European Archives of Oto-Rhino-Laryngology
https://doi.org/10.1007/s00405-024-09143-5

MISCELLANEOUS

Comparison between three abbreviated methods for the diagnosis of obstructive sleep apnea syndrome in children and adolescents in a real-world setting – a prospective study using polysomnography

Manon Marechal[1] · Emeline Renard[1] · Patricia Franco[2,3] · Sofia Da Mota[4] · Noémie Schweitzer[4] · Angelica Tiotiu[5,6] · Cyril Schweitzer[1,4,6] · Laurianne Coutier[3,7] · Iulia Ioan[4,6]

Received: 11 August 2024 / Accepted: 3 December 2024

Abstract

Background Oximetry was proposed as an abbreviated exam, easily accepted by the child, for the diagnosis of obstructive sleep apnea (OSA) for children located in regions where access to pediatric sleep labs is limited. The objective of this study was to determine the diagnostic value of the oxygen desaturation index (ODI), the number of ≥ 3% oxygen desaturations per hour of recording, obtained by portable oximetry performed in parallel with video-polysomnography (PSG), in a cohort of children, with and without comorbidities, referred for OSA.

Methods Data from portable oximetry performed in parallel with PSG were prospectively collected. The diagnostic value, sensitivity, and specificity of ODI to identify a *moderate/severe OSA* were computed.

Results 81 children aged 3 to 18 years were included, 56 (69%) with comorbidities, 50 (62%) with *moderate/severe OSA*. The area under the ROC curves was 0.92 for ODI by PSG, 0.86 for ODI by PSG's oximetry and 0.78 for ODI by portable oximetry, to diagnose a *moderate/severe* OSA. All ODIs presented high specificity (1.0 for PSG, 0.90 for PSG's oximetry, 0.87 for portable oximetry) and moderate sensitivity (0.84 for PSG, 0.72 for PSG's oximetry, 0.60 for portable oximetry).

Conclusion In children referred for OSA, particularly in those with a pre-existing comorbidity, ODI obtained by an abbreviated method had high specificity for the diagnosis of *moderate/severe OSA* and might be used to prioritize the access to a comprehensive sleep recording. Its low sensitivity suggests that a comprehensive sleep exam must be performed in case of a negative test.

Keywords Obstructive sleep apnea · Polysomnography · Sleep · Children · Simplified methods

✉ Iulia Ioan
ic.ioan@chru-nancy.fr

1 Service de Médecine Infantile, Centre Hospitalier Universitaire de Nancy, Nancy, France

2 Service Epilepsie, Sommeil, Explorations Fonctionnelles Neurologiques Pédiatriques, Hôpital Femme Mère Enfant, Hospices Civils de Lyon, Sommeil, Bron, France

3 U1028, CNRL, Université de Lyon 1, Lyon, France

4 Service d'Explorations Fonctionnelles Pédiatriques, Hôpital d'Enfants, Centre Hospitalier Universitaire de Nancy, Nancy, France

5 Service de Pneumologie, Centre Hospitalier Universitaire de Nancy, Nancy, France

6 DevAH, Faculté de Médecine, Université de Lorraine, Nancy, France

7 Service de pneumologie infantile, allergologie et centre de référence en mucoviscidose, Hôpital Femme Mère Enfant, Hospices Civils de Lyon, Bron, France

Introduction

Obesity, craniofacial abnormalities, metabolic disorders, as Prader-Willi syndrome, and genetic syndromes, as Down syndrome, are few pediatric disorders that predispose to obstructive sleep apnea syndrome (OSA) in children. The prevalence of OSA in children is approximately 2 to 5%; however, it may rise to 50% in the presence of a comorbidity [1]. These patients need to be periodically evaluated for the presence of OSA as the symptoms are non-specific and might be even absent. Undiagnosed and untreated OSA is linked to substantial neurocognitive and behavioral impairment, as well as cardiovascular morbidity [1, 2]. The reference exam for the diagnosis of OSA in children is the one-night polysomnography in a sleep lab with videorecording and a sleep technologist's attendance throughout the night (PSG) [1,

