagnoses defined by the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10).[23]

Sleep Parameters

Actigraphic sleep data were collected using the ActiSleep monitors and were analyzed using the ActiLife 6 data analysis software.[22] When worn during sleep episodes, the ActiSleep monitor can provide estimates of sleep onset, sleep latency, WASO, number and length of awakenings, sleep duration, and sleep efficiency. Sleep latency is the length of time taken to fall asleep, calculated as the time between "lights off" to the first period of 3 minutes of consecutive epochs scored as sleep. WASO is the number of minutes awake between sleep onset and time of final waking. Sleep efficiency is defined as the proportion of the estimated sleep periods spent asleep. Actigraphy data were collected in 1-min epochs using the zero-crossing modes, and the "Sadeh" sleep algorithm was used for children.[24] The majority of children (n=122, 97.6 %) had complete 7-day actigraphic sleep data; two children had 6-day actigraphic data and one child had 3-day data available for study. The averages of sleep parameters were calculated for children who had 3, 6, or 7 days of actigraphic data. There were no missing sleep log data for children included in this study. Caregivers were asked to record their children's sleep logs each morning up awakening and to make sure the sleep logs were complete. Research staff checked children's sleep logs when caregivers returned with ActiSleep monitors. Information from sleep logs were not used to substitute missing actigraphy data.

Sociodemographic Characteristics and Children's Disabilities

Interviewer-administered questionnaires were used to collect information on children's age, sex, daytime napping, medication use, caregiver-child relationship (e.g., mother), caregivers' age, employment status, and education level. Caregivers were asked to report the highest degree of education they had completed: less than 12th grade (<high school education), high school graduate or equivalent (high school education), some college degree, or college graduate or above (>high school education). According to the ICD-10,[23] children's disabilities were grouped as: 1) mental and behavioral disorders (e.g., ADHD, autism); 2) diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); 3) diseases of the nervous system (e.g., cerebral palsy); and 4) congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Statistical Analysis

Kolmogorov-Smirnov test was used to assess the normality of sleep parameters. Variables were described using means and standard deviations (SDs) for parametric variables and medians and interquartile ranges (IQRs) for nonparametric variables. Number of nocturnal awakenings and sleep efficiency were normally distributed, whereas sleep onset, sleep latency, WASO, awakening length, and sleep duration were not normally distributed. Student's t-test was used for age, number of awakenings, and sleep efficiency as parametric variables by child sex; Wilcoxon rank-sum test was used to test differences in nonparametric variables including sleep onset, sleep latency, WASO, awakening length, and sleep duration by child sex. Fisher's or χ^2 test was conducted to compare differences in sociodemographic factors, daytime napping, medication use, and disability groups by child sex. Analysis of variance or Kruskal-Wallis test was conducted to evaluate the differences in sleep parameters across children's disability groups and caregivers' education levels.

A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficiency across caregivers' education levels with adjustment for children's age, sex, disability, caregiver-child relationship, and caregivers' age. Univariate and multivariable linear regression analyses were performed to examine the associations of caregivers' education levels with sleep efficiency and the number of awakenings. Stratified analysis was conducted to evaluate whether the associations between caregivers' education levels and children's sleep disturbances differed according to children's disability groups. Given that we aimed to examine whether children whose caregivers had lower education level were more likely to have sleep disturbances (e.g., long sleep latency, long WASO) and to enhance interpretability, we created categorical variables for these sleep parameters and used in logistic regression models. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models to evaluate the associations of caregivers' educational attainment with children's long sleep latency ($\geq$30 vs. <30 minutes), long WASO ($\geq$90 vs. <90 minutes), and short sleep duration (<8 vs. ≥8 hours). These cut points were chosen based on the literature of sleep latency[25] and sleep duration,[26] as well as sleep data distributions in the study (WASO median=88 minutes, sleep duration median=8 hours; only 9.6% of children had sleep ≥9 hours). We also included a variable to represent study wave (I and II) in multivariable regression models and found similar results (data not shown). We conducted sensitivity analysis by including medication use and daytime napping in the models and did not find that they had an impact on our results in this study (data not shown). Statistical significance levels were set at P <0.05 for two-sided analyses. P values were not corrected for multiple testing. All tests were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

The mean age of children with disabilities was 9.2 (SD=2.2; range=6-12) years. Most caregivers were mothers (88.0%); 21.6% of caregivers reported having <high school education level (**Table 1**). There were no statistically significant differences in medication use, daytime napping, caregiver-child relationship, caregivers' age, employment status, or education level between boys and girls.

Median time for sleep onset was 22:39, sleep latency 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours (**Table 1**). The mean number of awakenings was 22.1 and sleep efficiency was 80.0%. There were no statistically significant differences in sleep parameters between boys and girls (all P >0.05). Overall, 43.2% of children had sleep latency ≥30 minutes, 51.2% had short sleep <8 hours, and 77.6% had low sleep efficiency <85%.

There were no significant differences in sleep parameters across disability groups (**Supplementary Figure 1**), except for the number of nocturnal awakenings (**Supplementary Table 1**). Children with diseases of musculoskeletal system and connective tissue, skin and subcutaneous tissue appeared to have more awakenings, reflecting more fragmented sleep, than children with other disabilities.

Children whose caregivers had <high school had longer sleep latency, longer WASO, longer awakening length, and lower sleep efficiency compared to children whose caregivers had >high school (**Figure 1, Table 2)**. Although children of caregivers with <high school tended to have later sleep onset, higher number of awakenings, and shorter sleep duration when compared to children of caregivers with higher education, these differences did not reach statistical significance.

Our general linear model with adjustment for child age, sex, disability group, caregiver-child relationship, and caregiver age showed that the mean sleep efficiency was the lowest among children of caregivers with <high school (75.7% [SE=1.4]), followed by children of caregivers with high school (80.4% [SE=1.0]) and >high school (81.9% [SE=1.0]). Univariate and multivariable linear regression analyses showed no significant associations between caregivers' education levels and children's awakening number. However, compared to children whose caregivers had >high school, children of caregivers with <high school had significantly lower sleep efficiency (adjusted beta=-6.3, SE=1.7; P=0.001) (**Table 3**). Caregivers' educational attainment was positively and significantly associated with children's sleep efficiency in the univariate model (P_{trend}=0.001) and the multivariable model (P_{trend}<0.001).

As shown in **Table 4** based on logistic regression models**,** compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep latency ≥30 minutes (adjusted OR=3.27; 95% CI=1.12-9.61) and longer WASO ≥90 minutes (OR=5.95; 95% CI=1.91-18.53). Caregivers' education levels were inversely and significantly associated with children's sleep latency and WASO (both P_{trend}<0.05). Children's short sleep duration (<8 hours) was not associated with caregivers' low educational level (OR=0.78; 95% CI=0.28-2.18).

The associations between caregivers' education and children's sleep efficiency varied little according to disability groups (data not shown in tables). For example, among children with mental and behavioral disorders, children of caregivers with <high school had lower sleep efficiency (beta=-6.2, SE=2.2; P=0.006), after adjustment for children's age, sex, caregiver-child relationship, and caregivers' age. Similar results were found for children with other disabilities.

DISCUSSION

In this cross-sectional pilot study, we assessed sleep patterns using wrist actigraphy over seven consecutive days among Chilean children with disabilities. We found that actigraphy-measured sleep disturbances including long sleep latency (median=27 minutes), long WASO (median=88 minutes), short sleep duration (median=8 hours), high number of nocturnal awakenings (mean=22), and low sleep efficiency (mean=80%) were common among children. These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency), and have increased sleep fragmentation (increased nocturnal awakenings). These indices are common in insomnia, which may occur secondary to chronic health conditions, and for many conditions, is associated with poor quality of life and increased disease-specific health burden including behavioral and cognitive problems.[27, 28] We also found strong associations between caregivers' low educational attainment and children's sleep disturbances (e.g., low sleep efficiency) independent of children's disability type and other covariates from both children and caregivers. To our knowledge, this is the first study to specifically quantify actigraphy-measured sleep patterns among children with disabilities in relation to caregivers' education levels. Furthermore, we address these questions among Patagonian Chilean children with disabilities, an understudied population in South America.

Children with a wide range of disabilities have been reported to have sleep disturbances, including prolonged sleep latency, increased WASO, short sleep duration, and decreased sleep efficiency in Europe and other developed countries including Canada and New Zealand.[4-6, 29, 30]

For example, in a small study of 8 UK children with mucopolysaccharidosis aged 2-15 years, median actigraphy-measured sleep latency was 35.4 minutes, WASO 83.4 minutes, and sleep efficiency was 75.6%.[30] Allik et al reported that children aged 8-12 years with Asperger syndrome and high-functioning autism in Sweden had actigraphy-measured longer sleep latency (mean=32 minutes) and lower sleep efficiency (mean=87%) than controls.[6] In a study of children aged 5-11 years with ADHD in Denmark, average sleep latency was 26 minutes and 31% of children had sleep latency >30 minutes.[5] A case-control study using 5 nights of actigraphy for 15 school-aged children with traumatic brain injury and 15 school-aged siblings in the UK reported that brain injury was significantly associated with children's longer sleep latency (mean=50 minutes), longer WASO (mean=65 minutes), and lower sleep efficiency (mean=80%).[29] To our knowledge, no research has been conducted on objectively measured sleep parameters in South America (e.g., Chile) among children with disabilities, an understudied sample. In our study of Chilean children with autism and other disabilities, the median of actigraphy-measured sleep latency was 27 minutes, WASO was 88 minutes, and the mean of sleep efficiency was 80%, which were similar to previous research findings.[5, 29, 30] We also found that a high proportion of Chilean children with disabilities experienced actigraphy-measured sleep disturbances: 43% of children had sleep latency ≥30 minutes, 51% had short sleep <8 hours (90% of children had sleep duration <9 hours), and 78% had sleep efficiency <85%. Although school-aged children are recommended to have at least 9 hours of sleep,[26, 31] in our study, only 10% of Chilean children with disabilities had sleep duration ≥9 hours. Gibbs et al reported that among 8 children aged 4-15 years with Prader-Willi syndrome in New Zealand, median 7-night actigraphy-measured WASO was 95 minutes.[32] Corkum et al reported the average of awakenings was 15 among Canadian children with ADHD (aged 7-11 years).[4] In our current study, the average number of nocturnal awakenings was 22 among Chilean children with ADHD and other disabilities. Our study along with previous research suggests that children with disabilities have difficulties initiating and maintaining good sleep.

Several researchers have reported that children with disabilities have late sleep onset.[33, 34] A study of US children aged 2-5 years with autism and other developmental disabilities reported that the mean of 7-day actigraphy-measured sleep onset time was 21:32.[33] In this study, we found that median sleep onset time was 22:39 among Chilean children with autism and other disabilities. Unique climate (e.g., late sunset) and lifestyle characteristics (e.g., late mealtime) in the Patagonia region may have partly contributed to children's late sleep onset time.[13,18] Our findings of late sleep onset are generally consistent with literature for children in this age range. For example, a cross-sectional study of 96 healthy Chilean children aged 10 years found that the mean of overnight polysomnography-measured sleep onset time was 23:10 for children with normal weight and 23:20 for children with overweight and obesity.[35] Another study of 58 healthy children aged 11-13 years in the US showed that the mean of 4-day actigraphy-measured sleep onset time was 23:27.[36] In the Cleveland Children's Sleep and Health Study, 14.8% of US children aged 8-11 years had bedtime 23:00 or later.[14] Future research is warranted to examine potential risk factors of late bedtime such as daytime napping and how to improve sleep onset time among children with disabilities.

It has been reported that children whose caregivers have low education levels are more likely to have adverse health outcomes, such as great body weight[16] and poor quality of life.[17] McDonald et al found that lower maternal education was independently associated with parent-reported shorter sleep (<11 hours/night) among young children.[12] Although several studies have reported that parental education is associated with child health,[12, 15] we are unaware of published reports that have investigated whether and how caregivers' education levels are related to objectively measured sleep problems among children with disabilities. In our study, caregivers' education level in relation to children's sleep disturbances was substantiated through statistically significant association as shown in univariate and multivariable linear and logistic regression models. Our study suggests the importance of tailoring sleep education for caregivers with lower educational attainment to improve children's sleep health. We considered low educational attainment a proxy for low socioeconomic status (SES). It has been reported that educational levels and SES are highly correlated.[37] Low SES, as well as low education, has been related to high risk for cardiovascular disease, cancer, and mortality.[38] Parental SES has been inversely associated with negative child health outcomes including cardiovascular disease and mortality.[39, 40] Some of the burden from low parental education level may be attributable to relatively lower health literacy, particularly sleep health literacy, which is pertinent to our pilot observations in the focus group study[13] and also in this pilot epidemiologic study.

Parents with low education levels may lack knowledge and resources about children's sleep practices and disabilities, resulting in adverse parenting practices known to affect sleep hygiene such as less limit setting, more variability in routines important to establish regular sleep patterns, suboptimal configuration of bedrooms to optimize sleep, inappropriate use of electronic devices, and meal timing in relationship to sleep. Better-educated parents may have more access to information about sleep and disabilities possibly through the internet or group membership with other parents of children diagnosed with disabilities. Future research should consider the impact of providing education and support such as sleep hygiene education, as well as initiatives to provide social support for parents and families of children with disabilities. Although our data suggest that these efforts may especially benefit less well-educated parents, all parents may have difficulties in navigating all of the controversies and different claims on the internet and may benefit from improved education and support. Our findings of the associations documented in our study population, if replicated, could help motivate the development and implementation of training programs to increase the parental health literacy (especially sleep health literacy). Parents of children with disabilities could benefit from sleep education workshops. Social support from families of children with disabilities as well as health care providers including occupational and physiotherapists and nurses could also be important in helping parents handle with their children's sleep problems.

