Sleep-disordered breathing in children with Down syndrome: Usefulness of home polysomnography

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ABSTRACT

Objective: To investigate the technical feasibility of unattended home polysomnography (HPSG) in children with Down syndrome.

Methods: Data from children with Down syndrome under 10 years of age referred to a diagnostic sleep study was analyzed. A full sleep-lab based polysomnography (PSG) or a HPSG with a portable device was performed. Uninterpretable HPSGs were defined as: recordings with (i) loss of ≥2 of the following channels: nasal flow, or thoracoabdominal sensors, or (ii) HPSG with less than 4 h of artifact-free recording time or (iii) less than 4 h SpO2 (peripheral capillary oxygen saturation) signal.

Results: A total of 44 children (68% males) were included in the study, with a mean age of 3.6 (0.1–10) years. PSG was performed in 8 cases and HPSG in 36 cases. Six HPSG recordings were classified as uninterpretable and had to be repeated. Age, gender and BMI were no significant predictors of uninterpretability of the HPSG. Obstructive sleep apnea (OSA) was present in 61% (n = 27) of all subjects, and classified as mild, moderate, and severe in 43% (n = 19), 11% (n = 5), and 7% (n = 3) of cases, respectively. Interpretable and technically acceptable HPSGs were obtained in 30 subjects (83%). Age, gender and BMI were no significant predictors for interpretability of the HPSG.

Discussion: This study demonstrates that a portable polysomnographic home device may be helpful for diagnosing OSA in children with Down syndrome. Considering the potential consequences of untreated OSA, this screening test may be helpful for early diagnosis of OSA in children with Down syndrome.

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1. Introduction

Sleep-disordered breathing (SDB) has a high prevalence among children with Down syndrome. The spectrum of SDB that affects this group of children ranges from primary snoring to obstructive sleep apnea (OSA), the latter with a reported prevalence of 31% to 63% [1,2], which accounts for a 10- to 20 fold higher prevalence of OSA than that observed in children without Down syndrome [3]. Children with Down syndrome have many several predisposing factors for SDB, including midface hypoplasia, mandibular hypoplasia, glossophtosis, a small upper airway, and enlarged tonsils [4]. In addition, children with Down syndrome have a small and hypotonic airway and an increased incidence of lower respiratory tract anomalies [5,6].

The consequences of untreated OSA may result in serious problems including poor academic performance [7,8], behavioral problems [9], hyperactivity [10], attention difficulties [11], and worsening of mental function [10]. Considering the growing body of evidence that links OSA with neurocognitive issues in children [10], the impact of untreated OSA on the mental function in children with Down syndrome is extremely concerning.

The high prevalence and serious consequences of OSA in children with Down syndrome have led to recommendations for screening all children with this condition for OSA at 5 years of age [12]. The presence of snoring, disturbed sleep, awakenings, and daytime symptoms like somnolence or hyperactivity may lead to earlier consultation and treatment. However, parents of children with Down syndrome may underestimate the severity of the sleep...
disturbances and overlook the presence of OSA [13]. Furthermore, OSA cannot be diagnosed based solely on clinical history or physical examination [7], a full-night sleep lab-based polysomnography (PSG) is currently the recommended gold standard for diagnosis [8]. Nevertheless, this test may be especially difficult to perform in children with Down syndrome, considering it involves an overnight hospital stay, away from the regular surroundings of the child. A noninvasive, home-based study for diagnosing OSA seems to be an interesting solution. Among the few studies that have demonstrated adequate diagnostic accuracy and feasibility [14], unattended portable polysomnography (HPSG) has shown promising results [10].

The feasibility of HPSG in a pediatric setting has been previously demonstrated [9,14], however, this has not been documented in children with Down syndrome. Therefore, the aim of the present study was to investigate the technical feasibility of unattended HPSG using portable equipment in children with Down syndrome. In addition, HPSG and PSG results were compared.

2. Methods

2.1. Subjects

We included all data from children with Down syndrome aged under 10 years who were referred to a sleep study between 2013 to 2015 at the Sleep Laboratory or the Respiratory Laboratory of the Pontificia Universidad Católica de Chile, Santiago, Chile. Only data of children with confirmed Down syndrome were selected for this study. These children were sent to perform either a HPSG, or PSG based on the clinical judgment of their physicians. The main reason for requesting the sleep study was habitual snoring, defined as snoring for more than 3 nights per week. No prior screening tool was used for the selection.

