Received: 15 May 2019 | Revised: 8 January 2020 | Accepted: 11 January 2020

DOI: 10.1002/mgg3.1153

ORIGINAL ARTICLE

Molecular Genetics & Genomic Medicine Open Access WILEY

Sleep patterns and problems among children with 22q11 deletion syndrome

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Abstract

Background: To delineate sleep habits and problems in children with 22q11.2 deletion syndrome (22q11DS).

Methods: Thirty children, age 1–15 (mean 6.8) years, participated in the study, which was an internet-based anonymous survey of parents of children with 22q11DS administered via the 22q11.2 Foundation. The main outcome was the Childhood Sleep Habits Questionnaire (CSHQ).

Results: Scores on the CSHQ demonstrated clinically significant sleep problems in 29 of the 30 children. When compared with previously reported normative values for typically developing children of the same age, children with 22q11DS had significantly greater sleep problems. Only 30% of children had previously undergone sleep study. While about half of children had tried a medication for sleep, it usually was not felt to be helpful. In contrast, parents reported that behavioral interventions, such as consistent bedtime routine and appropriate sleep environment, were helpful. This is one of the first studies to specifically address sleep problems other than obstructive sleep apnea in children with 22q11DS.

Conclusions: The findings suggest children with 22q11DS may have a higher risk of experiencing clinical sleep problems, compared to typically developing children. Consideration of additional screening and treatment of sleep disorders in children with 22q11DS is warranted.

KEYWORDS

22q deletion syndrome, behavioral insomnia, childhood sleep habits questionnaire, pediatrics, sleep disorders

1 | INTRODUCTION

22q11.2 deletion syndrome (2q11DS; OMIM 188400) is the most common chromosomal microdeletion syndrome. Historically, individuals with DiGeorge syndrome, velocardiofacial syndrome, and conotruncal anomaly face syndrome were thought to represent unique genetic disorders; however, with the evolution of cytogenetic and molecular genetic

Oral Presentation: These results were presented as a podium presentation at the 74th American Cleft Palate-Craniofacial Association meeting in Colorado Springs, CO (March 2017) and at the 11th Biennial International 22q11.2 Conference in Whistler, British Columbia, Canada (July 2018)

testing, it is known that a majority of persons with these disorders have a hemizygous microdeletion on the long arm of chromosome 22. Additionally, 22q11DS is also known to be the underlying cause of a portion of individuals clinically diagnosed with Opitz G/BBB syndrome and Cayler cardiofacial syndrome. Due to this variable clinical presentation, the often quoted prevalence of 1 in 4,000, is most likely an underestimate. This variable clinical presentation most often includes congenital heart defects, palate anomalies, characteristic facial features, developmental delays (DD) and/or intellectual disabilities (ID) and immune deficiency. Additional clinical findings may include endocrine dysfunction, gastrointestinal anomalies, renal anomalies, hearing loss, skeletal abnormalities, and ophthalmologic abnormalities. Practical guidelines were published in 2011 to aid providers with medical management of these complexities (Bassett et al., 2011).

Despite extensive research into the more common clinical presentations associated with 22q11DS, little is known about the specific sleep characteristics in this unique population. Previous studies have documented an increased risk of obstructive sleep apnea (OSA) in this population (Crockett, Goudy, Chinnadurai, & Wootten, 2014; Heike et al., 2007; Kennedy et al., 2014; Silvestre, Tahiri, Paliga, & Taylor, 2014). Beyond OSA, one prior study reported a greater prevalence of sleep problems in females with 22q11DS compared to males (Briegel, Schneider, & Schwab, 2007), and there is a case report of continuous spikes and waves during sleep (Valvo et al., 2012). Otherwise, to the best of our knowledge, there are no systematic studies of specific clinical sleep problems in children with 22q11DS. Therefore, the purpose of the present investigation was to evaluate sleep habits and problems in children with 22q11DS.

2 | METHODS

2.1 | Editorial policies and ethical compliance

The study was reviewed and approved by the Institutional Review Board (ethics board) at Children's Mercy Hospital. It complied with all recognized standards. Informed consent was obtained from all participants prior to their inclusion in the study.

2.2 | Participants

Participants were recruited by distributing a survey invitation via the 22q11.2 Foundation, Inc. (22q.org and associated organization Facebook group). In addition, the invitation encouraged others, such as professionals serving families of children with 22q11DS, to inform parents of the survey. The survey was web based, anonymous with no identifiers collected, and responses were recorded and stored on a secure server in a Research Electronic Data Capture (REDCap) database. Inclusion criteria included: the respondent was a parent over the age of 18, the parent has a child with 22q11DS between the ages of 1 and 18 years old, and the parent has access to the Internet. There were no exclusion criteria other than age. There were no direct benefits offered to parents or children for participation.