Lack of knowledge of healthy sleep behaviors among caregivers has been associated with an increased risk of having unhealthy sleep behaviors for their children.[41] Although sleep disturbances have been noted to be common in children with neurological conditions (e.g., cerebral palsy), there are no interventions specifically designed to improve sleep in these children.[42] Several small studies of children with ASD have reported that parent-based sleep education appears effective in improving child sleep health.[34, 43] For example, a study of 20 children with ASD showed that parent-based sleep education workshops improved sleep latency from 62.2 minutes to 45.6 minutes.[43] Malow et al reported that sleep education to parents of 80 children with ASD (aged 2-10 years) significantly decreased children's sleep latency from 58.2 to 39.6 minutes.[34] Our prior qualitative study in Chile has indicated that parental knowledge gaps regarding healthy sleep behaviors in children support the need for increased sleep health education among targeted caregivers.[13] Pediatricians and family physicians can be trained to provide adequate advice and educational messages (e.g., sleep health) to pediatric patients and their families.[44]

Our study has several limitations. First, as this was a cross-sectional pilot study that aimed to examine the feasibility of conducting future research with a larger sample size in this underserved population, we did not have a control group of children without disabilities. Second, this study was limited by its modest sample size and the heterogeneity of disabilities represented among children studied. As such, the confidence intervals were wider for some groups (e.g., the less than high school education group) and we were not able to report associations specific to any single disability category (e.g., autism). Third, we did not collect information pertaining to some aspects of sleep which may be associated with low education levels such as caregivers' shift work, sleep hygiene, and other factors such as co-sleeping, lack of knowledge about sleep health, or inability to obtain medications to treat sleep or conditions in this study. Hence we were not able to quantify the influence of these factors on children's sleep patterns. Our findings also focused on caregivers (majority were mothers) of children with disabilities in Chile, and may not be generalizable to other populations/groups. Although accepted to provide an objective measure of sleep-wake cycle, actigraphy has its limitations. For example, periods of quiet wakefulness may be interpreted by the device as sleep, and periods of restless sleep may be interpreted by the device as wakefulness.[8, 45] Recent literature has indicated limitations of actigraphy for accurately capturing children's awakenings.[46] Our study has indicated that children with diseases of the musculoskeletal system and connective, skin, and subcutaneous tissue have more awakenings because their restless sleep may be represented by actigraphy as awakenings, and/or due to medication use or body pain. Despite this, actigraphy has been well validated for objective estimation of nocturnal sleep parameters across age groups in the natural sleep environment.[9] As this was an exploratory study that aimed to examine whether parental education was associated with children's sleep disturbances, we did not adjust for multiple comparisons in this study. In addition, the simple adjustments for multiple comparisons might be overly conservative because many sleep problems (e.g., long WASO, low sleep efficiency) were correlated.

CONCLUSIONS

These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency), maintaining sleep (long WASO, low sleep efficiency), and sleep fragmentation (increased nocturnal awakenings). Among children with disabilities, lower levels of caregivers' educational attainment are strongly associated with children's sleep disturbances and these associations appear to be independent of children's age, sex, disability group, caregiver-child relationship, and caregiver age. Parental support and education programs directed to families with low education levels may be of particular importance for sleep behavior intervention among children with disabilities. Larger studies are warranted to confirm our findings. Future research is also needed regarding the effects of sleep education intervention as well as social support to low educational families of children with disabilities on sleep health, with taking into account of different cultural backgrounds.

Contributors' Statement

All of the authors have agreed to the content of this manuscript. XC conceptualized and designed the study, supervised data collection, carried the initial analyses, and drafted the initial manuscript. JCV and CB carried out the field survey, supervised data collection, and critically reviewed and revised the manuscript. MP carried out the field survey, coordinated data collection at the study site, and reviewed the manuscript. BG helped develop the study protocol, and critically reviewed and revised the manuscript. SR critically reviewed and revised the manuscript. MAW provided funding support to the study, supervised the study, conceptualized and designed the study, and critically reviewed and revised the manuscript.

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Data Sharing Statement: No additional data are available.

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Figure Legends

Figure 1 Children's Sleep Parameters, by Caregiver Education Levels

Table 1 Characteristics of Children with Disabilities and Their Primary Caregivers

	Total (n=125)	Boys (n=69)	Girls (n=56)
Child characteristics			
Age, mean (SD), years	9.2 (2.2)	8.8 (2.1)	9.8 (2.3)
Type of disability diagnosis, %			
Mental and behavioral disorders	48.0	59.4	33.9
Diseases of musculoskeletal system	16.8	10.1	25.0
Diseases of the nervous system	27.2	27.5	26.8
Congenital/chromosomal abnormalities	8.0	2.9	14.3
Daytime napping	16.8	14.5	19.6
Medication use	44.0	42.0	46.4
Sleep parameters			
Sleep onset, median (IQR)	22:39 (22:06, 23:08)	22:44 (22:24, 23:08)	22:33 (21:54, 23:09)
Sleep latency, median (IQR), minutes	27.3 (15.0, 38.9)	27.1 (14.4, 41.7)	27.4 (15.4, 38.2)
WASO, median (IQR), minutes	88.1 (65.6, 111.1)	92.4 (64.4, 112.4)	81.9 (66.2, 107.0)

Number of awakenings, mean (SD)[a]	22.1 (6.7)	22.5 (6.5)	21.6 (6.9)
Awakening length, median (IQR), minutes	5.1 (4.2, 7.1)	5.1 (4.2, 7.0)	5.1 (4.2, 7.1)
Sleep duration, median (IQR), hours	8.0 (7.5, 8.2)	8.0 (7.3, 8.2)	8.0 (7.5, 8.3)
Sleep efficiency, mean (SD), %[a]	80.0 (7.2)	79.0 (8.1)	81.2 (5.8)
Caregiver characteristics			
Age, mean (SD), years	38.3 (7.8)	38.5 (7.8)	38.0 (7.8)
Caregiver-child relationship, %			
Mother	88.0	88.4	87.5
Other	12.0	11.6	12.5
Employed/self-employed	60.0	62.3	57.1
Education level, %			
<High school	21.6	24.6	17.9
High school	37.6	29.0	48.2
>High school	40.8	46.4	33.9

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a] Of these sleep parameters, only number of awakenings and sleep efficiency were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$). While Student's t-test was used for number of awakenings and sleep efficiency, Wilcoxon rank-sum test was used for the other sleep parameters.

Table 2 Children's Sleep Parameters, By Caregivers' Education Levels

Sleep parameters	<High school (n=27)	High school (n=47)	>High school (n=51)
Sleep onset, median (IQR)	23:05 (22:17, 23:23)	22:31 (21:55, 23:04)	22:39 (22:24, 23:02)
Sleep latency, median (IQR), minutes	35.6 (17.3, 53.7)	27.1 (17.4, 38.4)	23.6 (11.1, 35.9)
WASO, median (IQR), minutes	99.1 (88.1, 121.0)	77.1 (63.4, 103.4)	77.0 (57.6, 106.0)
Number of awakenings, mean (SD)[a]	23.1 (5.7)	21.2 (6.3)	22.4 (7.5)
Awakening length, median (IQR), minutes	6.9 (5.0, 9.5)	5.2 (4.2, 7.2)	4.7 (3.9, 5.7)
Sleep duration, median (IQR), hours	7.9 (7.3, 8.4)	8.0 (7.6, 8.2)	8.0 (7.4, 8.2)
Sleep efficiency, mean (SD), %[a]	75.9 (7.0)	80.5 (7.3)	81.8 (6.5)

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Sleep efficiency and number of awakenings were normally distributed in this study.

Table 3 Linear Regression Models for Associations between Caregiver Education and Child Sleep Parameters

	Number of awakenings		Sleep efficiency (%)	
	Beta (SE)	P value	Beta (SE)	P value
Univariate model				
Caregiver education (ref: >high school)				
High school	-1.2 (1.3)	0.384	-1.3 (1.4)	0.357
<High school	0.7 (1.6)	0.662	-5.9 (1.7)	<0.001
P value for trend test		*0.838*		*0.001*
Multivariable model[a]				
Caregiver education (ref: >high school)				
High school	-0.6 (1.4)	0.674	-1.6 (1.4)	0.269
<High school	1.9 (1.7)	0.245	-6.3 (1.7)	0.001
P value for trend test		*0.364*		*<0.001*

Abbreviation: SE, standard error.

[a] Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

Table 4 Logistic Regression Models for Associations between Caregiver Education and Child Sleep Disturbances

	Sleep latency ≥30 vs. <30 minutes		WASO ≥90 vs. <90 minutes		Sleep dur vs. ≥8
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI
Univariate model					
Caregiver education (ref: >high school)					
High school	0.95 (0.42, 2.17)	0.911	1.36 (0.61, 3.04)	0.449	0.72 (0.33, 1.6
<High school	3.37 (1.26, 8.98)	0.015	4.43 (1.58, 12.38)	0.005	0.89 (0.35, 2.2
P value for trend test		*0.029*		*0.006*	
Multivariable model					
Caregiver education (ref: >high school)[a]					
High school	1.02 (0.42, 2.45)	0.966	1.38 (0.58, 3.30)	0.468	0.70 (0.30, 1.6
<High school	3.27 (1.12, 9.61)	0.031	5.95 (1.91, 18.53)	0.002	0.78 (0.28, 2.1
P value for trend test		*0.056*		*0.004*	

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio; WASO, wake after sleep onset.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

Figure 1 Children's Sleep Parameters, by Caregiver Education Levels (HS: high school)

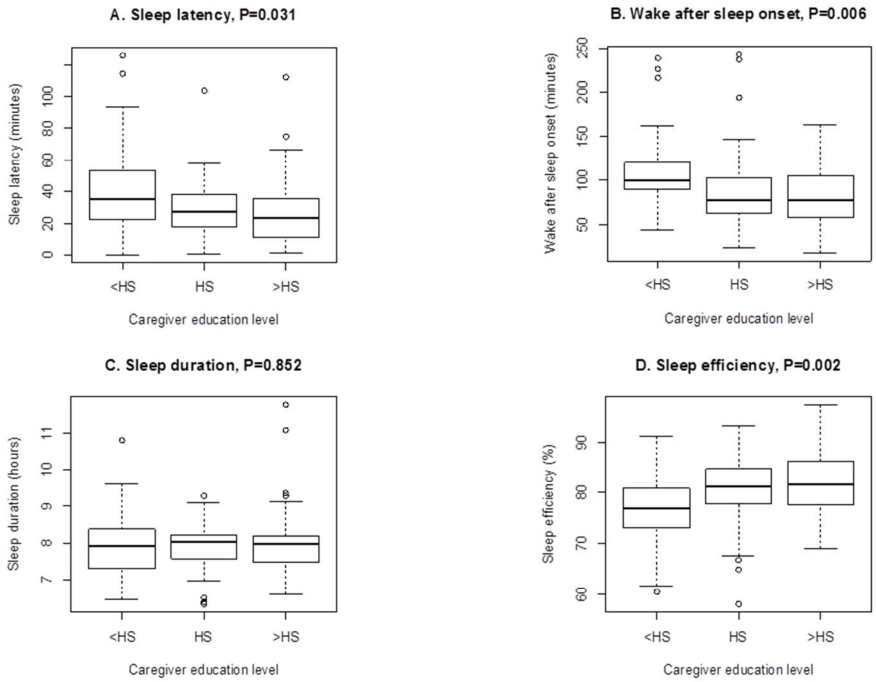


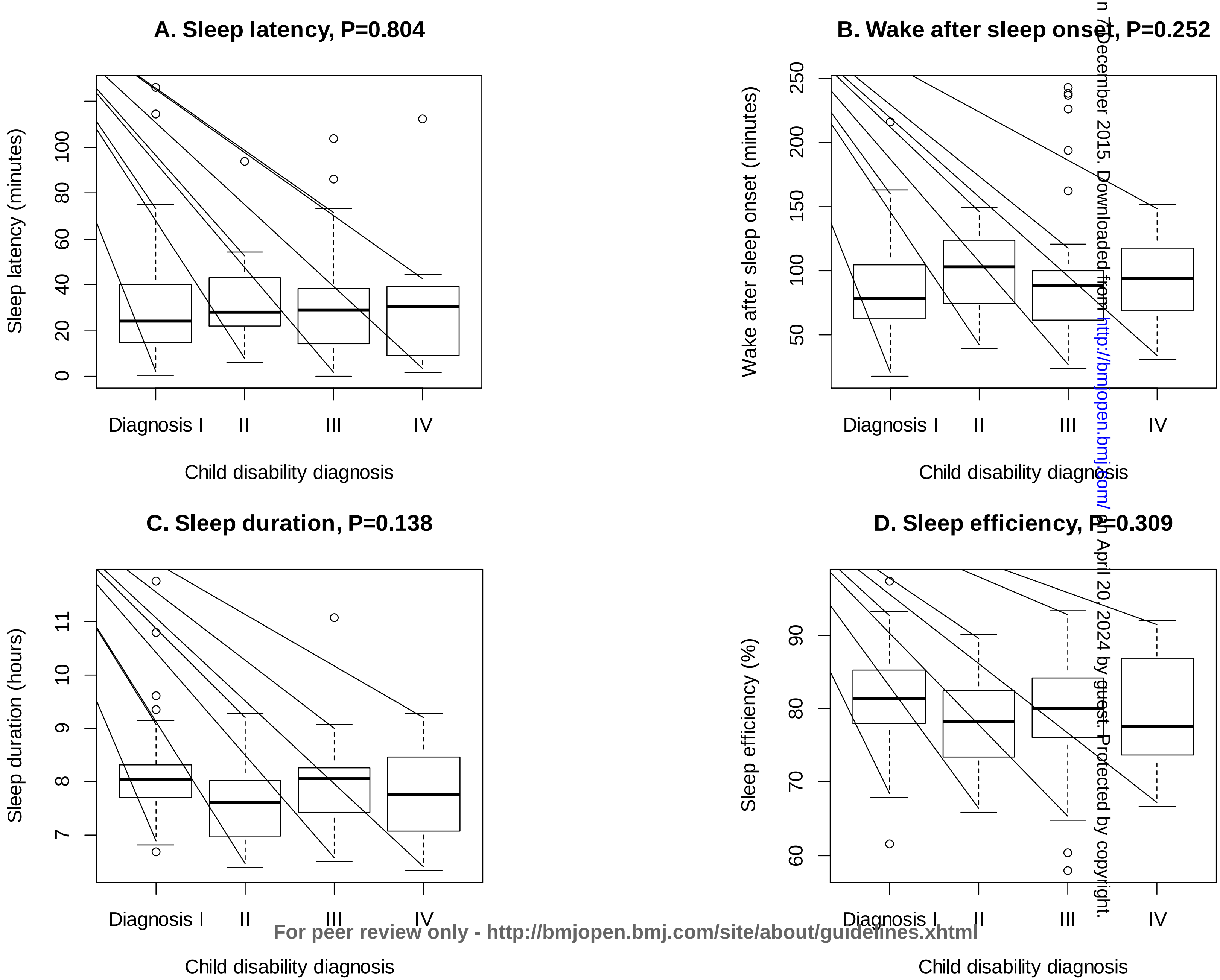
Figure in TIFF format
254x190mm (96 x 96 DPI)