Demographic data, nutritional status, and health records were obtained and registered into the dataset. Nutritional status was assessed using body mass index (BMI, kg/m²). Age and gender-specific z-scores were obtained for each subject’s BMI. Associated autism spectrum disorder was recorded if a pediatric neurologist had made the diagnosis. Other associated comorbidities such as congenital heart disease, hypothyroidism, respiratory problems, and use of supplemental oxygen or mechanical ventilation were obtained from the subject’s health records. The study and use of the subject’s clinical data was approved by the Ethics Committee of the Faculty of Medicine at the Pontificia Universidad Católica in Santiago, Chile (Approval number 14-327).

2.2. Procedures

For HPSG, a portable cardiorespiratory device was used unattended at home (Embleta® Gold III, Embla, Broomfield, Colorado, USA). This procedure has been previously reported by our group in habitually snoring children [14]. The following six channels were recorded: (i) nasal flow using a pressure transducer cannula, (ii) thoracic movements, (iii) abdominal movements, (iv) pulse oximetry, (v) heart rate measured by electrocardiography, (vi) position sensor. The device used for the HPSG was installed in the respiratory lab and returned by the parents of the children the next morning. A hotline number was given to parents in order to answer questions or solve problems.

Those patients sent for PSG used a computerized polysomnographic system (ALICE 5.0, Respironics, Andover, MA, USA). PSG was performed in the sleep lab at night with continuous attendance. The study montage included the following channels: 3-lead electroencephalography, 2-lead electrooculography, 3-lead submentalis electromyography, chest and abdominal wall movements, nasal pressure transducer, snoring, pulse oximetry-derived arterial hemoglobin oxygen saturation and pulse waveform, heart rate, digital audio and video.

For both PSG and HPSG, respiratory events and sleep architecture were analyzed according to current criteria [15]. Arousals were identified as defined by the American Sleep Disorders Association Task Force report [16]. Central, obstructive, and mixed apneas and hypopneas were identified according to current recommendations [17]. Obstructive apneas were defined as the absence of airflow with continued chest wall and abdominal movement for the duration of at least two breaths. Central apneas were defined as the absence of nasal flow and thoraco-abdominal movements for more than 20 s, or for more than 2 breaths if the episode was accompanied by desaturation or arousal. Hypopneas were defined as a decrease in nasal flow of at least 30% with a corresponding decrease in SpO₂ (peripheral capillary oxygen saturation) of 3% or more and/or an arousal [17]. The apnea-hypopnea index (AHI) was calculated based on the number of obstructive and mixed apneas and hypopneas per hour of total sleep time. OSA was defined as an AHI >1 [17]. Mild, moderate, and severe OSA was defined as an AHI <5, >5, and >15, respectively. All studies were reported by the same investigator.

2.3. Evaluation of feasibility

Based on the feasibility criteria of our previous publication on habitually snoring children [14] we determined the need for a new recording due to interpretability as the main failure criteria. An uninterpretable study was defined as those with ≥ of the following criteria: (i) loss of the following channels: nasal flow, or thoracic or abdominal sensors, (ii) recordings with less than 4 h of artifact-free recording time or (iii) less than 4 h of SpO₂ signal [14]. These criteria were applied to both PSG and HPSG.

2.4. Statistics

Descriptive statistics were used to summarize the children’s demographic and polysomnographic characteristics (i.e., numbers, percentages, median, minimum, maximum for non-normal distributed data; and mean and standard deviation for data with normal distribution). Comparisons between PSG and HPSG were conducted using Mann Whitney U-Test for not-normal data, and Student’s t-test for normally distributed variables. Factors that may have influenced the interpretability of the recordings were investigated using logistic regression. Age, gender, AHI, and BMI z-scores were analyzed as independent variables in the logistic regression equation. Odds ratios and their 95% confidence intervals (95% CI) were calculated. Statistical software SPSS 20.0 (Statistical Package for the Social Science 20.0 for Mac) was used for all analyses. A p-value <0.05 was considered statistically significant.

3. Results

Of the n = 44 children included in the study, n = 30 (68%) were males. Mean age was 3.6 (0.1–10) years. A total of n = 8 PSG, and n = 36 HPSG were performed in the patients. A diagnosis of congenital heart disease was present in 27 (61%) cases, autism spectrum disorder in n = 4 (9%) (all of them male, aged 6, 4, 3, and 3 y), hypothyroidism in n = 27 (61%), and swallowing/feeding disorder in n = 13 (30%) cases. Table 1 shows the demographic and clinical characteristics of the HPSG and PSG groups, none of them were statistically significant, except for the use of home oxygen in n = 3 (43%) versus n = 2 (6%) children, respectively (p = 0.024).

OSA was diagnosed in n = 27 (61%) of all subjects. OSA was classified as mild, moderate, and severe in n = 19 (43%), n = 5 (11%), and n = 3 (7%) children, respectively. There were n = 7 (16%) children with OSA in the PSG group, compared to n = 20 (56%) in
interpretable and possible to perform. For the first time, the feasibility of a portable home device has been demonstrated in children with Down syndrome.