2.3 | Measures

Basic demographic information was elicited, including: age, gender, country of residence, and which parent completed the survey. Parents were asked if their child had any of the following comorbidities or characteristics: congenital heart disease, cleft palate (repaired or not), kidney disease, developmental delay, immunodeficiency, seasonal allergies, eczema, seizure disorder requiring daily medications, and/or reflux. Parents were asked if their child had ever had an overnight sleep study, been diagnosed with sleep apnea, had surgery to remove tonsils, or used a CPAP machine. Finally, two open-ended questions asked about challenges and helpful interventions for their child's sleep.

Sleep characteristics were measured via the Children's Sleep Habits Questionnaire (CSHQ). The CSHQ is a comprehensive, parent-reported 33-item questionnaire that measures sleep habits in eight sleep domains: Bedtime Resistance, Sleep Onset Delay, Sleep Duration, Sleep Anxiety, Night Wakings, Parasomnias, Sleep-Disordered Breathing, and Daytime Sleepiness (Owens, Spirito, & McGuinn, 2000). The CSHQ has been demonstrated to have adequate internal consistency, test–retest reliability, and validity across community and clinical samples (Owens et al., 2000). Each question within subdomains asks about the frequency of a specific sleep habit over the course of a week; some items require reverse scoring, and all are summed to obtain total subdomain scores. A total CSHQ score is also calculated, with higher scores indicating more sleep problems and a cutoff of 41 considered indicative of clinical sleep problems (Owens et al., 2000). This instrument has previously been utilized in studies examining sleep characteristics of children with neurodevelopmental disorders, such as autism spectrum disorders (Malow et al., 2006; Souders et al., 2009), fetal alcohol syndrome (Chen, Olson, Picciano, Starr, & Owens, 2012), and Down syndrome (Hoffmire, Magyar, Connolly, Fernandez, & Wijngaarden, 2014). The CSHQ has been validated in children aged 4–10 years, but has also been utilized in children down to 1 year of age and into adolescence in previously published studies (Bassell, Phan, Leu, Kronk, & Visootsak, 2015; Goldman, Richdale, Clemons, & Malow, 2012; Goodlin-Jones, Sitnick, Tang, Liu, & Anders, 2008; Liu, Liu, Owens, & Kaplan, 2005).

2.4 | Statistical analysis

Results were summarized with mean and standard deviation for continuous variables and frequencies for categorical variables. Scores on the CSHQ were tabulated for the entire sample as well as those children aged 4–10 years for the purposes of comparison with a previous large national sample of typically developing 4- to 10-year-old children in the United States; published means, standard deviations, and sample size made summary independent samples *t* tests possible (Liu et al., 2005). The assumption of equal variances was tested via Hartley test in each comparison, and the *p*-values reported are based on if the assumption was accepted or rejected. A total CSHQ score of 41 was chosen as a cutoff to indicate clinically significant sleep problems. Possible associations between sample characteristics and CSHQ scores were explored via backwards stepwise logistic regression. Results of open-ended questions were analyzed in a qualitative fashion.

Statistical tests were two-sided with results considered statistically significant at $p < .05$ level. This study was approved by the Institutional Review Board at Children's Mercy Hospital. All data analyses were performed in SPSS (IBM Corp. Released 2014. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.).

3 | RESULTS

Forty-one parents viewed the online survey, with 31 completing it in its entirety. One of the participants was >18 years of age and was excluded, leaving a final sample of 30 participants for analysis. Twenty-seven mothers and three fathers completed the survey regarding their child. Most participants lived in the United States ($n = 23$), but there were also responses from the United Kingdom ($n = 2$), Australia ($n = 1$), Canada ($n = 1$), Ireland ($n = 1$), Netherlands ($n = 1$), and Spain ($n = 1$). The sample was 53% female, and ranged from 1 to 15 years old with a mean age of 6.8 years. Important comorbidities included speech delay ($n = 23$), seasonal allergies ($n = 14$), congenital heart disease ($n = 13$), immunodeficiency ($n = 12$), cleft palate ($n = 5$ unrepaired and $n = 4$ repaired), reflux ($n = 9$), eczema ($n = 6$), epilepsy ($n = 3$), growth hormone deficiency ($n = 1$), and hypothyroidism ($n = 1$).

Nine (30%) participants had undergone sleep study in the past, and only 6 (20%) of the 30 participants had been diagnosed with obstructive sleep apnea. Seven children (23%) had undergone tonsillectomy, and four (13%) used CPAP. Sixteen (53%) children had previously used a medication for sleep; 11 (37%) had tried melatonin and 5 found it helpful, 4 (13%) had tried supplemental iron and 1 found it helpful, 1 (3%) had taken clonidine and did not find it helpful, and no child had previously taken trazodone, gabapentin, or zolpidem.