Supplementary Table 1 Children's Sleep Parameters, By Types of Disability Diagnoses

Sleep parameters	Diagnosis I (n=60)	Diagnosis II (n=21)	Diagnosis III (n=34)	Diagnosis IV (n=10)	P value
Sleep onset, median (IQR)	22:35 (22:04, 23:03)	23:05 (22:25, 23:22)	22:37 (22:19, 23:05)	22:35 (21:45, 23:03)	0.187
Sleep latency, median (IQR), minutes	24.1 (14.7, 40.1)	28.1 (22.1, 43.0)	28.8 (14.1, 38.4)	30.5 (9.1, 39.4)	0.804
WASO, median (IQR), minutes	78.4 (63.5, 104.9)	103.3 (75.0, 123.7)	89.1 (61.7, 100.0)	94.0 (69.9, 117.9)	0.252
Number of awakenings, mean (SD)[a]	22.4 (6.6)	25.1 (5.1)	19.3 (6.5)	23.6 (7.6)	0.011
Sleep duration, median (IQR), hours	8.0 (7.7, 8.3)	7.6 (7.0, 8.0)	8.0 (7.4, 8.3)	7.8 (7.1, 8.5)	0.138
Sleep efficiency, mean (SD), %[a]	81.2 (6.5)	78.2 (6.2)	79.5 (8.6)	78.3 (8.2)	0.309

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.
Only sleep efficiency (%) and number of awakenings were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$).
[a]Analysis of variance was used for sleep efficiency and number of awakenings (normally distributed), while Kruskal-Wallis test was used for other sleep parameters.
Diagnosis I: mental and behavioral disorders (e.g., autism, ADHD, mental retardation); Diagnosis II: diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); Diagnosis III: diseases of the nervous system (e.g., cerebral palsy); Diagnosis IV: congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Supplementary Figure 1 Children's Sleep Parameters, by Disability Diagnoses



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).
Bias	9	
Study size	10	This is a cross-sectional, pilot study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
Results		
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Outcome data	15	
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study.

Evaluation of Actigraphy-Measured Sleep Patterns among Children with Disabilities and Associations with Caregivers' Educational Attainment: Results from a Cross-Sectional Pilot Study

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Evaluation of Actigraphy-Measured Sleep Patterns among Children with Disabilities and Associations with Caregivers' Educational Attainment: Results from a Cross-Sectional Pilot Study

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Supplementary figure: 1

KEY WORDS
Child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

ABBREVIATIONS

ADHD: attention-deficit/hyperactivity disorder
ASD: autism spectrum disorder
CI: confidence interval
CPASS: Chile Pediatric and Adult Sleep and Stress Study
ICD: International Classification of Diseases
ICF-CY: International Classification of Functioning, Disability and Health for Children and Youth

IQR: interquartile range
OR: odds ratio
SD: standard deviation
SE: standard error
WASO: wake after sleep onset

Abstract

Objectives: To test the feasibility of using wrist-actrigrphy to collect objective measures of sleep and to characterize actigraphy-measured sleep patterns among children with disabilities. We also assessed the extent to which, if at all, caregivers' education is associated with children's sleep disturbances.

Design: Cross-sectional pilot study.

Setting: A rehabilitation center in the Patagonia region, Chile.

Methods: This study was conducted among 125 children aged 6-12 years with disabilities (boys: 55.2%) and their primary caregivers in Chile. Children wore ActiSleep monitors for seven days. A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficiency (proportion of the sleep period spent asleep) across caregivers' education levels adjusting for children's age, sex, disability type, caregiver-child relationship, and caregivers' age. Multivariable logistic regression analyses were conducted to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of longer sleep latency (≥30 minutes) and longer wake after sleep onset (WASO) (≥90 minutes) (a measure of sleep fragmentation) in relation to caregivers' educational attainment.

Results: Median sleep latency was 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours. Mean sleep efficiency was 80.0%. Caregivers' education was positively and significantly associated with children's sleep efficiency (P_{trend}<0.001). Adjusted mean sleep efficiency was 75.7% (SE=1.4) among children of caregivers <high school education, and 81.9% (SE=1.0) among children of caregivers ≥high school education. Compared to children whose caregivers

had >high school, children of caregivers with <high school had higher odds of longer sleep latency (OR=3.27; 95% CI=1.12-9.61) and longer WASO (OR=5.95; 95% CI=1.91-18.53). Associations were consistent across disability types.

Conclusions: Children with disabilities experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency). Among children with disabilities, lower level of caregivers' education is associated with more sleep disturbances.

KEY WORDS: child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

Strengths and limitations of this study

- This cross-sectional pilot study is strengthened by its use of wrist-actigraphy which has been well validated for objective estimation of nighttime sleep parameters in the natural sleep environment.
- Our study was unique in being the first study to examine the associations between caregivers' education and actigraphy-measured sleep among children with disabilities.
- Its strength also lies in the statistical analysis that was performed using univariate and multivariable linear and logistic regression models.
- This is a cross-sectional, pilot study with a small sample size and high heterogeneity of disabilities included.

INTRODUCTION

Approximately 150 million children live with disabilities worldwide.[1] Sleep disturbances, particularly difficulty initiating and maintaining sleep, are commonly reported among children with a wide range of disabilities including Down syndrome, attention-deficit/hyperactivity disorder (ADHD), and autism.[2-6] There are discrepancies between objective measures of sleep and those reported by parents of children with disabilities.[5] Parents may be unaware of children's sleep disturbances, such as night awakenings, and tend to overestimate their children's sleep duration.[7] Inferences from prior studies are limited because investigators have relied on parental report of child sleep.[3] Although polysomnography is considered the gold standard for measuring sleep, it is burdensome and not easily amenable for use with children who have difficulties sleeping in unfamiliar surroundings. Actigraphy-based sleep offers opportunities to obtain objective measures of sleep in children's typical environment. Actigraphy has been validated for objective measures of sleep in clinical- and population-based studies.[8, 9]

Sleep disturbances have been related to sociodemographic, environmental, and behavioral factors.[10-13] Children's sleep disturbances have been connected with their home environment that may be influenced by caregivers' characteristics.[13, 14] Our recent qualitative study showed that while Chilean caregivers and rehabilitation providers recognized the importance of sleep health, they differed in their understanding of how sleep practices influence children's sleep health.[13] Parental ability to provide support for healthy behaviors including sleep may be influenced by parental education, a known factor associated with child health measures.[12, 15-17] Magana et al

reported that maternal education and knowledge about autism accounted for differences in the number of specialty services received by Latino children with autism spectrum disorder (ASD) as compared with White children in the US.[15] However, to our knowledge, little research has been conducted regarding the role of caregivers' education in objectively measured sleep among children with disabilities, particularly among Patagonian Chilean children, an understudied population with documented high burden of obesity and related chronic disorders.[18]

This cross-sectional pilot study was designed to examine the feasibility of conducting future research using wrist-actigraphy as a means for collecting objective measures of sleep patterns among children with disabilities. Our primary objective for designing and conducting this pilot study was to document the feasibility of using this data collection approach in a relatively understudied population, and to use the information to design a larger study in this population. Using collected data from this pilot study, we also sought to characterize actigraphy-measured sleep patterns and to examine whether caregivers' education level is associated with sleep disturbances among children with disabilities. Specifically, we sought to estimate the prevalence of actigraphy-measured sleep disturbances including long sleep latency, long wake after sleep onset (WASO), short sleep duration, and poor sleep quality (low sleep efficiency) among Chilean children with disabilities. Further, following up on results from a previous qualitative study,[13] we sought to determine the extent to which, if at all, caregivers' low levels of educational attainment are associated with children's sleep disturbances and overall poor sleep quality.

METHODS

Participants

The Chile Pediatric and Adult Sleep and Stress Study (CPASS) was a cross-sectional pilot study that was established in September 2012 at the Centro de Rehabilitacion Club de Leones Cruz del Sur in Punta Arenas, Chile.[13] The CPASS was designed to establish the feasibility of using wrist-actigraphy to characterize sleep patterns of children with disabilities. Specifically, the study was designed to yield information that would guide the design of a larger full-scale study in the future, hence, particular attention was paid to establishing the protocols for data collection, assessing protocol adherence among children with a wide range of developmental disabilities, and using collected data to preliminary assess study hypotheses.

The first wave of the CPASS (CPASS I) was conducted between September and December in 2012 among children aged 6-12 years who were receiving routine clinical care for disabilities at the center and their primary caregivers. Children with disabilities in this study were those who had impairments, activity limitations, and participation restrictions due to health conditions such as autism, Down syndrome, and cerebral palsy, according to the World Health Organization, the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY).[19] All children were diagnosed by a clinical care team composed of a pediatric neurologist, a pediatrician with extensive experience in developmental disabilities, and a rehabilitation medicine specialist using diagnostic criteria and/or standardized tests with the input of families and teachers. Primary caregivers were parents, grandparents, relatives, or other adults and were principally responsible for children's well-being and did not have developmental or intellectual disabilities. Research staff talked with caregivers to determine if they could complete the interviewer-administered questionnaire survey. In addition, a physician helped confirm that caregivers had no developmental or intellectual disabilities. Of 153 children whose families were contacted via telephone by research staff, 110 adult caregivers (71.9%) consented to participate in this study. A total of 110 children and caregivers (one caregiver per child) were recruited in the CPASS I. Five children were excluded from this study due to fewer than 3 days of actigraphy data: four children removed monitors after day one or day two of the study; one child lost the monitor on day two. These children had no sleep log data. A total of 105 child-caregiver dyads (95.5% of enrolled families) completed the CPASS I study protocol.

The second wave of the CPASS (CPASS II) was conducted among children with disabilities aged 10-21 years and their primary caregivers between April and July in 2013 at the center.[20, 21] Research personnel invited 129 caregivers of children with disabilities to participate. A total of 90 caregivers (69.8%) agreed to participate in the study. Twenty children were aged 10-12 years from the CPASS II. As these two studies (CPASS I and CPASS II) were conducted between September 2012 and July 2013 at the same rehabilitation center in Chile, with the same staff and with identical study protocols used for assessing sleep traits, we combined the results from the two studies in order to have a larger sample size with increased statistical power in the present analysis. In total, 125 children aged 6-12 years were included in the current study. The final sample size of this pilot was determined on the basis of available resources (e.g., ActiSleep monitors) and not based on formal *a priori* sample size and statistical power determinations.

Written informed consents were obtained from primary caregivers of children with disabilities. This study was approved by the institutional review boards of the Centro de Rehabilitacion Club de Leones Cruz del Sur and Harvard T.H. Chan School of Public Health Office of Human Research Administration.

Study Procedures

A psychologist administered structured questionnaires to caregivers to collect information on sociodemographic and lifestyle factors of both children and caregivers. Research staff instructed children to wear ActiSleep monitors (ActiLife, ActiGraph R&D, Florida, USA)[22] on their non-dominant wrists for seven consecutive days. Although the monitors are waterproof, children were instructed to remove them from their wrists before taking showers and/or before swimming. Caregivers were also instructed to keep sleep logs of time in bed and time out of bed for their children. Electronic medical records were reviewed by a physician in order to extract children's diagnoses defined by the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10).[23]

Sleep Parameters

Actigraphic sleep data were collected using the ActiSleep monitors and were analyzed using the ActiLife 6 data analysis software.[22] When worn during sleep episodes, the ActiSleep monitor can provide estimates of sleep onset, sleep latency, WASO, number and length of awakenings, sleep duration, and sleep efficiency. Sleep latency is the length of time taken to fall asleep, calculated as the time between "lights off" to the first period of 3 minutes of consecutive epochs scored as sleep. WASO is the number of minutes awake between sleep onset and time of final waking. Sleep efficiency is defined as the proportion of the estimated sleep periods spent asleep. Actigraphy data were collected in 1-min epochs using the zero-crossing modes, and the "Sadeh" sleep algorithm was used for children.[24] The majority of children (n=122, 97.6 %) had complete 7-day actigraphic sleep data; two children had 6-day actigraphic data and one child had 3-day data available for study. The averages of sleep parameters were calculated for children who had 3, 6, or 7 days of actigraphic data. There were no missing sleep log data for children included in this study. Caregivers were asked to record their children's sleep logs each morning up awakening and to make sure the sleep logs were complete. Research staff checked children's sleep logs when caregivers returned with ActiSleep monitors. Information from sleep logs were not used to substitute missing actigraphy data.