Published online: 14 December 2024

3]. PSG involves numerous electrodes installed on child's body to score the sleep stages, micro-arousals, and respiratory events and their impact on pulse oxygen saturation (SpO2) and heart rate. The apnea-hypopnea index (AHI) is obtained from the PSG, which is used to diagnose OSA and stage its severity. Nevertheless, the availability of pediatric sleep laboratories is restricted and conditioned upon the child's geographic location, with significant delays and lack of pediatric sleep physicians in certain regions. Consequently, it is necessary to perform more fundamental tests that can be conducted in the child's home as a screening to determine the severity of OSA and the necessity of a more comprehensive sleep lab evaluation. Since most respiratory events are linked to oxygen desaturations and/or hypoxemia [4], portable oximetry is an example of such a basic test. Prior research has established oximetric scores and indexes to assist clinicians in making treatment decisions in the context of clinical OSA. For instance, the McGill score enables the visual analysis of nocturnal oximetric recordings by accounting for desaturation clusters [5–7]. The oxygen desaturation index (ODI), which is the number of oxygen desaturations per hour of recording, can be used as a substitute for PSG to determine the severity of OSA. ODI can be derived directly from the PSG [8, 9] or from the oximetry integrated in the PSG device [10, 11] or from portable oximetry [12, 13]. Most previous studies involved the assessment of the diagnostic ability of ODI computed either by the PSG alone [8, 9] or by the PSG's oximetry alone analyzed separately from the PSG [13, 14], or by portable oximetry alone [10] or the comparison between two of them.

The aim of our study was to compare the diagnostic ability of ODI computed by three different methods, by PSG, by PSG's oximetry, and by portable oximetry, to identify a *moderate/severe OSA* in a population of children and adolescents in a real-world setting of a tertiary sleep clinic. More specific, our aim was to demonstrate the superiority of one method compared to the other for the diagnosis of *moderate/severe OSA*.

Materials and methods

Population

A prospective cohort monocentric study including children older than 3 years of age referred for OSA who performed a routinely one-night PSG with videorecording and sleep technologist's attendance in the sleep unit of the Lung Function Department from University Children's Hospital of Nancy, France, as part of standard clinical care practice, has been conducted in 2022–2023. This hospital is a tertiary pediatric hospital comprising all the pediatric medical and surgical subspecialties and reference centers for rare diseases. Children were referred for assessment of OSA by ear-nose-throat, metabolic, or genetic diseases physicians, pediatric pulmonologists, sleep specialists or orthodontists. Children with interpretable PSG with more than 4 h of total sleep time (TST) and interpretable portable oximetry without artifact for more than 4 h of total recording time (TRT) were included in this study. Children and their parents were informed of the anonymized use of their child's PSG data and did not oppose. The study was conducted in agreement with the French regulations and had received appropriate legal and ethical approval from the Institutional Review Board of the French Learned Society for Respiratory Medicine (Société de Pneumologie de Langue Française) (CEPRO 2022-039).

Study design

Children were hospitalized a single night in the sleep unit to perform a PSG in parallel with a portable oximetry. The study design is presented in Fig. 1.

The child's clinical assessment with detailed medical history and physical examination were conducted by the resident doctor. The demographic and clinical characteristics retained for analysis were: age, gender, body mass index (BMI) expressed as z-score [15], the co-morbidities and the presence of nocturnal symptoms (snoring more than 3 times per week from more than 3 months, apnea perceived by the parents, restless sleep, nocturnal awakenings, nocturnal sweats, enuresis, mouth breathing, respiratory efforts), and the diurnal symptoms (morning dry mouth, difficult wakening, morning headache, diurnal fatigue, attention and concentration difficulties or behavioral issues).