Overall CSHQ results are presented in Table 1. The mean total CSHQ score was significantly elevated at 57.2, with all but one participant having a score >41. When the 22q group aged 4–10 years was compared to previously published normative data for 4- to 10-year-old children, there were no significant differences in sleep schedule in terms of bedtime, waketime, or sleep duration; in contrast, total CSHQ score as well as all subdomains were significantly worse compared to typically developing children. Within the age category of 4–10 years, all children with 22q11DS in our sample had total CSHQ scores above 41, indicating clinically significant sleep problems.

Potential associations between participant characteristics and sleep problems were explored via backward stepwise

TABLE 1 CSHQ scores of children with 22q compared to previously reported typically developing children. Values are mean (*SD*)

	22q11DS, all ages ($n = 30$)	22q11DS, 4–10 years ($n = 13$)	Typically developing sample, 4–10 years ($n = 357$–415)	*p*-value, 22q11DS 4–10 years versus typically developing 4–10 years
Bedtime, hr	8.5 (0.8)	8.4 (0.6)	8.4 (0.5)	1.000
Waketime, hr	6.6 (1.4)	6.2 (1.6)	6.9 (0.4)	.141
Sleep duration, hr	10.6 (2.1)	10.5 (1.7)	10.1 (0.6)	.414
Bedtime resistance	10.3 (3.6)	10.6 (3.8)	7.0 (1.8)	.005
Sleep onset delay	1.9 (0.9)	1.9 (0.9)	1.2 (0.5)	.016
Sleep duration	5.2 (1.9)	4.6 (1.3)	3.4 (0.9)	.006
Sleep anxiety	7.1 (1.7)	7.3 (1.9)	4.8 (1.4)	<.001
Night waking	5.8 (1.8)	5.8 (2.1)	3.4 (0.8)	.001
Parasomnias	11.2 (3.0)	10.6 (2.2)	8.1 (1.3)	.001
Sleep-disordered breathing	4.4 (1.8)	4.4 (1.9)	3.2 (0.6)	.042
Daytime sleepiness	14.7 (4.2)	14.0 (4.1)	9.7 (2.8)	.003
Total CSHQ	57.2 (9.9)	55.5 (8.5)	38.7 (5.5)	<.001

regression analysis and results are presented in Table 2. Variables were retained in the model based on probability of F-to-remove>/=0.100. Younger age was associated with more bedtime resistance (Beta = −0.460, p = .011), night wakings (Beta = −0.327, p = .066), parasomnias (Beta = −0.386, p = .020), and sleep-disordered breathing (Beta = −0.390, p = .019), but less problems with sleep onset delay (Beta = 0.322, p = .083). Female persons had more sleep anxiety (Beta = 0.391, p = .042) and night wakings (Beta = 0.468, p = .013). Children with a history of congenital heart disease (Beta = 0.361, p = .028) or developmental delay (Beta = 0.471, p = .005) had more problems with sleep duration. Immunodeficiency was associated with parasomnias (Beta = 0.532, p = .002) and sleep-disordered breathing (Beta = 0.520, p = .003). Seasonal allergies were associated with overall score (Beta = 0.419, p = .018), sleep anxiety (Beta = 0.369, p = .054), and night wakings (Beta = 0.377, p = .047). Eczema was associated with daytime sleepiness (Beta = 0.307, p = .079). Epilepsy was associated with overall score (Beta = 0.452, p = .011) and daytime sleepiness (Beta = 0.356, p = .044). Finally, reflux was associated with overall score (Beta = 0.395, p = .019). Although many associations were found, as listed above, all of the final models explained a very modest amount of variability in sleep scores (ranging 10%–36%).

Finally, responses to open-ended questions were reviewed. Selected qualitative responses regarding sleep challenges and interventions are provided in Table 3. When asked, "What is the biggest sleep challenge your child faces?", responses included: sleeping independently (n = 6), frequent nighttime awakenings (n = 5), anxiety or fears (n = 4), bedtime resistance or difficulty falling asleep (n = 3), restlessness or restless legs (n = 3), snoring or sleep apnea (n = 3), daytime sleepiness (n = 2), irregularity in sleep schedule (n = 1), early morning awakenings (n = 1), and bed-wetting (n = 1). When asked "What have you found helpful for your child's sleep?", common themes were: cosleeping with parent (n = 5), white noise machine (n = 4), consistent bedtime routine (n = 4), increasing daytime physical activity (n = 3), nothing (n = 3), keeping the room cool and dark (n = 2). Individually, parents also reported rocking to sleep (n = 1), sleeping in their own bed and room (n = 1), bath before bed (n = 1), soothing with bottle (n = 1), reward system for staying in bed (n = 1), essential oils (n = 1), okay to wake alarm (n = 1), and melatonin (n = 1).