Sociodemographic Characteristics and Children's Disabilities

Interviewer-administered questionnaires were used to collect information on children's age, sex, daytime napping, medication use, caregiver-child relationship (e.g., mother), caregivers' age, employment status, and education level. Caregivers were asked to report the highest degree of education they had completed: less than 12th grade (<high school education), high school graduate or equivalent (high school education), some college degree, or college graduate or above (>high school education). According to the ICD-10,[23] children's disabilities were grouped as: 1) mental and behavioral disorders (e.g., ADHD, autism); 2) diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); 3) diseases of the nervous system (e.g., cerebral palsy); and 4) congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Statistical Analysis

Kolmogorov-Smirnov test was used to assess the normality of sleep parameters. Variables were described using means and standard deviations (SDs) for parametric variables and medians and interquartile ranges (IQRs) for nonparametric variables. Number of nocturnal awakenings and sleep efficiency were normally distributed, whereas sleep onset, sleep latency, WASO, awakening length, and sleep duration were not normally distributed. Student's t-test was used for age, number of awakenings, and sleep efficiency as parametric variables by child sex; Wilcoxon rank-sum test was used to test differences in nonparametric variables including sleep onset, sleep latency, WASO, awakening length, and sleep duration by child sex. Fisher's or χ^2 test was conducted to compare differences in sociodemographic factors, daytime napping, medication use, and disability groups by child sex. Analysis of variance or Kruskal-Wallis test was conducted to evaluate the differences in sleep parameters across children's disability groups and caregivers' education levels.

A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficiency across caregivers' education levels with adjustment for children's age, sex, disability, caregiver-child relationship, and caregivers' age. Univariate and multivariable linear regression analyses were performed to examine the associations of caregivers' education levels with sleep efficiency and the number of awakenings. Stratified analysis was conducted to evaluate whether the associations between caregivers' education levels and children's sleep disturbances differed according to children's disability groups. Given that we aimed to examine whether children whose caregivers had lower education level were more likely to have sleep disturbances (e.g., long sleep latency, long WASO) and to enhance interpretability, we created categorical variables for these sleep parameters and used in logistic regression models. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models to evaluate the associations of caregivers' educational attainment with children's long sleep latency (≥30 vs. <30 minutes), long WASO (≥90 vs. <90 minutes), and short sleep duration (<8 vs. ≥8 hours). These cut points were chosen based on the literature of sleep latency[25] and sleep duration,[26] as well as sleep data distributions in the study (WASO median=88 minutes, sleep duration median=8 hours; only 9.6% of children had sleep ≥9 hours). We also included a variable to represent study wave (I and II) in multivariable regression models and found similar results (data not shown). We conducted sensitivity analysis by including medication use and daytime napping in the models and did not find that they had an impact on our results in this study (data not shown). Statistical significance levels were set at P <0.05 for two-sided analyses.

P values were not corrected for multiple testing. All tests were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

The mean age of children with disabilities was 9.2 (SD=2.2; range=6-12) years. Most caregivers were mothers (88.0%); 21.6% of caregivers reported having <high school education level (**Table 1)**. There were no statistically significant differences in medication use, daytime napping, caregiver-child relationship, caregivers' age, employment status, or education level between boys and girls.

Median time for sleep onset was 22:39, sleep latency 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours (**Table 1**). The mean number of awakenings was 22.1 and sleep efficiency was 80.0%. There were no statistically significant differences in sleep parameters between boys and girls (all $P > 0.05$). Overall, 43.2% of children had sleep latency ≥30 minutes, 51.2% had short sleep <8 hours, and 77.6% had low sleep efficiency <85%.

There were no significant differences in sleep parameters across disability groups (**Supplementary Figure 1**), except for the number of nocturnal awakenings (**Supplementary Table 1**). Children with diseases of musculoskeletal system and connective tissue, skin and subcutaneous tissue appeared to have more awakenings, reflecting more fragmented sleep, than children with other disabilities.

Children whose caregivers had <high school had longer sleep latency, longer WASO, longer awakening length, and lower sleep efficiency compared to children whose caregivers had >high school (**Figure 1, Table 2)**. Although children of caregivers with <high school tended to have later sleep onset, higher number of awakenings, and shorter sleep duration when compared to children of caregivers with higher education, these differences did not reach statistical significance.

Our general linear model with adjustment for child age, sex, disability group, caregiver-child relationship, and caregiver age showed that the mean sleep efficiency was the lowest among children of caregivers with <high school (75.7% [SE=1.4]), followed by children of caregivers with high school (80.4% [SE=1.0]) and >high school (81.9% [SE=1.0]). Univariate and multivariable linear regression analyses showed no significant associations between caregivers' education levels and children's awakening number. However, compared to children whose caregivers had >high school, children of caregivers with <high school had significantly lower sleep efficiency (adjusted beta=-6.3, SE=1.7; P=0.001) (**Table 3**). Caregivers' educational attainment was positively and significantly associated with children's sleep efficiency in the univariate model (P_{trend}=0.001) and the multivariable model (P_{trend}<0.001).

As shown in **Table 4** based on logistic regression models**,** compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer

sleep latency ≥30 minutes (adjusted OR=3.27; 95% CI=1.12-9.61) and longer WASO ≥90 minutes (OR=5.95; 95% CI=1.91-18.53). Caregivers' education levels were inversely and significantly associated with children's sleep latency and WASO (both P_{trend}<0.05). Children's short sleep duration (<8 hours) was not associated with caregivers' low educational level (OR=0.78; 95% CI=0.28-2.18).

The associations between caregivers' education and children's sleep efficiency varied little according to disability groups (data not shown in tables). For example, among children with mental and behavioral disorders, children of caregivers with <high school had lower sleep efficiency (beta=-6.2, SE=2.2; P=0.006), after adjustment for children's age, sex, caregiver-child relationship, and caregivers' age. Similar results were found for children with other disabilities.

DISCUSSION

In this cross-sectional pilot study, we assessed sleep patterns using wrist actigraphy over seven consecutive days among Chilean children with disabilities. We found that actigraphy-measured sleep disturbances including long sleep latency (median=27 minutes), long WASO (median=88 minutes), short sleep duration (median=8 hours), high number of nocturnal awakenings (mean=22), and low sleep efficiency (mean=80%) were common among children. These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency), and have increased sleep fragmentation (increased nocturnal awakenings). These indices are common in insomnia, which may occur secondary to chronic health conditions, and for many conditions, is associated with poor quality of life and increased disease-specific health burden including behavioral and cognitive problems.[27, 28] We also found strong associations between caregivers' low educational attainment and children's sleep disturbances (e.g., low sleep efficiency) independent of children's disability type and other covariates from both children and caregivers. To our knowledge, this is the first study to specifically quantify actigraphy-measured sleep patterns among children with disabilities in relation to caregivers' education levels. Furthermore, we address these questions among Patagonian Chilean children with disabilities, an understudied population in South America.

Children with a wide range of disabilities have been reported to have sleep disturbances, including prolonged sleep latency, increased WASO, short sleep duration, and decreased sleep efficiency in Europe and other developed countries including Canada and New Zealand.[4-6, 29, 30] For example, in a small study of 8 UK children with mucopolysaccharidosis aged 2-15 years, median actigraphy-measured sleep latency was 35.4 minutes, WASO 83.4 minutes, and sleep efficiency was 75.6%.[30] Allik et al reported that children aged 8-12 years with Asperger syndrome and high-functioning autism in Sweden had actigraphy-measured longer sleep latency (mean=32 minutes) and lower sleep efficiency (mean=87%) than controls.[6] In a study of children aged 5-11 years with ADHD in Denmark, average sleep latency was 26 minutes and 31% of children had sleep latency >30 minutes.[5] A case-control study using 5 nights of actigraphy for 15 school-aged children with traumatic brain injury and 15 school-aged siblings in the UK reported that brain injury was significantly associated with children's longer sleep latency (mean=50 minutes), longer WASO (mean=65 minutes), and lower sleep efficiency (mean=80%).[29] To our knowledge, no research has been conducted on objectively measured sleep parameters in South America (e.g., Chile) among children with disabilities, an understudied sample. In our study of Chilean children with autism and other disabilities, the median of actigraphy-measured sleep latency was 27 minutes, WASO was 88 minutes, and the mean of sleep efficiency was 80%, which were similar to previous research findings.[5, 29, 30] We also found that a high proportion of Chilean children with disabilities experienced actigraphy-measured sleep disturbances: 43% of children had sleep latency ≥30 minutes, 51% had short sleep <8 hours (90% of children had sleep duration <9 hours), and 78% had sleep efficiency <85%. Although school-aged children are recommended to have at least 9 hours of sleep,[26, 31] in our study, only 10% of Chilean children with disabilities had sleep duration ≥9 hours. Gibbs et al reported that among 8 children aged 4-15 years with Prader-Willi syndrome in New Zealand, median 7-night actigraphy-measured WASO was 95 minutes.[32] Corkum et al reported the average of awakenings was 15 among Canadian children with ADHD (aged 7-11 years).[4] In our current study, the average number of nocturnal awakenings was 22 among Chilean children with ADHD and other disabilities. Our study along with previous research suggests that children with disabilities have difficulties initiating and maintaining good sleep.

Several researchers have reported that children with disabilities have late sleep onset.[33, 34] A study of US children aged 2-5 years with autism and other developmental disabilities reported that the mean of 7-day actigraphy-measured sleep onset time was 21:32.[33] In this study, we found that median sleep onset time was 22:39 among Chilean children with autism and other disabilities. Unique climate (e.g., late sunset) and lifestyle characteristics (e.g., late mealtime) in the Patagonia region may have partly contributed to children's late sleep onset time.[13,18] Our findings of late sleep onset are generally consistent with literature for children in this age range. For example, a cross-sectional study of 96 healthy Chilean children aged 10 years found that the mean of overnight polysomnography-measured sleep onset time was 23:10 for children with normal weight and 23:20 for children with overweight and obesity.[35] Another study of 58 healthy children aged 11-13 years in the US showed that the mean of 4-day actigraphy-measured sleep onset time was 23:27.[36] In the Cleveland Children's Sleep and Health Study, 14.8% of US children aged 8-11 years had bedtime 23:00 or later.[14] Future research is warranted to examine potential risk factors of late bedtime such as daytime napping and how to improve sleep onset time among children with disabilities.

It has been reported that children whose caregivers have low education levels are more likely to have adverse health outcomes, such as great body weight[16] and poor quality of life.[17] McDonald et al found that lower maternal education was independently associated with parent-reported shorter sleep (<11 hours/night) among young children.[12] Although several studies have reported that parental education is associated with child health,[12, 15] we are unaware of published reports that have investigated whether and how caregivers' education levels are related to objectively measured sleep problems among children with disabilities. In our study, caregivers' education level in relation to children's sleep disturbances was substantiated through statistically significant association as shown in univariate and multivariable linear and logistic regression models. Our study suggests the importance of tailoring sleep education for caregivers with lower educational attainment to improve children's sleep health. We considered low educational attainment a proxy for low socioeconomic status (SES). It has been reported that educational levels and SES are highly correlated.[37] Low SES, as well as low education, has been related to high risk for cardiovascular disease, cancer, and mortality.[38] Parental SES has been inversely associated with negative child health outcomes including cardiovascular disease and mortality.[39, 40] Some of the burden from low parental education level may be attributable to relatively lower health literacy, particularly sleep health literacy, which is pertinent to our pilot observations in the focus group study[13] and also in this pilot epidemiologic study.

Parents with low education levels may lack knowledge and resources about children's sleep practices and disabilities, resulting in adverse parenting practices known to affect sleep hygiene such as less limit setting, more variability in routines important to establish regular sleep patterns, suboptimal configuration of bedrooms to optimize sleep, inappropriate use of electronic devices, and meal timing in relationship to sleep. Better-educated parents may have more access to information about sleep and disabilities possibly through the internet or group membership with other parents of children diagnosed with disabilities. Future research should consider the impact of providing education and support such as sleep hygiene education, as well as initiatives to provide social support for parents and families of children with disabilities. Although our data suggest that these efforts may especially benefit less well-educated parents, all parents may have difficulties in navigating all of the controversies and different claims on the internet and may benefit from improved education and support. Our findings of the associations documented in our study population, if replicated, could help motivate the development and implementation of training programs to increase the parental health literacy (especially sleep health literacy). Parents of children with disabilities could benefit from sleep education workshops. Social support from families of children with disabilities as well as health care providers including occupational and physiotherapists and nurses could also be important in helping parents handle with their children's sleep problems.

Lack of knowledge of healthy sleep behaviors among caregivers has been associated with an increased risk of having unhealthy sleep behaviors for their children.[41] Although sleep disturbances have been noted to be common in children with neurological conditions (e.g., cerebral palsy), there are no interventions specifically designed to improve sleep in these children.[42] Several small studies of children with ASD have reported that parent-based sleep education appears effective in improving child sleep health.[34, 43] For example, a study of 20 children with ASD showed that parent-based sleep education workshops improved sleep latency from 62.2 minutes to 45.6 minutes.[43] Malow et al reported that sleep education to parents of 80 children with ASD (aged 2-10 years) significantly decreased children's sleep latency from 58.2 to 39.6 minutes.[34] Our prior qualitative study in Chile has indicated that parental knowledge gaps regarding healthy sleep behaviors in children support the need for increased sleep health education among targeted caregivers.[13] Pediatricians and family physicians can be trained to provide adequate advice and educational messages (e.g., sleep health) to pediatric patients and their families.[44]

Our study has several limitations. First, as this was a cross-sectional pilot study that aimed to examine the feasibility of conducting future research with a larger sample size in this underserved population, we did not have a control group of children without disabilities. Second, this study was limited by its modest sample size and the heterogeneity of disabilities represented among children studied. As such, the confidence intervals were wider for some groups (e.g., the less than high school education group) and we were not able to report associations specific to any single disability category (e.g., autism). Third, we did not collect information pertaining to some aspects of sleep which may be associated with low education levels such as caregivers' shift work, sleep hygiene, and other factors such as co-sleeping, lack of knowledge about sleep health, or inability to obtain medications to treat sleep or conditions in this study. Hence we were not able to quantify the influence of these factors on children's sleep patterns. Our findings also focused on caregivers (majority were mothers) of children with disabilities in Chile, and may not be generalizable to other populations/groups. Although accepted to provide an objective measure of sleep-wake cycle, actigraphy has its limitations. For example, periods of quiet wakefulness may be interpreted by the device as sleep, and periods of restless sleep may be interpreted by the device as wakefulness.[8, 45] Recent literature has indicated limitations of actigraphy for accurately capturing children's awakenings.[46] Our study has indicated that children with diseases of the musculoskeletal system and connective, skin, and subcutaneous tissue have more awakenings because their restless sleep may be represented by actigraphy as awakenings, and/or due to medication use or body pain. Despite this, actigraphy has been well validated for objective estimation of nocturnal sleep parameters across age groups in the natural sleep environment.[9] As this was an exploratory study that aimed to examine whether parental education was associated with children's sleep disturbances, we did not adjust for multiple comparisons in this study. In addition, the simple adjustments for multiple comparisons might be overly conservative because many sleep problems (e.g., long WASO, low sleep efficiency) were correlated.