Computation of oximetric indexes by polysomnography

The polysomnographic device used was A1-NOX (ResMed, France) and involved recording the brain activity by electroencephalogram (EEG), the eyes movement by electrooculogram (EOG), the muscle activity by chin and legs electromyogram (EMG), the respiratory flow by a nasal cannula, the respiratory efforts by thoraco-abdominal belts, the pulse oxygen saturation (SpO2) by an oximeter placed at child's finger, the heart rate by electrocardiogram, the body position during sleep by an integrated actimeter. The oximeter integrated in the PSG device was a Nonin oximeter (Nonin, Plymouth, Minn, USA) with a 3s averaging time and a sampling frequency of 4 Hz [16]. The sleep technologist installed the PSG device late in the afternoon. During the night, he checked and adjusted the child's sensors if necessary and a video-camera recorded the child. The device

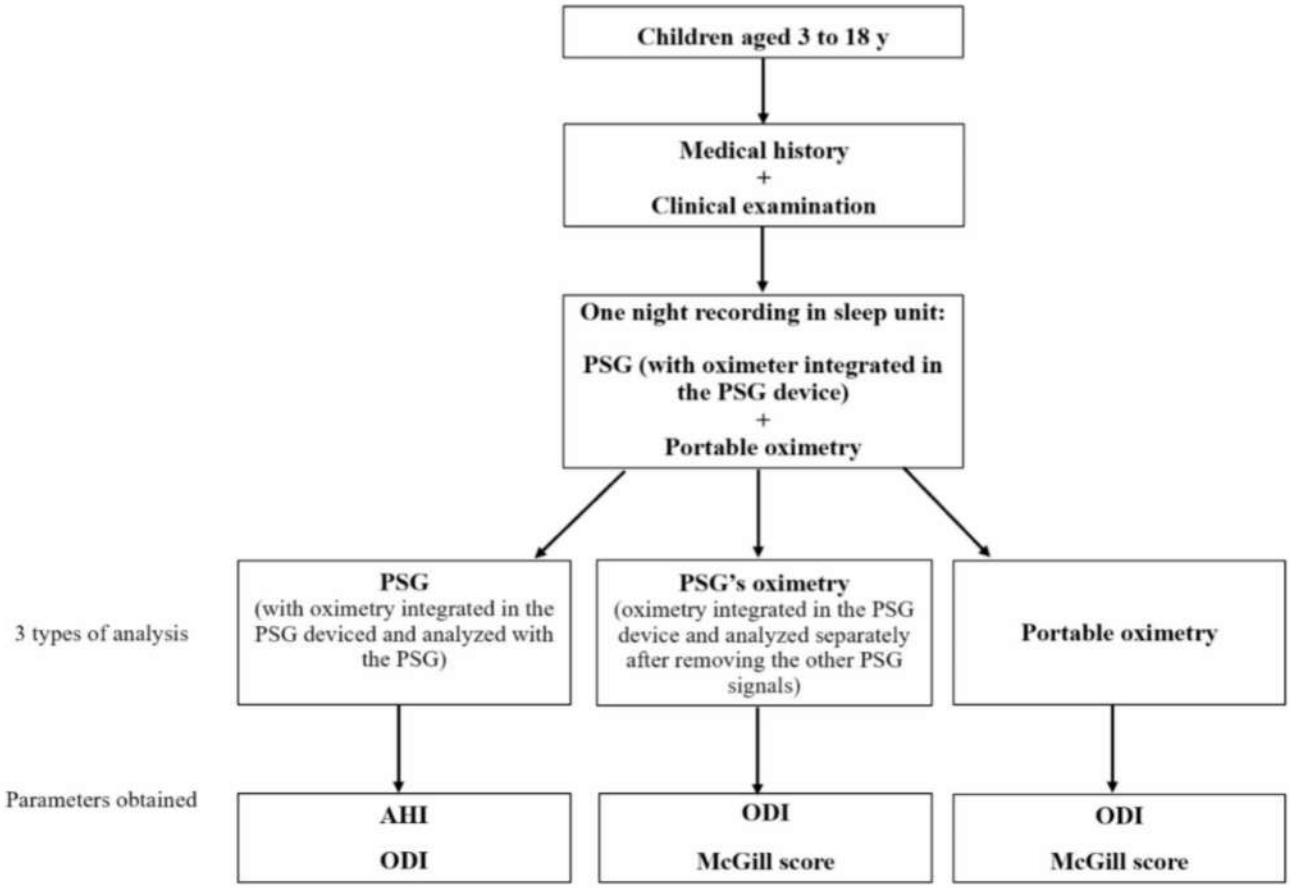

Fig. 1 Flow chart showing the types of analysis performed and the parameters obtained