TABLE 2 Relationship between patient characteristics and sleep problems. Predictors retained in the final model from stepwise regression analysis are displayed. Values are B (SE)

	CSHQ total	Bedtime resistance	Sleep onset delay	Sleep duration	Sleep anxiety
Age	—	−0.39 (0.14)	0.07 (0.03)	—	—
Gender	—	—	—	—	1.3 (0.6)
Congenital heart disease	—	—	—	1.3 (0.5)	—
Developmental delay	—	—	—	1.9 (0.6)	—
Immunodeficiency	—	—	—	—	—
Seasonal allergies	8.2 (3.2)	—	—	—	1.2 (0.6)
Eczema	—	—	—	—	—
Epilepsy	14.8 (5.3)	—	—	—	—
Reflux	8.4 (3.3)	—	—	—	—
Model R^2	0.368	0.211	0.104	0.347	0.194
	Night wakings	**Parasomnias**	**Sleep-disordered breathing**		**Daytime sleepiness**
Age	−0.14 (0.07)	−0.28 (0.11)	−0.17 (0.07)		—
Gender	1.6 (0.6)	—	—		—
Congenital heart disease	—	—	—		—
Developmental delay	—	—	—		—
Immunodeficiency	—	3.2 (0.9)	1.9 (0.5)		—
Seasonal allergies	1.3 (0.6)	—	—		—
Eczema	—	—	—		3.2 (1.7)
Epilepsy	—	—	—		4.9 (2.3)
Reflux	—	—	—		—
Model R^2	0.292	0.363	0.354		0.245

TABLE 3 Selected qualitative responses regarding sleep challenges and interventions

What is the biggest sleep challenge your child faces?
"Getting him to start winding down when it's bedtime. He is always on the go and will often times want to go play more even though it's time to settle down."
"Sleep study shows he wakes up around 86 times a night. He stops breathing around 8 times an hour and he physically wakes up to where I have to wake up with him 10 times a night."
"Going to sleep by themselves. My husband is with her every night."
"Our daughter has difficulty going to sleep and staying asleep. Her mind is constantly going although we have tried Clonidine and Melatonin. They work occasionally but our daughter awakens more drowsy than if she hadn't been medicated. She sleep walks, talks and eats."
"Staying asleep once she falls asleep. She usually doesn't want leave her room when she wakes because we've been pretty strict about staying in her room but I often find her asleep on the floor or when I go in in the morning she has ten books in her bed. She also wakes up screaming at least a couple of times a week."
"Seems to have trouble getting to sleep because of anxiety, worrying about the next day's events."
What have you found helpful for your child's sleep?
"To NOT allow him to sleep in mom and dads bed. He does so much better when he sleeps on his own. We've also found keeping the room cool and dark keeps him sleeping through the night."
"Making sure he has an active day to help him sleep better at night."
"Keeping a consistent routine. TV is switched off after 7 p.m., we read him a couple of books and give him plenty of cuddles before bed."
"Nothing apart from sharing a bed with myself or his dad."
"We use a noise machine. It helps drown out other little noises that stimulate and scare our daughter. She likes the nature sounds."
"Using an 'okay to wake' alarm clock that changes colors in the morning. She knows it has to be green for her to leave her room and will stay in there if it hasn't changed usually, and often she falls back to sleep after being up. I don't know if it helps her sleep but it helps the rest of the family stay well-rested."
"Nothing."

4 | DISCUSSION

22q11DS is the most common microdeletion syndrome. Despite its relative commonality, the awareness and understanding of all facets encompassing this syndrome are continuing to be explored. Of the almost 200 characteristics that can be seen in children with 22q11DS, the five most commonly cited are DD/ID, congenital heart disease, palatal abnormalities, immune deficiency, and parathyroid issues/hypocalcemia.

Other than obstructive sleep apnea, clinical sleep problems have historically not been readily highlighted or systematically investigated for this population. There have been several papers reporting on the increased risk specifically of OSA in persons with 22q11DS compared to nonsyndromic children; often these studies are referencing obstructive sleep concerns in relation to surgical correction of a cleft palate or velopharyngeal insufficiency (Crockett et al., 2014; Heike et al., 2007; Kennedy et al., 2014; Silvestre et al., 2014). While awareness has been growing around the increased risk of OSA in these persons, the existence, understanding, and impact of other sleep problems in children with 22q11DS has not previously been fully addressed. This is one of the first studies to specifically address sleep problems other than OSA in persons with 22q11DS.