CONCLUSIONS

This cross-sectional pilot study suggests the feasibility of using wrist-actigraphy as a means of collecting objective measures of sleep patterns among Chilean Patagonian children with disabilities. Using collected data, we noted that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency), maintaining sleep (long WASO, low sleep efficiency), and sleep fragmentation (increased nocturnal awakenings). Among children with disabilities, lower levels of caregivers' educational attainment are strongly associated with children's sleep disturbances and these associations appear to be independent of children's age, sex, disability group, caregiver-child relationship, and caregiver age. Parental support and education programs directed to families with low education levels may be of particular importance for sleep behavior intervention among children with disabilities. Larger studies, using wrist-actigraphy methods to objectively measure sleep in this relatively understudied population, are warranted to confirm our findings. Future research is also needed regarding the effects of sleep education intervention as well as social support to low educational families of children with disabilities on sleep health, with taking into account of different cultural backgrounds.

Contributors' Statement

All of the authors have agreed to the content of this manuscript. XC conceptualized and designed the study, supervised data collection, carried the initial analyses, and drafted the initial manuscript. JCV and CB carried out the field survey, supervised data collection, and critically reviewed and revised the manuscript. MP carried out the field survey, coordinated data collection at the study site, and reviewed the manuscript. BG helped develop the study protocol, and critically reviewed and revised the manuscript. SR critically reviewed and revised the manuscript. MAW provided funding support to the study, supervised the study, conceptualized and designed the study, and critically reviewed and revised the manuscript.

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Figure Legends

Figure 1 Children's Sleep Parameters, by Caregiver Education Levels (HS: high school)

Table 1 Characteristics of Children with Disabilities and Their Primary Caregivers

	Total (n=125)	Boys (n=69)	Girls (n=56)
Child characteristics			
Age, mean (SD), years	9.2 (2.2)	8.8 (2.1)	9.8 (2.3)
Type of disability diagnosis, %			
Mental and behavioral disorders	48.0	59.4	33.9
Diseases of musculoskeletal system	16.8	10.1	25.0
Diseases of the nervous system	27.2	27.5	26.8
Congenital/chromosomal abnormalities	8.0	2.9	14.3
Daytime napping	16.8	14.5	19.6
Medication use	44.0	42.0	46.4
Sleep parameters			
Sleep onset, median (IQR)	22:39 (22:06, 23:08)	22:44 (22:24, 23:08)	22:33 (21:54, 23:09)
Sleep latency, median (IQR), minutes	27.3 (15.0, 38.9)	27.1 (14.4, 41.7)	27.4 (15.4, 38.2)
WASO, median (IQR), minutes	88.1 (65.6, 111.1)	92.4 (64.4, 112.4)	81.9 (66.2, 107.0)

Number of awakenings, mean (SD)[a]	22.1 (6.7)	22.5 (6.5)	21.6 (6.9)
Awakening length, median (IQR), minutes	5.1 (4.2, 7.1)	5.1 (4.2, 7.0)	5.1 (4.2, 7.1)
Sleep duration, median (IQR), hours	8.0 (7.5, 8.2)	8.0 (7.3, 8.2)	8.0 (7.5, 8.3)
Sleep efficiency, mean (SD), %[a]	80.0 (7.2)	79.0 (8.1)	81.2 (5.8)
Caregiver characteristics			
Age, mean (SD), years	38.3 (7.8)	38.5 (7.8)	38.0 (7.8)
Caregiver-child relationship, %			
Mother	88.0	88.4	87.5
Other	12.0	11.6	12.5
Employed/self-employed	60.0	62.3	57.1
Education level, %			
<High school	21.6	24.6	17.9
High school	37.6	29.0	48.2
>High school	40.8	46.4	33.9

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a] Of these sleep parameters, only number of awakenings and sleep efficiency were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$). While Student's t-test was used for number of awakenings and sleep efficiency, Wilcoxon rank-sum test was used for the other sleep parameters.

Table 2 Children's Sleep Parameters, By Caregivers' Education Levels

Sleep parameters	<High school (n=27)	High school (n=47)	>High school (n=51)
Sleep onset, median (IQR)	23:05 (22:17, 23:23)	22:31 (21:55, 23:04)	22:39 (22:24, 23:02)
Sleep latency, median (IQR), minutes	35.6 (17.3, 53.7)	27.1 (17.4, 38.4)	23.6 (11.1, 35.9)
WASO, median (IQR), minutes	99.1 (88.1, 121.0)	77.1 (63.4, 103.4)	77.0 (57.6, 106.0)
Number of awakenings, mean (SD)[a]	23.1 (5.7)	21.2 (6.3)	22.4 (7.5)
Awakening length, median (IQR), minutes	6.9 (5.0, 9.5)	5.2 (4.2, 7.2)	4.7 (3.9, 5.7)
Sleep duration, median (IQR), hours	7.9 (7.3, 8.4)	8.0 (7.6, 8.2)	8.0 (7.4, 8.2)
Sleep efficiency, mean (SD), %[a]	75.9 (7.0)	80.5 (7.3)	81.8 (6.5)

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Sleep efficiency and number of awakenings were normally distributed in this study.

Table 3 Linear Regression Models for Associations between Caregiver Education and Child Sleep Parameters

	Number of awakenings		Sleep efficiency (%)	
	Beta (SE)	P value	Beta (SE)	P value
Univariate model				
Caregiver education (ref: >high school)				
High school	-1.2 (1.3)	0.384	-1.3 (1.4)	0.357
<High school	0.7 (1.6)	0.662	-5.9 (1.7)	<0.001
P value for trend test		*0.838*		*0.001*
Multivariable model[a]				
Caregiver education (ref: >high school)				
High school	-0.6 (1.4)	0.674	-1.6 (1.4)	0.269
<High school	1.9 (1.7)	0.245	-6.3 (1.7)	0.001
P value for trend test		*0.364*		*<0.001*

Abbreviation: SE, standard error.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

Table 4 Logistic Regression Models for Associations between Caregiver Education and Child Sleep Disturbances

	Sleep latency ≥30 vs. <30 minutes		WASO ≥90 vs. <90 minutes		Sleep dur vs. ≥8
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI
Univariate model					
Caregiver education (ref: >high school)					
High school	0.95 (0.42, 2.17)	0.911	1.36 (0.61, 3.04)	0.449	0.72 (0.33, 1.6
<High school	3.37 (1.26, 8.98)	0.015	4.43 (1.58, 12.38)	0.005	0.89 (0.35, 2.2
P value for trend test		*0.029*		*0.006*	
Multivariable model					
Caregiver education (ref: >high school)[a]					
High school	1.02 (0.42, 2.45)	0.966	1.38 (0.58, 3.30)	0.468	0.70 (0.30, 1.6
<High school	3.27 (1.12, 9.61)	0.031	5.95 (1.91, 18.53)	0.002	0.78 (0.28, 2.1
P value for trend test		*0.056*		*0.004*	

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio; WASO, wake after sleep onset.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

Figure 1 Children's Sleep Parameters, by Caregiver Education Levels (HS: high school)

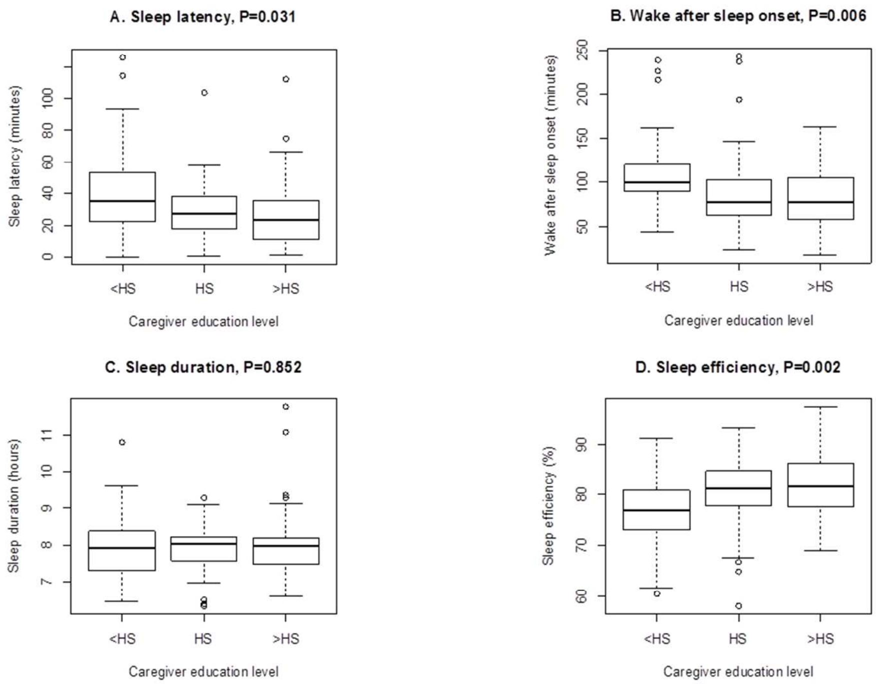


Figure in TIFF format
254x190mm (96 x 96 DPI)

Supplementary Table 1 Children's Sleep Parameters, By Types of Disability Diagnoses

Sleep parameters	Diagnosis I (n=60)	Diagnosis II (n=21)	Diagnosis III (n=34)	Diagnosis IV (n=10)	P value
Sleep onset, median (IQR)	22:35 (22:04, 23:03)	23:05 (22:25, 23:22)	22:37 (22:19, 23:05)	22:35 (21:45, 23:03)	0.187
Sleep latency, median (IQR), minutes	24.1 (14.7, 40.1)	28.1 (22.1, 43.0)	28.8 (14.1, 38.4)	30.5 (9.1, 39.4)	0.804
WASO, median (IQR), minutes	78.4 (63.5, 104.9)	103.3 (75.0, 123.7)	89.1 (61.7, 100.0)	94.0 (69.9, 117.9)	0.252
Number of awakenings, mean (SD)[a]	22.4 (6.6)	25.1 (5.1)	19.3 (6.5)	23.6 (7.6)	0.011
Sleep duration, median (IQR), hours	8.0 (7.7, 8.3)	7.6 (7.0, 8.0)	8.0 (7.4, 8.3)	7.8 (7.1, 8.5)	0.138
Sleep efficiency, mean (SD), %[a]	81.2 (6.5)	78.2 (6.2)	79.5 (8.6)	78.3 (8.2)	0.309

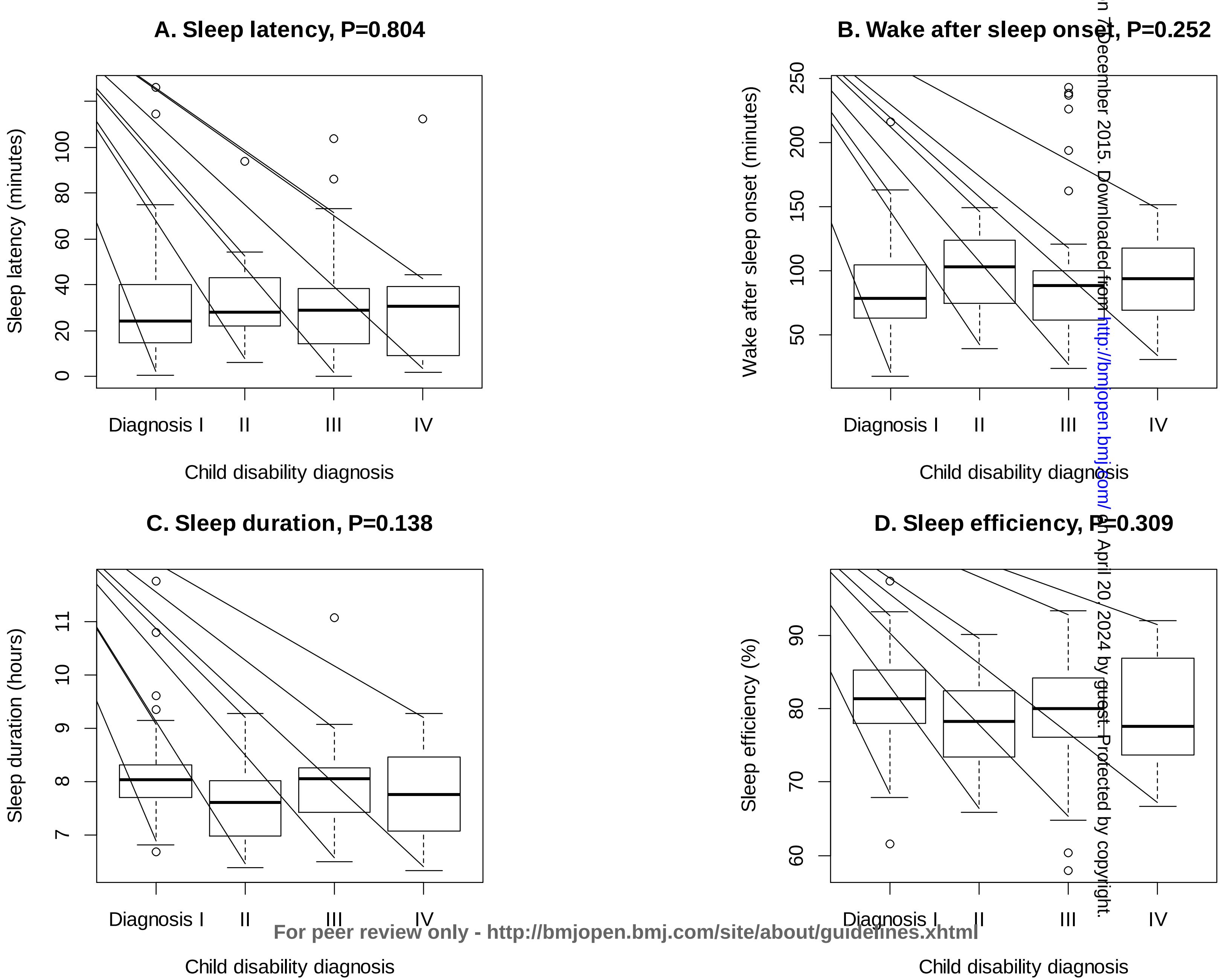
Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

Only sleep efficiency (%) and number of awakenings were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$).