OSA is highly prevalent in children with Down syndrome. Previous studies have reported a prevalence of OSA ranging between 31% and 63% [1,18]. Even after treatment, up to two thirds of children with Down syndrome may still suffer from OSA, and have abnormal sleep patterns [19]. In one of the first studies to investigate the prevalence of abnormal sleep in children with Down syndrome, Marcus et al. demonstrated that 77% of all sleep studies were abnormal [1]. In that study, the prevalence of OSA was 63%, however 57% of the included children had no history suggesting OSA. The lack of previous history suggesting OSA, especially the absence of snoring seems to be a frequent problem in this group of children [1]. The inaccuracy of parental reporting may be more common in parents of children with Down syndrome. We hypothesize that this may reflect the parents’ tendency to assume that their child’s irregular breathing or the presence of apneas during sleep is normal for a child with Down syndrome. Therefore, it seems important to follow current pediatric recommendations [12] and screen for OSA in all children with Down syndrome, even in the absence of evident clinical snoring.

On the other hand, Fitzgerald et al. state that up to 97% of children with Down syndrome consecutively referred to a sleep study because of snoring should moderate to severe OSA on PSG [20]. In a Norwegian study, an apnea hypopnea index > 1.5 was found in 28/29 children and an obstructive apnea index >1 in 24/29 children with Down syndrome [21]. Similar to that finding, our study shows that 88% of the conducted PSG revealed an OSA. Similar to Fitzgerald’s study [20], our sample consisted of children that were referred to a sleep study due to habitual snoring. Like the findings in previous studies, we observed a higher prevalence of OSA in children who took a PSG than in those with a HPSG [1,18]. We hypothesize that this might reflect a selection bias, as children with more symptoms may be sent to the sleep lab instead of an ambulatory home screening tool like the HPSG. The higher frequency of oxygen use in the PSG group supports the hypothesis that in presence of clinical symptoms, the probability that the attending physician chooses a PSG instead of a HPSG may be higher in children with Down syndrome. On the other hand, PSG data showed a significantly higher AHI than in HPSG. This higher AHI was due especially to more hypopneas and central apneas in the PSG group. We speculate that this is based on different scoring, and that a less accurate identification of central apneas and hypopneas (due to the lack of electroencephalography channels) could underestimate these events in HPSG.

An important limitation of this and other studies concerning OSA in children with Down syndrome is the diversity of diagnostic methods and cutoffs applied in PSG, HPSG, questionnaires or oximetry. Also, the differences in age range and the variation of selected cut off values may lead to different assumptions in the diagnosis of OSA in children with Down syndrome. To date, there are no specific age and gender-based reference values for polysomnographic parameters in children with Down syndrome.

The high prevalence of OSA found in this and several previous studies [1,19–21] supports the need for diagnosing OSA in snoring children with Down syndrome. The under recognition of OSA in children with Down syndrome has potential severe consequences. Neurocognitive problems have been associated with OSA in several studies in children without Down syndrome [7,8,10,22]. Even in children with primary snoring, the apparently mildest form of sleep-disordered breathing (SDB), the association with problems like poor school performance, daytime somnolence, and hyperactivity has been demonstrated [23]. It is thought that intermittent hypoxia, sleep fragmentation, and sleep disruption are physiological correlates of SDB, and suspected to cause prefrontal cortical

The present study shows that the majority of sleep studies conducted at home in children with Down syndrome are

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<th>Table 1</th>
<th>Demographic and clinical characteristics of the study sample.</th>
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<td></td>
<td>Total N = 44</td>
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<td></td>
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<tr>
<td>Males: N (%)</td>
<td>30 (68)</td>
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<tr>
<td>Age [y]: median (min–max)</td>
<td>3.6 (0.1–10)</td>
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<td>BMI [kg/m²] z-score: mean ± SD</td>
<td>−0.5 ± 1.4</td>
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<td>Obesity: N (%)</td>
<td>5 (11)</td>
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<tr>
<td>Home oxygen use, N (%)</td>
<td>5 (11)</td>
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<tr>
<td>OSA, N (%)</td>
<td>27 (61)</td>
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Abbreviations: BMI, body mass index; OSA, obstructive sleep apnea; PSG, polysomnography; HPSG, unattended home polysomnography; TST, total sleep time; SD, standard deviation.

the HPSG group (p = 0.102). Median (minimum–maximum) AHI was 3.8 (0–59.6) for the whole sample, with 4.9 (0.8–59.6) in the PSG group versus 1.2 (0–11.9) in the HPSG group (p = 0.008).