The results of this study demonstrate that persons with 22q11DS potentially have a higher prevalence of clinically meaningful sleep problems, even beyond OSA, compared to typically developing children. All but one child in the current sample had scores on their sleep habits questionnaire that exceeded the threshold for clinical sleep problems, and all subdomains of clinical sleep problems were elevated compared to typically developing children. These data suggest that providers caring for persons with 22q11DS should consider inquiring not only about obstructive sleep apnea symptoms, but additionally investigate whether concerns for other sleep problems exist as well. To assist with this, routine screening of persons with 22q11DS for sleep problems using validated questionnaires (i.e., CSHQ or Pediatric Sleep Questionnaire) may be helpful. If clinically significant sleep problems are elicited, referral to sleep specialist may be beneficial.

Several characteristics were identified as potential predictors of sleep problems among children with 22q11DS, many of which have also been observed in other populations. Our age findings are expected, with bedtime resistance and parasomnias typically more prevalent in younger children, and delayed sleep phase and psychophysiologic insomnia more common among teenagers. Seasonal allergies and eczema have both previously been shown to result in disrupted sleep at night in children (Fishbein et al., 2015; Koinis-Mitchell et al., 2015). Previous studies have demonstrated that children with reflux have more difficulty falling and staying asleep at night, adolescents with reflux treated with proton pump inhibitor experience improvement in sleep dysfunction, and reflux may contribute to obstructive sleep apnea (Ghaem et al., 1998; Gunasekaran et al., 2009; Wasilewska, Kaczmarski, & Debkowska, 2011; Wasilewska et al., 2012). It is not surprising that developmental delay was associated with more problems in sleep duration given the known high prevalence of sleep problems in that population. Similarly, there is a known bidirectional relationship between epilepsy and sleep problems in children (Ekinci, Isik, Gunes, & Ekinci, 2016; Jain, Horn, Simakajornboon, & Glauser, 2013; Jain et al., 2012). Interestingly, immunodeficiency was associated with more sleep duration problems. In adults, immunodeficiency has previously been shown to be related to decreased sleep duration, with T-cell counts, cytokine levels, and cytokine polymorphisms related to sleep disturbance (Lee et al., 2014).

Given the high prevalence of immunodeficiency and autoimmune/atopic disease among children with 22q11DS, future investigation into the intersection of the immune system and sleep seems warranted.

Open-ended responses from parents were illuminating. The issues that parents identified as their child's most challenging sleep problem spanned the entire spectrum rather than focusing on just sleep-related breathing disorders. One representative response was: "Our daughter has difficulty going to sleep and staying asleep. Her mind is constantly going although we have tried Clonidine and Melatonin. They work occasionally but our daughter awakens more drowsy [sic] than if she hadn't been medicated. She sleep walks, talks and eats." Parents also reported strategies that they have found helpful with their child's sleep, and these largely seemed to reflect known treatments for behavioral insomnia of childhood, including consistent bedtime routine, ensuring an appropriate sleeping environment, and use of a good morning light. For example, one parent reported: "Keeping a consistent routine. TV is switched off after 7 p.m., we read him a couple of books and give him plenty of cuddles before bed." Another reported: "Using an 'okay to wake' alarm clock that changes colors in the morning. She knows it has to be green for her to leave her room and will stay in there if it hasn't changed usually, and often she falls back to sleep after being up. I don't know if it helps her sleep but it helps the rest of the family stay well-rested." These parent-reported experiences suggest that behavioral treatments commonly used in typically developing children or other special populations may be beneficial for children with 22q11DS.

Interestingly, there were relatively few children in our sample who had significant sleep interventions in the past. Only about a third of children had undergone a sleep study and even fewer diagnosed with sleep apnea, which is surprising given the known high prevalence of OSA in this population. Additionally, while about half of children had tried a medication for sleep in the past, most parents did not feel that the medication helped and almost all children still had clinically meaningful sleep problems. This is potentially concerning given the well-established deleterious impact of OSA on neurocognitive function (Hunter et al., 2016), with recent studies demonstrating that children with untreated OSA have reduced gray matter volume (Philby et al., 2017), evidence of neuronal injury (Halbower et al., 2006), and increased neuronal recruitment (mental effort) to perform at similar levels compared to children without OSA (Kheirandish-Gozal, Yoder, Kulkarni, Gozal, & Decety, 2014). These changes may translate into real-word outcomes, such as affecting school performance (Gozal, 1998) and contributing to daytime behavioral challenges (Smith et al., 2016). Similar behavioral and cognitive effects may be seen with other untreated sleep disorders in children, including restless legs syndrome (Picchietti & Picchietti, 2008), chronic insomnia (Angriman, Caravale, Novelli, Ferri, & Bruni, 2015), and narcolepsy (Rocca, Pizza, Ricci, & Plazzi, 2015). Intervention for sleep disorders may be particularly important in children with underlying neurodevelopmental disorders, given that smaller effects may result in larger real world functional impairment due to lower baseline cognitive levels. These data suggest that there is a need for additional screening and treatment of sleep disorders in children with 22q11DS.