[a]Analysis of variance was used for sleep efficiency and number of awakenings (normally distributed), while Kruskal-Wallis test was used for other sleep parameters.

Diagnosis I: mental and behavioral disorders (e.g., autism, ADHD, mental retardation); Diagnosis II: diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); Diagnosis III: diseases of the nervous system (e.g., cerebral palsy); Diagnosis IV: congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Supplementary Figure 1 Children's Sleep Parameters, by Disability Diagnoses



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).
Bias	9	
Study size	10	This is a cross-sectional, pilot study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
Results		
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Outcome data	15	
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study.

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Evaluation of Actigraphy-Measured Sleep Patterns among Children with Disabilities and Associations with Caregivers' Educational Attainment: Results from a Cross-Sectional Study

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Evaluation of Actigraphy-Measured Sleep Patterns among Children with Disabilities and Associations with Caregivers' Educational Attainment: Results from a Cross-Sectional Study

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Child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

ABBREVIATIONS
ADHD: attention-deficit/hyperactivity disorder
ASD: autism spectrum disorder
CI: confidence interval
CPASS: Chile Pediatric and Adult Sleep and Stress Study
ICD: International Classification of Diseases
ICF-CY: International Classification of Functioning, Disability and Health for Children and Youth

IQR: interquartile range
OR: odds ratio
SD: standard deviation
SE: standard error
WASO: wake after sleep onset

Abstract

Objectives: To use wrist-actrigrphy to collect objective measures of sleep and to characterize actigraphy-measured sleep patterns among children with disabilities. We also assessed the extent to which, if at all, caregivers' education is associated with children's sleep disturbances.

Design: Cross-sectional study.

Setting: A rehabilitation center in the Patagonia region, Chile.

Methods: This study was conducted among 125 children aged 6-12 years with disabilities (boys: 55.2%) and their primary caregivers in Chile. Children wore ActiSleep monitors for seven days. A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficiency (proportion of the sleep period spent asleep) across caregivers' education levels adjusting for children's age, sex, disability type, caregiver-child relationship, and caregivers' age. Multivariable logistic regression analyses were conducted to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of longer sleep latency (≥30 minutes) and longer wake after sleep onset (WASO) (≥90 minutes) (a measure of sleep fragmentation) in relation to caregivers' educational attainment.

Results: Median sleep latency was 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours. Mean sleep efficiency was 80.0%. Caregivers' education was positively and significantly associated with children's sleep efficiency (P_{trend}<0.001). Adjusted mean sleep efficiency was 75.7% (SE=1.4) among children of caregivers <high school education, and 81.9% (SE=1.0) among children of caregivers >high school education. Compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep

latency (OR=3.27; 95% CI=1.12-9.61) and longer WASO (OR=5.95; 95% CI=1.91-18.53). Associations were consistent across disability types.

Conclusions: Children with disabilities experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency). Among children with disabilities, lower level of caregivers' education is associated with more sleep disturbances.

KEY WORDS: child, disability, caregiver, education, sleep parameter, actigraphy, sleep duration, sleep efficiency, sleep latency, wake after sleep onset

Strengths and limitations of this study

- This cross-sectional study is strengthened by its use of wrist-actigraphy which has been well validated for objective estimation of nighttime sleep parameters in the natural sleep environment.
- Our study was unique in being the first study to examine the associations between caregivers' education and actigraphy-measured sleep among children with disabilities.
- Its strength also lies in the statistical analysis that was performed using univariate and multivariable linear and logistic regression models.
- This is a cross-sectional study with a small sample size and high heterogeneity of disabilities included.

INTRODUCTION

Approximately 150 million children live with disabilities worldwide.[1] Sleep disturbances, particularly difficulty initiating and maintaining sleep, are commonly reported among children with a wide range of disabilities including Down syndrome, attention-deficit/hyperactivity disorder (ADHD), and autism.[2-6] There are discrepancies between objective measures of sleep and those reported by parents of children with disabilities.[5] Parents may be unaware of children's sleep disturbances, such as night awakenings, and tend to overestimate their children's sleep duration.[7] Inferences from prior studies are limited because investigators have relied on parental report of child sleep.[3] Although polysomnography is considered the gold standard for measuring sleep, it is burdensome and not easily amenable for use with children who have difficulties sleeping in unfamiliar surroundings. Actigraphy-based sleep offers opportunities to obtain objective measures of sleep in children's typical environment. Actigraphy has been validated for objective measures of sleep in clinical- and population-based studies.[8, 9]

Sleep disturbances have been related to sociodemographic, environmental, and behavioral factors.[10-13] Children's sleep disturbances have been connected with their home environment that may be influenced by caregivers' characteristics.[13, 14] Our recent qualitative study showed that while Chilean caregivers and rehabilitation providers recognized the importance of sleep health, they differed in their understanding of how sleep practices influence children's sleep health.[13] Parental ability to provide support for healthy behaviors including sleep may be influenced by parental education, a known factor associated with child health measures.[12, 15-17] Magana et al

reported that maternal education and knowledge about autism accounted for differences in the number of specialty services received by Latino children with autism spectrum disorder (ASD) as compared with White children in the US.[15] However, to our knowledge, little research has been conducted regarding the role of caregivers' education in objectively measured sleep among children with disabilities, particularly among Patagonian Chilean children, an understudied population with documented high burden of obesity and related chronic disorders.[18]

This cross-sectional study was designed to use wrist-actigraphy as a means for collecting objective measures of sleep patterns among children with disabilities. We also sought to characterize actigraphy-measured sleep patterns and to examine whether caregivers' education level is associated with sleep disturbances among children with disabilities. Specifically, we sought to estimate the prevalence of actigraphy-measured sleep disturbances including long sleep latency, long wake after sleep onset (WASO), short sleep duration, and poor sleep quality (low sleep efficiency) among Chilean children with disabilities. Further, following up on results from a previous qualitative study,[13] we sought to determine the extent to which, if at all, caregivers' low levels of educational attainment are associated with children's sleep disturbances and overall poor sleep quality.

METHODS

Participants

The Chile Pediatric and Adult Sleep and Stress Study (CPASS) was a cross-sectional study that was established in September 2012 at the Centro de Rehabilitacion Club de Leones Cruz del Sur in Punta Arenas, Chile.[13] The CPASS was designed to use wrist-actigraphy to characterize sleep patterns of children with disabilities. Particular attention was paid to establishing the protocols for data collection, assessing protocol adherence among children with a wide range of developmental disabilities, and using collected data to preliminary assess study hypotheses.

The first wave of the CPASS (CPASS I) was conducted between September and December in 2012 among children aged 6-12 years who were receiving routine clinical care for disabilities at the center and their primary caregivers. Children with disabilities in this study were those who had impairments, activity limitations, and participation restrictions due to health conditions such as autism, Down syndrome, and cerebral palsy, according to the World Health Organization, the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY).[19] All children were diagnosed by a clinical care team composed of a pediatric neurologist, a pediatrician with extensive experience in developmental disabilities, and a rehabilitation medicine specialist using diagnostic criteria and/or standardized tests with the input of families and teachers. Primary caregivers were parents, grandparents, relatives, or other adults and were principally responsible for children's well-being and did not have developmental or intellectual disabilities. Research staff talked with caregivers to determine if they could complete the interviewer-administered questionnaire survey. In addition, a physician helped confirm that caregivers had no developmental or intellectual disabilities. Of 153 children whose families were contacted via telephone by research staff, 110 adult caregivers (71.9%) consented to participate in this study. A total of 110 children and caregivers (one caregiver per child) were recruited in the CPASS I. Five children were excluded from this study due to fewer than 3 days of actigraphy data: four children removed monitors after day one or day two of the study; one child lost the monitor on day two. These children had no sleep log data. A total of 105 child-caregiver dyads (95.5% of enrolled families) completed the CPASS I study protocol.

The second wave of the CPASS (CPASS II) was conducted among children with disabilities aged 10-21 years and their primary caregivers between April and July in 2013 at the center.[20, 21] Research personnel invited 129 caregivers of children with disabilities to participate. A total of 90 caregivers (69.8%) agreed to participate in the study. Twenty children were aged 10-12 years from the CPASS II. As these two studies (CPASS I and CPASS II) were conducted between September 2012 and July 2013 at the same rehabilitation center in Chile, with the same staff and with identical study protocols used for assessing sleep traits, we combined the results from the two studies in order to have a larger sample size with increased statistical power in the present analysis. In total, 125 children aged 6-12 years were included in the current study. The final sample size of this study was determined on the basis of available resources (e.g., ActiSleep monitors) and not based on formal *a priori* sample size and statistical power determinations.

Written informed consents were obtained from primary caregivers of children with disabilities. This study was approved by the institutional review boards of the Centro de Rehabilitacion Club de Leones Cruz del Sur and Harvard T.H. Chan School of Public Health Office of Human Research Administration.

Study Procedures

A psychologist administered structured questionnaires to caregivers to collect information on sociodemographic and lifestyle factors of both children and caregivers. Research staff instructed children to wear ActiSleep monitors (ActiLife, ActiGraph R&D, Florida, USA)[22] on their non-dominant wrists for seven consecutive days. Although the monitors are waterproof, children were instructed to remove them from their wrists before taking showers and/or before swimming. Caregivers were also instructed to keep sleep logs of time in bed and time out of bed for their children. Electronic medical records were reviewed by a physician in order to extract children's diagnoses defined by the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10).[23]

Sleep Parameters

Actigraphic sleep data were collected using the ActiSleep monitors and were analyzed using the ActiLife 6 data analysis software.[22] When worn during sleep episodes, the ActiSleep monitor can provide estimates of sleep onset, sleep latency, WASO, number and length of awakenings, sleep duration, and sleep efficiency. Sleep latency is the length of time taken to fall asleep, calculated as the time between "lights off" to the first period of 3 minutes of consecutive epochs scored as sleep. WASO is the number of minutes awake between sleep onset and time of final waking. Sleep efficiency is defined as the proportion of the estimated sleep periods spent asleep. Actigraphy data were collected in 1-min epochs using the zero-crossing modes, and the "Sadeh" sleep algorithm was used for children.[24] The majority of children (n=122, 97.6 %) had complete 7-day actigraphic sleep data; two children had 6-day actigraphic data and one child had 3-day data available for study. The averages of sleep parameters were calculated for children who had 3, 6, or 7 days of actigraphic data. There were no missing sleep log data for children included in this study. Caregivers were asked to record their children's sleep logs each morning up awakening and to make sure the sleep logs were complete. Research staff checked children's sleep logs when caregivers returned with ActiSleep monitors. Information from sleep logs were not used to substitute missing actigraphy data.

Sociodemographic Characteristics and Children's Disabilities

Interviewer-administered questionnaires were used to collect information on children's age, sex, daytime napping, medication use, caregiver-child relationship (e.g., mother), caregivers' age, employment status, and education level. Caregivers were asked to report the highest degree of education they had completed: less than 12th grade (<high school education), high school graduate or equivalent (high school education), some college degree, or college graduate or above (>high school education). According to the ICD-10,[23] children's disabilities were grouped as: 1) mental and behavioral disorders (e.g., ADHD, autism); 2) diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); 3) diseases of the nervous system (e.g., cerebral palsy); and 4) congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Statistical Analysis

Kolmogorov-Smirnov test was used to assess the normality of sleep parameters. Variables were described using means and standard deviations (SDs) for parametric variables and medians and interquartile ranges (IQRs) for nonparametric variables. Number of nocturnal awakenings and sleep efficiency were normally distributed, whereas sleep onset, sleep latency, WASO, awakening length, and sleep duration were not normally distributed. Student's t-test was used for age, number of awakenings, and sleep efficiency as parametric variables by child sex; Wilcoxon rank-sum test was used to test differences in nonparametric variables including sleep onset, sleep latency, WASO, awakening length, and sleep duration by child sex. Fisher's or χ^2 test was conducted to compare differences in sociodemographic factors, daytime napping, medication use, and disability groups by child sex. Analysis of variance or Kruskal-Wallis test was conducted to evaluate the differences in sleep parameters across children's disability groups and caregivers' education levels.

A general linear model was fitted to generate least-square means and standard errors (SEs) of sleep efficiency across caregivers' education levels with adjustment for children's age, sex, disability, caregiver-child relationship, and caregivers' age. Univariate and multivariable linear regression analyses were performed to examine the associations of caregivers' education levels with sleep efficiency and the number of awakenings. Stratified analysis was conducted to evaluate whether the associations between caregivers' education levels and children's sleep disturbances differed according to children's disability groups. Given that we aimed to examine whether children whose caregivers had lower education level were more likely to have sleep disturbances (e.g., long sleep latency, long WASO) and to enhance interpretability, we created categorical variables for these sleep parameters and used in logistic regression models. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models to evaluate the associations of caregivers' educational attainment with children's long sleep latency (≥30 vs. <30 minutes), long WASO (≥90 vs. <90 minutes), and short sleep duration (<8 vs. ≥8 hours). These cut points were chosen based on the literature of sleep latency[25] and sleep duration,[26] as well as sleep data distributions in the study (WASO median=88 minutes, sleep duration median=8 hours; only 9.6% of children had sleep ≥9 hours). We also included a variable to represent study wave (I and II) in multivariable regression models and found similar results (data not shown). We conducted sensitivity analysis by including medication use and daytime napping in the models and did not find that they had an impact on our results in this study (data not shown). Statistical significance levels were set at P <0.05 for two-sided analyses. P values were not corrected for multiple testing. All tests were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

The mean age of children with disabilities was 9.2 (SD=2.2; range=6-12) years. Most caregivers were mothers (88.0%); 21.6% of caregivers reported having <high school education level (**Table 1)**. There were no statistically significant differences in medication use, daytime napping, caregiver-child relationship, caregivers' age, employment status, or education level between boys and girls.