Table 2 shows the detailed polysomnographic results according to the type of study performed.

No PSG had to be repeated. In the HPSG group, there were n = 6 children (17%) that needed a repetition of the test due to signal failure according to the above-mentioned criteria. Median (minimum–maximum) age of the subjects with an uninterpretable recording was 1.4 (0.6–5.5) years, 5 of them were males. In the remaining n = 30 subjects (83%), HPSG was interpretable according to the above-mentioned criteria and the results were technically acceptable. There were 3 cases of destruction of a HPSG cable. Of the n = 6 children that had an uninterpretable study, n = 4 were repeated and showed acceptable results in the second HPSG. In n = 2 children a final repetition was impossible to perform.

Parents of both groups referred no complaints concerning either type of sleep study. Logistic regression analysis failed to determine any significant predictors for uninterpretability of the HPSG (OR [95% CI]): age 0.40 [0.04; 3.88], gender 0.76 [0.4; 2.1], BMI 0.93 [0.6; 1.4], and AHI 0.95 [0.66; 1.37]. The presence of congenital heart disease, hypothyroidism, autism spectrum disorder, or the use of home oxygen were also not significant predictors for uninterpretability of the HPSG.

In addition, no significant predictors for determining which children were more likely to receive a PSG versus HPSG were found (OR [95% CI]): age 1.15 [0.60; 2.18], gender 1.87 [0.11; 32.23], BMI 1.12 [0.52; 2.44], and AHI 0.59 [0.33; 1.07].

4. Discussion

The present study shows that the majority of sleep studies conducted at home in children with Down syndrome are

<table>
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<th>Table 2</th>
<th>Comparison of polysomnographic items categorized by type of study cases and controls.</th>
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<td></td>
<td>Total N = 44</td>
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<tr>
<td>TST [min]</td>
<td>565 (420–600)</td>
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<tr>
<td>Central apnea index</td>
<td>0.1 (0–7.1)</td>
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<tr>
<td>Obstructive apnea index</td>
<td>0.5 (0–39.8)</td>
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<tr>
<td>Hypopnea index</td>
<td>0.1 (0–3.6)</td>
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<tr>
<td>AHI</td>
<td>3.8 (0–59.6)</td>
</tr>
<tr>
<td>Mean SpO₂ during sleep [%]</td>
<td>96 (84–98)</td>
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<tr>
<td>Time [%] spent &lt;SpO₂ 90s</td>
<td>0.3 (0–75)</td>
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Abbreviations: AHI, apnea hypopnea index; TST, total sleep time; all results are given in medians (minimum–maximum).
dysfunction leading to impaired cognitive execution [24]. Specifically in children with Down syndrome, there are sparse studies that aim at establishing an association between OSA and neurocognitive function. In one of the few studies available, Brooks et al. analyzed the relationship between several sleep-disordered breathing parameters and the performance on neuropsychological tests in n = 25 children with Down syndrome [25]. Explanations for the lack of significant findings in that study may be based on the fact that children with Down syndrome have lower baseline neuropsychological function compared with children without Down syndrome. In addition, standard neurocognitive tests may not recognize subtle differences in neurocognitive function in children with Down syndrome [25]. On the other hand, associations between sleep-disordered breathing and neurocognitive consequences could reflect a variety of confounding social and health factors. In the Brooks et al. study, however, there was a significant improvement in attention in a subgroup of patients after treatment [25]. Also, the quality and quantity of sleep was a strong predictor of behavior and academic achievement in the recruited children [25].

The present study has the strength that it is the first to show that a simple portable device may aid in the diagnosis of OSA in children with Down syndrome. HPSG showed a lower feasibility rate compared with children without Down syndrome: i.e., 83% versus 93% [14]. This comparison is based on the same equipment, nurse, and diagnostic cutoff [14]. Notwithstanding this difference, we believe that 83% for an unattended home study is reasonable and good enough for this portable and noninvasive diagnostic technique. We would like to emphasize that the diagnostic value of PSG is important. In contrast to PSG, several sleep quality and neurophysiologic parameters cannot be evaluated with HPSG. Considering the high prevalence of OSA in children with Down syndrome, however, a screening procedure with HPSG seems to be helpful. In addition, OSA tends to persist if untreated, so a prompt diagnosis and treatment seems to be urgent in children with Down syndrome. In a recent study in adults with Down syndrome, it was shown that they had high rates of OSA and hypventilation [26].

5. Conclusions

This study has shown that a portable polysomnographic home device may be helpful for diagnosing OSA in children with Down syndrome. Considering all the efforts that have been made to improve the health of children with Down syndrome and the serious consequences of untreated OSA, this screening test may be helpful for the early diagnosis and treatment of OSA in these children.

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