This study has several limitations. We measured sleep habits and problems with the CSHQ, which is parent reported and subjective. We did not have objective sleep metrics from actigraphy or polysomnography. However, the CSHQ is a standardized and validated tool which can be used to compare across previous and future studies. In addition, subjective clinical symptoms are often more important to families than formal sleep study metrics. Another limitation of this study is its cross-sectional design, which precludes any cause-effect inferences. Our sample size was limited, and we utilized previously reported normative data rather than collecting data for a new comparison group; that said, the normative data were from a recent, large, national study. In addition, the voluntary recruitment of participants via an online source creates a significant selection bias for parents with a higher educational level and greater motivation to seek services and knowledge. This bias may have impacted our results by causing an increase in positive responders with incentive to report positive findings in his/her child. Lastly, the demographics may be skewed given the online nature of the study recruitment and survey toward a higher socioeconomic status.

While the results of the present investigation are novel and of clinical importance, significant knowledge gaps on this topic remain, highlighting the great potential and need for future research. Larger prospective studies incorporating both subjective and objective measures are needed to better elucidate sleep characteristics and underlying contributing factors among children with 22q11DS. This study did not focus specifically on behavioral issues, such as autism spectrum disorder, which can be associated with children with 22q11DS; behavioral challenges during the day may contribute to sleep difficulties, and vice versa. Future studies are needed to determine the interaction of behavioral challenges and sleep quality in these children and its subsequent relationship to underlying attention, affect, and school performance. Another question for future research includes assessing the children's sleep issues specifically in relationship to their underlying health problems. One example would be looking at children with 22q11DS and congenital heart disease, and their sleep quality in relation to development and medical interventions. It is unknown whether there is a change in sleep patterns for these children after surgical intervention or after requiring a prolonged anesthesia or time on cardiopulmonary bypass; answers to these questions may shed light on causality. Overall, there

is a significant need for future research on this topic to continue and help fill the current knowledge gaps.

In conclusion, this is one of the first studies to specifically address sleep problems other than OSA in children with 22q11DS. The results of this study suggest that these children may have a higher risk of having clinical sleep problems, compared to typically developing children. The findings suggest there is a need for additional screening and treatment of sleep disorders in children with 22q11DS. Larger prospective studies are needed to better elucidate sleep characteristics among children with 22q11DS and continue to fill the current knowledge gaps.

ACKNOWLEDGMENTS

The authors have no conflict of interest relevant to this manuscript. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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REFERENCES

Angriman, M., Caravale, B., Novelli, L., Ferri, R., & Bruni, O. (2015). Sleep in children with neurodevelopmental disabilities. *Neuropediatrics*, *46*(3), 199–210. https://doi.org/10.1055/s-0035-1550151

Bassell, J. L., Phan, H., Leu, R., Kronk, R., & Visootsak, J. (2015). Sleep profiles in children with down syndrome. *American Journal of Medical Genetics. Part A*, *167*(8), 1830–1835. https://doi.org/10.1002/ajmg.a.37096

Bassett, A. S., McDonald-McGinn, D. M., Devriendt, K., Digilio, M. C., Goldenberg, P., Habel, A., … Vorstman, J. (2011). Practical guidelines for managing patients with 22q11.2 deletion syndrome. *The Journal of Pediatrics*, *159*(2), 332–339.e1. https://doi.org/10.1016/j.jpeds.2011.02.039

Briegel, W., Schneider, M., & Schwab, K. O. (2007). 22q11.2 deletion syndrome: Behaviour problems of infants and parental stress. *Child: Care, Health and Development*, *33*(3), 319–324. https://doi.org/10.1111/j.1365-2214.2006.00654.x

Chen, M. L., Olson, H. C., Picciano, J. F., Starr, J. R., & Owens, J. (2012). Sleep problems in children with fetal alcohol spectrum disorders. *Journal of Clinical Sleep Medicine*, *8*(4), 421–429. https://doi.org/10.5664/jcsm.2038

Crockett, D. J., Goudy, S. L., Chinnadurai, S., & Wootten, C. T. (2014). Obstructive sleep apnea syndrome in children with 22q11.2 deletion syndrome after operative intervention for velopharyngeal insufficiency. *Frontiers in Pediatrics*, *2*, 84. https://doi.org/10.3389/fped.2014.00084

Ekinci, O., Isik, U., Gunes, S., & Ekinci, N. (2016). Understanding sleep problems in children with epilepsy: Associations with quality of life, attention-deficit hyperactivity disorder and maternal emotional symptoms. *Seizure*, *40*, 108–113. https://doi.org/10.1016/j.seizure.2016.06.011