Median time for sleep onset was 22:39, sleep latency 27.3 minutes, WASO 88.1 minutes, and sleep duration 8.0 hours (**Table 1**). The mean number of awakenings was 22.1 and sleep efficiency was 80.0%. There were no statistically significant differences in sleep parameters between boys and girls (all P >0.05). Overall, 43.2% of children had sleep latency ≥30 minutes, 51.2% had short sleep <8 hours, and 77.6% had low sleep efficiency <85%.

There were no significant differences in sleep parameters across disability groups (**Supplementary Figure 1**), except for the number of nocturnal awakenings (**Supplementary Table 1**). Children with diseases of musculoskeletal system and connective tissue, skin and subcutaneous tissue appeared to have more awakenings, reflecting more fragmented sleep, than children with other disabilities.

Children whose caregivers had <high school had longer sleep latency, longer WASO, longer awakening length, and lower sleep efficiency compared to children whose caregivers had >high school (**Figure 1; Table 2**). Although children of caregivers with <high school tended to have

later sleep onset, higher number of awakenings, and shorter sleep duration when compared to children of caregivers with higher education, these differences did not reach statistical significance.

Our general linear model with adjustment for child age, sex, disability group, caregiver-child relationship, and caregiver age showed that the mean sleep efficiency was the lowest among children of caregivers with <high school (75.7% [SE=1.4]), followed by children of caregivers with high school (80.4% [SE=1.0]) and >high school (81.9% [SE=1.0]). Univariate and multivariable linear regression analyses showed no significant associations between caregivers' education levels and children's awakening number. However, compared to children whose caregivers had >high school, children of caregivers with <high school had significantly lower sleep efficiency (adjusted beta=-6.3, SE=1.7; P=0.001) (**Table 3**). Caregivers' educational attainment was positively and significantly associated with children's sleep efficiency in the univariate model (P_{trend}=0.001) and the multivariable model (P_{trend}<0.001).

As shown in **Table 4** based on logistic regression models**,** compared to children whose caregivers had >high school, children of caregivers with <high school had higher odds of longer sleep latency ≥30 minutes (adjusted OR=3.27; 95% CI=1.12-9.61) and longer WASO ≥90 minutes (OR=5.95; 95% CI=1.91-18.53). Caregivers' education levels were inversely and significantly associated with children's sleep latency and WASO (both P_{trend}<0.05). Children's short sleep duration (<8 hours) was not associated with caregivers' low educational level (OR=0.78; 95% CI=0.28-2.18).

The associations between caregivers' education and children's sleep efficiency varied little according to disability groups (data not shown in tables). For example, among children with mental and behavioral disorders, children of caregivers with <high school had lower sleep efficiency (beta=-6.2, SE=2.2; P=0.006), after adjustment for children's age, sex, caregiver-child relationship, and caregivers' age. Similar results were found for children with other disabilities.

DISCUSSION

In this cross-sectional study, we assessed sleep patterns using wrist actigraphy over seven consecutive days among Chilean children with disabilities. We found that actigraphy-measured sleep disturbances including long sleep latency (median=27 minutes), long WASO (median=88 minutes), short sleep duration (median=8 hours), high number of nocturnal awakenings (mean=22), and low sleep efficiency (mean=80%) were common among children. These findings indicate that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency) and maintaining sleep (long WASO, low sleep efficiency), and have increased sleep fragmentation (increased nocturnal awakenings). These indices are common in insomnia, which may occur secondary to chronic health conditions, and for many conditions, is associated with poor quality of life and increased disease-specific health burden including behavioral and cognitive problems.[27, 28] We also found strong associations between caregivers' low educational attainment and children's sleep disturbances (e.g., low sleep efficiency) independent of children's disability type and other covariates from both children and caregivers. To our knowledge, this is the first study to specifically quantify actigraphy-measured sleep patterns among children with disabilities in relation to caregivers' education levels. Furthermore, we address these questions among Patagonian Chilean children with disabilities, an understudied population in South America.

Children with a wide range of disabilities have been reported to have sleep disturbances, including prolonged sleep latency, increased WASO, short sleep duration, and decreased sleep efficiency in Europe and other developed countries including Canada and New Zealand.[4-6, 29, 30] For example, in a small study of 8 UK children with mucopolysaccharidosis aged 2-15 years, median actigraphy-measured sleep latency was 35.4 minutes, WASO 83.4 minutes, and sleep efficiency was 75.6%.[30] Allik et al reported that children aged 8-12 years with Asperger syndrome and high-functioning autism in Sweden had actigraphy-measured longer sleep latency (mean=32 minutes) and lower sleep efficiency (mean=87%) than controls.[6] In a study of children aged 5-11 years with ADHD in Denmark, average sleep latency was 26 minutes and 31% of children had sleep latency >30 minutes.[5] A case-control study using 5 nights of actigraphy for 15 school-aged children with traumatic brain injury and 15 school-aged siblings in the UK reported that brain injury was significantly associated with children's longer sleep latency (mean=50 minutes), longer WASO (mean=65 minutes), and lower sleep efficiency (mean=80%).[29] To our knowledge, no research has been conducted on objectively measured sleep parameters in South

America (e.g., Chile) among children with disabilities, an understudied sample. In our study of Chilean children with autism and other disabilities, the median of actigraphy-measured sleep latency was 27 minutes, WASO was 88 minutes, and the mean of sleep efficiency was 80%, which were similar to previous research findings.[5, 29, 30] We also found that a high proportion of Chilean children with disabilities experienced actigraphy-measured sleep disturbances: 43% of children had sleep latency ≥30 minutes, 51% had short sleep <8 hours (90% of children had sleep duration <9 hours), and 78% had sleep efficiency <85%. Although school-aged children are recommended to have at least 9 hours of sleep,[26, 31] in our study, only 10% of Chilean children with disabilities had sleep duration ≥9 hours. Gibbs et al reported that among 8 children aged 4-15 years with Prader-Willi syndrome in New Zealand, median 7-night actigraphy-measured WASO was 95 minutes.[32] Corkum et al reported the average of awakenings was 15 among Canadian children with ADHD (aged 7-11 years).[4] In our current study, the average number of nocturnal awakenings was 22 among Chilean children with ADHD and other disabilities. Our study along with previous research suggests that children with disabilities have difficulties initiating and maintaining good sleep.

Several researchers have reported that children with disabilities have late sleep onset.[33, 34] A study of US children aged 2-5 years with autism and other developmental disabilities reported that the mean of 7-day actigraphy-measured sleep onset time was 21:32.[33] In this study, we found that median sleep onset time was 22:39 among Chilean children with autism and other disabilities. Unique climate (e.g., late sunset) and lifestyle characteristics (e.g., late mealtime) in the Patagonia region may have partly contributed to children's late sleep onset time.[13,18] Our findings of late sleep onset are generally consistent with literature for children in this age range. For example, a cross-sectional study of 96 healthy Chilean children aged 10 years found that the mean of overnight polysomnography-measured sleep onset time was 23:10 for children with normal weight and 23:20 for children with overweight and obesity.[35] Another study of 58 healthy children aged 11-13 years in the US showed that the mean of 4-day actigraphy-measured sleep onset time was 23:27.[36] In the Cleveland Children's Sleep and Health Study, 14.8% of US children aged 8-11 years had bedtime 23:00 or later.[14] Future research is warranted to examine potential risk factors of late bedtime such as daytime napping and how to improve sleep onset time among children with disabilities.

It has been reported that children whose caregivers have low education levels are more likely to have adverse health outcomes, such as great body weight[16] and poor quality of life.[17] McDonald et al found that lower maternal education was independently associated with parent-reported shorter sleep (<11 hours/night) among young children.[12] Although several studies have reported that parental education is associated with child health,[12, 15] we are unaware of published reports that have investigated whether and how caregivers' education levels are related to objectively measured sleep problems among children with disabilities. In our study, caregivers' education level in relation to children's sleep disturbances was substantiated through statistically significant association as shown in univariate and multivariable linear and logistic regression models. Our study suggests the importance of tailoring sleep education for caregivers with lower educational attainment to improve children's sleep health. We considered low educational attainment a proxy for low socioeconomic status (SES). It has been reported that educational levels and SES are highly correlated.[37] Low SES, as well as low education, has been related to high risk for cardiovascular disease, cancer, and mortality.[38] Parental SES has been inversely associated with negative child health outcomes including cardiovascular disease and mortality.[39, 40] Some of the burden from low parental education level may be attributable to relatively lower health literacy, particularly sleep health literacy, which is pertinent to our observations in the focus group study[13] and also in this epidemiologic study.

Parents with low education levels may lack knowledge and resources about children's sleep practices and disabilities, resulting in adverse parenting practices known to affect sleep hygiene such as less limit setting, more variability in routines important to establish regular sleep patterns, suboptimal configuration of bedrooms to optimize sleep, inappropriate use of electronic devices, and meal timing in relationship to sleep. Better-educated parents may have more access to information about sleep and disabilities possibly through the internet or group membership with other parents of children diagnosed with disabilities. Future research should consider the impact of providing education and support such as sleep hygiene education, as well as initiatives to provide social support for parents and families of children with disabilities. Although our data suggest that these efforts may especially benefit less well-educated parents, all parents may have difficulties in navigating all of the controversies and different claims on the internet and may benefit from improved education and support. Our findings of the associations documented in our study population, if replicated, could help motivate the development and implementation of training programs to increase the parental health literacy (especially sleep health literacy). Parents of children with disabilities could benefit from sleep education workshops. Social support from families of children with disabilities as well as health care providers including occupational and physiotherapists and nurses could also be important in helping parents handle with their children's sleep problems.

Lack of knowledge of healthy sleep behaviors among caregivers has been associated with an increased risk of having unhealthy sleep behaviors for their children.[41] Although sleep disturbances have been noted to be common in children with neurological conditions (e.g., cerebral palsy), there are no interventions specifically designed to improve sleep in these children.[42] Several small studies of children with ASD have reported that parent-based sleep education appears effective in improving child sleep health.[34, 43] For example, a study of 20 children with ASD showed that parent-based sleep education workshops improved sleep latency from 62.2 minutes to 45.6 minutes.[43] Malow et al reported that sleep education to parents of 80 children with ASD (aged 2-10 years) significantly decreased children's sleep latency from 58.2 to 39.6 minutes.[34] Our prior qualitative study in Chile has indicated that parental knowledge gaps regarding healthy sleep behaviors in children support the need for increased sleep health education among targeted caregivers.[13] Pediatricians and family physicians can be trained to provide adequate advice and educational messages (e.g., sleep health) to pediatric patients and their families.[44]

Our study has several limitations. First, we did not have a comparison group of children without disabilities. Second, this study was limited by its modest sample size and the heterogeneity of disabilities represented among children studied. As such, the confidence intervals were wider for some groups (e.g., the less than high school education group) and we were not able to report associations specific to any single disability category (e.g., autism). Third, we did not collect information pertaining to some aspects of sleep which may be associated with low education levels such as caregivers' shift work, sleep hygiene, and other factors such as co-sleeping, lack of knowledge about sleep health, or inability to obtain medications to treat sleep or conditions in this study. Hence we were not able to quantify the influence of these factors on children's sleep patterns. Our findings also focused on caregivers (majority were mothers) of children with disabilities in Chile, and may not be generalizable to other populations/groups. Although accepted to provide an objective measure of sleep-wake cycle, actigraphy has its limitations. For example, periods of quiet wakefulness may be interpreted by the device as sleep, and periods of restless sleep may be interpreted by the device as wakefulness.[8, 45] Recent literature has indicated limitations of actigraphy for accurately capturing children's awakenings.[46] Our study has indicated that children with diseases of the musculoskeletal system and connective, skin, and subcutaneous tissue have more awakenings because their restless sleep may be represented by actigraphy as awakenings, and/or due to medication use or body pain. Despite this, actigraphy has been well validated for objective estimation of nocturnal sleep parameters across age groups in the natural sleep environment.[9] As this was an exploratory study that aimed to examine whether parental education was associated with children's sleep disturbances, we did not adjust for multiple comparisons in this study. In addition, the simple adjustments for multiple comparisons might be overly conservative because many sleep problems (e.g., long WASO, low sleep efficiency) were correlated.

CONCLUSIONS

We were successful in using wrist-actigraphy as a means of collecting objective measures of sleep patterns among Chilean Patagonian children with disabilities (e.g., 97.6% of children completed the 7-day data collection protocol). Using collected data, we noted that children with disabilities frequently experience difficulties initiating sleep (prolonged sleep latency), maintaining sleep (long WASO, low sleep efficiency), and sleep fragmentation (increased nocturnal awakenings). Among children with disabilities, lower levels of caregivers' educational attainment are strongly associated with children's sleep disturbances and these associations appear to be independent of children's age, sex, disability group, caregiver-child relationship, and caregiver age. Parental support and education programs directed to families with low education levels may be of particular importance for sleep behavior intervention among children with disabilities. Larger studies, using wrist-actigraphy methods to objectively measure sleep in this relatively understudied population, are warranted to confirm our findings. Future research is also needed regarding the effects of sleep education intervention as well as social support to low educational families of children with disabilities on sleep health, with taking into account of different cultural backgrounds.

Contributors' Statement

All of the authors have agreed to the content of this manuscript. XC conceptualized and designed the study, supervised data collection, carried the initial analyses, and drafted the initial manuscript. JCV and CB carried out the field survey, supervised data collection, and critically reviewed and revised the manuscript. MP carried out the field survey, coordinated data collection at the study site, and reviewed the manuscript. BG helped develop the study protocol, and critically reviewed and revised the manuscript. SR critically reviewed and revised the manuscript. MAW provided funding support to the study, supervised the study, conceptualized and designed the study, and critically reviewed and revised the manuscript.