Fishbein, A. B., Vitaterna, O., Haugh, I. M., Bavishi, A. A., Zee, P. C., Turek, F. W., … Paller, A. S. (2015). Nocturnal eczema: Review of sleep and circadian rhythms in children with atopic dermatitis and future research directions. *The Journal of Allergy and Clinical Immunology*, *136*(5), 1170–1177. https://doi.org/10.1016/j.jaci.2015.08.028

Ghaem, M., Armstrong, K. L., Trocki, O., Cleghorn, G. J., Patrick, M. K., & Shepherd, R. W. (1998). The sleep patterns of infants and young children with gastro-oesophageal reflux. *Journal of Paediatrics and Child Health*, *34*(2), 160–163. https://doi.org/10.1046/j.1440-1754.1998.00191.x

Goldman, S. E., Richdale, A. L., Clemons, T., & Malow, B. A. (2012). Parental sleep concerns in autism spectrum disorders: Variations from childhood to adolescence. *Journal of Autism and Developmental Disorders*, *42*(4), 531–538. https://doi.org/10.1007/s10803-011-1270-5

Goodlin-Jones, B. L., Sitnick, S. L., Tang, K., Liu, J., & Anders, T. F. (2008). The Children's Sleep Habits Questionnaire in toddlers and preschool children. *Journal of Developmental and Behavioral Pediatrics*, *29*(2), 82–88. https://doi.org/10.1097/DBP.0b013e318163c39a

Gozal, D. (1998). Sleep-disordered breathing and school performance in children. *Pediatrics*, *102*(3 Pt 1), 616–620. https://doi.org/10.1542/peds.102.3.616

Gunasekaran, T., Tolia, V., Colletti, R. B., Gold, B. D., Traxler, B., Illueca, M., & Crawley, J. A. (2009). Effects of esomeprazole treatment for gastroesophageal reflux disease on quality of life in 12- to 17-year-old adolescents: An international health outcomes study. *BMC Gastroenterology*, *9*, 84. https://doi.org/10.1186/1471-230X-9-84

Halbower, A. C., Degaonkar, M., Barker, P. B., Earley, C. J., Marcus, C. L., Smith, P. L., … Mahone, E. M. (2006). Childhood obstructive sleep apnea associates with neuropsychological deficits and neuronal brain injury. *PLoS Med*, *3*(8), e301. https://doi.org/10.1371/journal.pmed.0030301

Heike, C. L., Avellino, A. M., Mirza, S. K., Kifle, Y., Perkins, J., Sze, R., … Hing, A. V. (2007). Sleep disturbances in 22q11.2 deletion syndrome: A case with obstructive and central sleep apnea. *Cleft Palate-Craniofacial Journal*, *44*(3), 340–346. https://doi.org/10.1597/05-196

Hoffmire, C. A., Magyar, C. I., Connolly, H. V., Fernandez, I. D., & van Wijngaarden, E. (2014). High prevalence of sleep disorders and associated comorbidities in a community sample of children with Down syndrome. *Journal of Clinical Sleep Medicine*, *10*(4), 411–419. https://doi.org/10.5664/jcsm.3618

Hunter, S. J., Gozal, D., Smith, D. L., Philby, M. F., Kaylegian, J., & Kheirandish-Gozal, L. (2016). Effect of sleep-disordered breathing severity on cognitive performance measures in a large community cohort of young school-aged children. *American Journal of Respiratory and Critical Care Medicine*, *194*(6), 739–747. https://doi.org/10.1164/rccm.201510-2099OC

Jain, S. V., Horn, P. S., Simakajornboon, N., & Glauser, T. A. (2013). Obstructive sleep apnea and primary snoring in children with epilepsy. *Journal of Child Neurology*, *28*(1), 77–82. https://doi.org/10.1177/0883073812440326

Jain, S. V., Simakajornboon, S., Shapiro, S. M., Morton, L. D., Leszczyszyn, D. J., & Simakajornboon, N. (2012). Obstructive

sleep apnea in children with epilepsy: Prospective pilot trial. *Acta Neurologica Scandinavica*, *125*(1), e3–e6. https://doi.org/10.1111/j.1600-0404.2011.01506.x

Kennedy, W. P., Mudd, P. A., Maguire, M. A., Souders, M. C., McDonald-McGinn, D. M., Marcus, C. L., … Elden, L. M. (2014). 22q11.2 deletion syndrome and obstructive sleep apnea. *International Journal of Pediatric Otorhinolaryngology*, *78*(8), 1360–1364. https://doi.org/10.1016/j.ijporl.2014.05.031

Kheirandish-Gozal, L., Yoder, K., Kulkarni, R., Gozal, D., & Decety, J. (2014). Preliminary functional MRI neural correlates of executive functioning and empathy in children with obstructive sleep apnea. *Sleep*, *37*(3), 587–592. https://doi.org/10.5665/sleep.3504

Koinis-Mitchell, D., Kopel, S. J., Boergers, J., Ramos, K., LeBourgeois, M., McQuaid, E. L., … Klein, R. B. (2015). Asthma, allergic rhinitis, and sleep problems in urban children. *Journal of Clinical Sleep Medicine*, *11*(2), 101–110. https://doi.org/10.5664/jcsm.4450

Lee, K. A., Gay, C., Pullinger, C. R., Hennessy, M. D., Zak, R. S., & Aouizerat, B. E. (2014). Cytokine polymorphisms are associated with poor sleep maintenance in adults living with human immunodeficiency virus/acquired immunodeficiency syndrome. *Sleep*, *37*(3), 453–463. https://doi.org/10.5665/sleep.3474

Liu, X., Liu, L., Owens, J. A., & Kaplan, D. L. (2005). Sleep patterns and sleep problems among schoolchildren in the United States and China. *Pediatrics*, *115*(1 Suppl), 241–249. https://doi.org/10.1542/peds.2004-0815F

Malow, B. A., Marzec, M. L., McGrew, S. G., Wang, L., Henderson, L. M., & Stone, W. L. (2006). Characterizing sleep in children with autism spectrum disorders: A multidimensional approach. *Sleep*, *29*(12), 1563–1571. https://doi.org/10.1093/sleep/29.12.1563

Owens, J. A., Spirito, A., & McGuinn, M. (2000). The Children's Sleep Habits Questionnaire (CSHQ): Psychometric properties of a survey instrument for school-aged children. *Sleep*, *23*(8), 1043–1051. https://doi.org/10.1093/sleep/23.8.1d

Philby, M. F., Macey, P. M., Ma, R. A., Kumar, R., Gozal, D., & Kheirandish-Gozal, L. (2017). Reduced regional grey matter volumes in pediatric obstructive sleep apnea. *Scientific Reports*, *7*, 44566. https://doi.org/10.1038/srep44566

Picchietti, M. A., & Picchietti, D. L. (2008). Restless legs syndrome and periodic limb movement disorder in children and adolescents. *Seminars in Pediatric Neurology*, *15*(2), 91–99. https://doi.org/10.1016/j.spen.2008.03.005

Rocca, F. L., Pizza, F., Ricci, E., & Plazzi, G. (2015). Narcolepsy during childhood: An update. *Neuropediatrics*, *46*(3), 181–198. https://doi.org/10.1055/s-0035-1550152

Silvestre, J., Tahiri, Y., Paliga, J. T., & Taylor, J. A. (2014). Screening for obstructive sleep apnea in children with syndromic cleft lip and/or palate. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, *67*(11), 1475–1480. https://doi.org/10.1016/j.bjps.2014.07.026

Smith, D. L., Gozal, D., Hunter, S. J., Philby, M. F., Kaylegian, J., & Kheirandish-Gozal, L. (2016). Impact of sleep disordered breathing on behaviour among elementary school-aged children: A cross-sectional analysis of a large community-based sample. *European Respiratory Journal*, *48*(6), 1631–1639. https://doi.org/10.1183/13993003.00808-2016

Souders, M. C., Mason, T. B., Valladares, O., Bucan, M., Levy, S. E., Mandell, D. S., … Pinto-Martin, J. (2009). Sleep behaviors and sleep quality in children with autism spectrum disorders. *Sleep*, *32*(12), 1566–1578. https://doi.org/10.1093/sleep/32.12.1566

Valvo, G., Novara, F., Brovedani, P., Ferrari, A. R., Guerrini, R., Zuffardi, O., & Sicca, F. (2012). 22q11.2 Microduplication syndrome and epilepsy with continuous spikes and waves during sleep (CSWS). A case report and review of the literature. *Epilepsy & Behavior*, *25*(4), 567–572. https://doi.org/10.1016/j.yebeh.2012.09.035

Wasilewska, J., Kaczmarski, M., & Debkowska, K. (2011). Obstructive hypopnea and gastroesophageal reflux as factors associated with residual obstructive sleep apnea syndrome. *International Journal of Pediatric Otorhinolaryngology*, *75*(5), 657–663. https://doi.org/10.1016/j.ijporl.2011.02.004

Wasilewska, J., Semeniuk, J., Cudowska, B., Klukowski, M., Debkowska, K., & Kaczmarski, M. (2012). Respiratory response to proton pump inhibitor treatment in children with obstructive sleep apnea syndrome and gastroesophageal reflux disease. *Sleep Medicine*, *13*(7), 824–830. https://doi.org/10.1016/j.sleep.2012.04.016

How to cite this article: Arganbright JM, Tracy M, Hughes SS, Ingram DG. Sleep patterns and problems among children with 22q11 deletion syndrome. *Mol Genet Genomic Med*. 2020;8:e1153. https://doi.org/10.1002/mgg3.1153