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Figure Legends

Figure 1 Children's Sleep Parameters, by Caregiver Education Levels (HS: high school)

Table 1 Characteristics of Children with Disabilities and Their Primary Caregivers

	Total (n=125)	Boys (n=69)	Girls (n=56)	P valu
l characteristics				
mean (SD), years	9.2 (2.2)	8.8 (2.1)	9.8 (2.3)	0.01
of disability diagnosis, %				
ntal and behavioral disorders	48.0	59.4	33.9	0.00
eases of musculoskeletal system	16.8	10.1	25.0	
eases of the nervous system	27.2	27.5	26.8	
genital/chromosomal abnormalities	8.0	2.9	14.3	
me napping	16.8	14.5	19.6	0.44
cation use	44.0	42.0	46.4	0.62
parameters				
ep onset, median (IQR)	22:39 (22:06, 23:08)	22:44 (22:24, 23:08)	22:33 (21:54, 23:09)	0.18
ep latency, median (IQR), minutes	27.3 (15.0, 38.9)	27.1 (14.4, 41.7)	27.4 (15.4, 38.2)	0.51
ASO, median (IQR), minutes	88.1 (65.6, 111.1)	92.4 (64.4, 112.4)	81.9 (66.2, 107.0)	0.41

mber of awakenings, mean (SD)[a]	22.1 (6.7)	22.5 (6.5)	21.6 (6.9)	0.44
akening length, median (IQR), minutes	5.1 (4.2, 7.1)	5.1 (4.2, 7.0)	5.1 (4.2, 7.1)	0.92
ep duration, median (IQR), hours	8.0 (7.5, 8.2)	8.0 (7.3, 8.2)	8.0 (7.5, 8.3)	0.45
ep efficiency, mean (SD), %[a]	80.0 (7.2)	79.0 (8.1)	81.2 (5.8)	0.07
giver characteristics				
mean (SD), years	38.3 (7.8)	38.5 (7.8)	38.0 (7.8)	0.69
giver-child relationship, %				
ther	88.0	88.4	87.5	0.87
er	12.0	11.6	12.5	
oyed/self-employed	60.0	62.3	57.1	0.55
ation level, %				
gh school	21.6	24.6	17.9	0.08
h school	37.6	29.0	48.2	
gh school	40.8	46.4	33.9	

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a] Of these sleep parameters, only number of awakenings and sleep efficiency were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$). While Student's t-test was used for number of awakenings and sleep efficiency, Wilcoxon rank-sum test was used for the other sleep parameters.

Table 2 Children's Sleep Parameters, By Caregivers' Education Levels

parameters	<High school (n=27)	High school (n=47)	>High school (n=51)	P value
onset, median (IQR)	23:05 (22:17, 23:23)	22:31 (21:55, 23:04)	22:39 (22:24, 23:02)	0.098
latency, median (IQR), minutes	35.6 (17.3, 53.7)	27.1 (17.4, 38.4)	23.6 (11.1, 35.9)	0.031
O, median (IQR), minutes	99.1 (88.1, 121.0)	77.1 (63.4, 103.4)	77.0 (57.6, 106.0)	0.006
ber of awakenings, mean (SD)[a]	23.1 (5.7)	21.2 (6.3)	22.4 (7.5)	0.470
kening length, median (IQR), minutes	6.9 (5.0, 9.5)	5.2 (4.2, 7.2)	4.7 (3.9, 5.7)	0.001
duration, median (IQR), hours	7.9 (7.3, 8.4)	8.0 (7.6, 8.2)	8.0 (7.4, 8.2)	0.852
efficiency, mean (SD), %[a]	75.9 (7.0)	80.5 (7.3)	81.8 (6.5)	0.002

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.

[a]Sleep efficiency and number of awakenings were normally distributed in this study.

Table 3 Linear Regression Models for Associations between Caregiver Education and Child Sleep Parameters

	Number of awakenings		Sleep efficiency (%)	
	Beta (SE)	P value	Beta (SE)	P value
Univariate model				
Caregiver education (ref: >high school)				
High school	-1.2 (1.3)	0.384	-1.3 (1.4)	0.357
<High school	0.7 (1.6)	0.662	-5.9 (1.7)	<0.001
P value for trend test		*0.838*		*0.001*
Multivariable model[a]				
Caregiver education (ref: >high school)				
High school	-0.6 (1.4)	0.674	-1.6 (1.4)	0.269
<High school	1.9 (1.7)	0.245	-6.3 (1.7)	0.001
P value for trend test		*0.364*		*<0.001*

Abbreviation: SE, standard error.

[a] Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

Table 4 Logistic Regression Models for Associations between Caregiver Education and Child Sleep Disturbances

	Sleep latency ≥30 vs. <30 minutes		WASO ≥90 vs. <90 minutes		Sleep duration <8 vs. ≥8 hours	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P va
riate model						
iver education (ref: >high school)						
gh school	0.95 (0.42, 2.17)	0.911	1.36 (0.61, 3.04)	0.449	0.72 (0.33, 1.60)	0.4
ligh school	3.37 (1.26, 8.98)	0.015	4.43 (1.58, 12.38)	0.005	0.89 (0.35, 2.25)	0.7
P value for trend test		*0.029*		*0.006*		*0.6*
variable model						
iver education (ref: >high school)[a]						
gh school	1.02 (0.42, 2.45)	0.966	1.38 (0.58, 3.30)	0.468	0.70 (0.30, 1.64)	0.4
ligh school	3.27 (1.12, 9.61)	0.031	5.95 (1.91, 18.53)	0.002	0.78 (0.28, 2.18)	0.6
P value for trend test		*0.056*		*0.004*		*0.5*

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio; WASO, wake after sleep onset.

[a]Adjusted for child age, sex, disability, caregiver-child relationship, and caregiver age.

Figure 1 Children's Sleep Parameters, by Caregiver Education Levels (HS: high school)

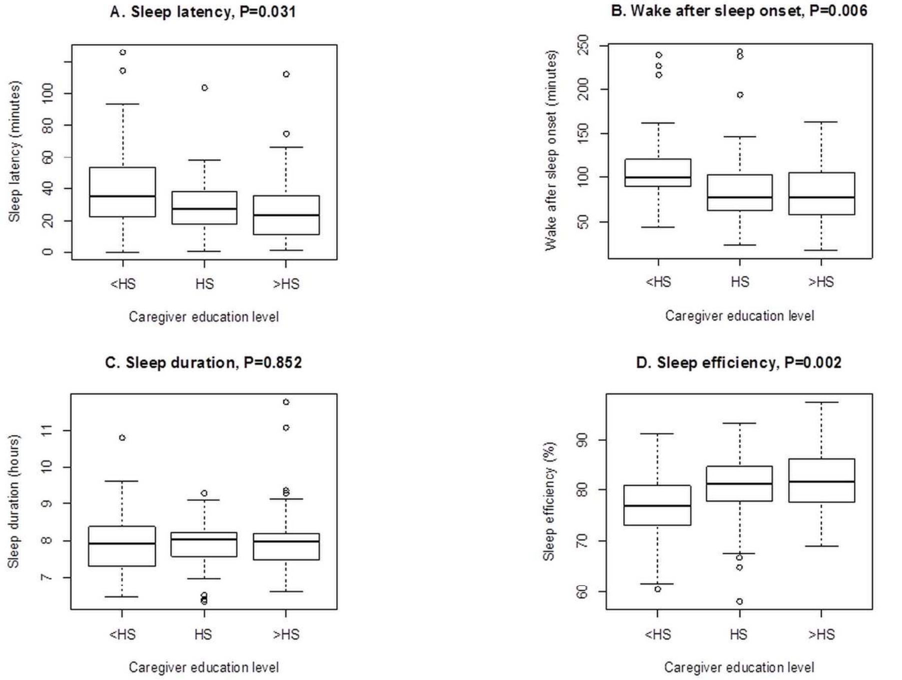


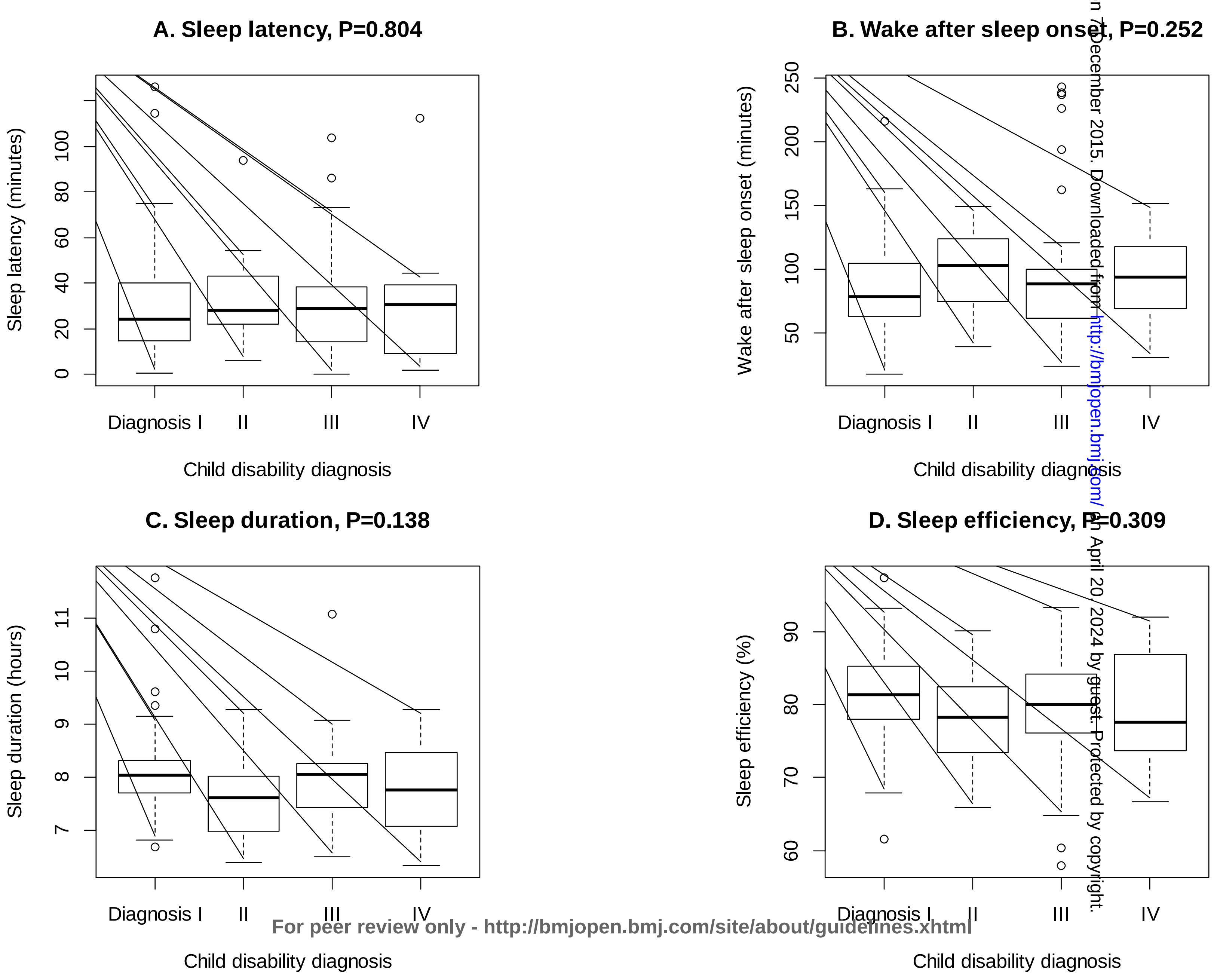
Figure in TIFF format
190x142mm (300 x 300 DPI)

Supplementary Table 1 Children's Sleep Parameters, By Types of Disability Diagnoses

Sleep parameters	Diagnosis I (n=60)	Diagnosis II (n=21)	Diagnosis III (n=34)	Diagnosis IV (n=10)	P value
Sleep onset, median (IQR)	22:35 (22:04, 23:03)	23:05 (22:25, 23:22)	22:37 (22:19, 23:05)	22:35 (21:45, 23:03)	0.187
Sleep latency, median (IQR), minutes	24.1 (14.7, 40.1)	28.1 (22.1, 43.0)	28.8 (14.1, 38.4)	30.5 (9.1, 39.4)	0.804
WASO, median (IQR), minutes	78.4 (63.5, 104.9)	103.3 (75.0, 123.7)	89.1 (61.7, 100.0)	94.0 (69.9, 117.9)	0.252
Number of awakenings, mean (SD)[a]	22.4 (6.6)	25.1 (5.1)	19.3 (6.5)	23.6 (7.6)	0.011
Sleep duration, median (IQR), hours	8.0 (7.7, 8.3)	7.6 (7.0, 8.0)	8.0 (7.4, 8.3)	7.8 (7.1, 8.5)	0.138
Sleep efficiency, mean (SD), %[a]	81.2 (6.5)	78.2 (6.2)	79.5 (8.6)	78.3 (8.2)	0.309

Abbreviations: IQR, interquartile range; SD, standard deviation; WASO, wake after sleep onset.
Only sleep efficiency (%) and number of awakenings were normally distributed (Kolmogorov-Smirnov test: $P > 0.05$).
[a]Analysis of variance was used for sleep efficiency and number of awakenings (normally distributed), while Kruskal-Wallis test was used for other sleep parameters.
Diagnosis I: mental and behavioral disorders (e.g., autism, ADHD, mental retardation); Diagnosis II: diseases of the musculoskeletal system and connective tissue, skin and subcutaneous tissue (e.g., scoliosis); Diagnosis III: diseases of the nervous system (e.g., cerebral palsy); Diagnosis IV: congenital malformations, deformations and chromosomal abnormalities (e.g., Down syndrome).

Supplementary Figure 1 Children's Sleep Parameters, by Disability Diagnoses



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).
Bias	9	
Study size	10	This is a cross-sectional, pilot study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
Results		
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Outcome data	15	
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study.