was removed the next morning, and the recording was downloaded and manually analyzed by a board-certified pediatric sleep physician (I.I.) using pediatric recommendations of American Academy of Sleep Medicine (AASM) to score the sleep and respiratory events [17, 18]. An apnea was defined as a decrease of more than 90% of the flow signal for more than 2 breaths with the persistence of thoraco-abdominal efforts in obstructive apnea and the absence of the thoraco-abdominal efforts in central apnea. Hypopnea was defined as a decrease of more than 30% of flow signal for more than 2 breaths associated with ≥ 3% desaturation and/or microarousal and/or arousal [17]. The following parameters were retained for analysis: TST (defined as the difference between the time spent in bed and the wakefulness periods), the sleep efficiency (computed as the percentage of TST from the total time spent in bed), the percentage of the rapid eye movement (REM) and the non-REM sleep from the TST, the total microarousal index and the respiratory-related microarousal index (computed as the number of microarousals, respectively respiratory-related microarousals divided by TST), the index of obstructive apnea-hypopnea (OAHI, defined as the total number of obstructive apneas, mixed apneas and hypopneas divided by TST), of central apnea (defined as the total number of central apneas divided by TST), of total apnea-hypopnea (defined as the total number of apneas and hypopneas divided by TST), mean SpO2 and the percentage of TST spent with a SpO2 less than 90%. ODI was computed as the total number of ≥ 3% desaturations divided by the TST obtained after manually scoring the PSG (referred here as "*ODI by PSG*").

Computation of oximetric indexes from the oximetry of the polysomnography

After a few weeks since the first PSG analysis, the sleep physician (I.I.) erased the previous PSG scoring and all the signals, except for the oximetry signal. He then blindly scored the oximetry, excluding the child's wakening times and periods with motion artifacts by using the charts filled out by the parents, thereby obtaining another TST. ODI was computed by dividing the total number of ≥ 3% desaturations by this last TST (referred here as "*ODI by PSG's oximetry*"). The sleep physician additionally gave a McGill score

between 1 and 4 to each oximetry tracing [6] that was also retained for analysis.

Computation of oximetric indexes from the nocturnal portable oximetry

A second oximeter sensor from the Radical 7 oximeter (Masimo, France) was put on the child's finger in addition to the oximeter sensor integrated in the PSG device, as part of our standard protocol. The averaging time of this oximeter was 3s and the sampling rate of 1 Hz [19]. The recording was set to start automatically at 20 h in the evening and stop at 8 h in the morning. It was downloaded the following day using the Visi-Download software (Stowood Scientific Instruments Ltd, Oxford, UK). The software automatically extracted artifacts caused by low signal quality and movement. In parallel to the sleep technologist's notes, parents were asked to fill out a chart with the times their child went to sleep and awakened in the morning and through the night. These charts helped to manually analyzed the oximetric recording and the child's wakening times and the periods with motion artifacts were removed by the sleep physician (I.I.), thereby obtaining a total recording time (TRT). The graphical representation of mean SpO2 and cardiac frequency trends, the mean SpO2, the percentage of TRT spent with a SpO2 less than 90%, were then automatically generated by the software, and retained for analysis. ODI was automatically computed by the software as the total number of $\geq 3\%$ desaturations divided by TRT (referred here as "*ODI by portable oximetry*"). A McGill score between 1 and 4 was additionally given to each oximetry tracing and retained for analysis.

Statistical analysis

The statistical analysis was performed using SAS OnDemand for Academics. The quantitative variables were expressed as median [1st; 3rd quartile], as not normally distributed, and the qualitative variables as number (percentage). A descriptive analysis was performed for the entire group and for the children with *moderate/severe OSA* (children with AHI > 5 /h of sleep) [1]. The pairwise comparison between the oximetric parameters obtained by the three methods, was performed by using non-parametric paired Wilcoxon signed rank test. After adjusting for multiple comparisons using Bonferroni correction, a p value ≤ 0.008 was considered statistically significant. The ability of the ODIs to diagnose a *moderate/severe OSA* was tested by using Receiver Operating Characteristics (ROC) curves at different thresholds and the area under the ROC curve (AUC) and its 95% confidence interval (95CI) computed. The sensitivity, the specificity, the positive (PPV) and negative predictive values (NPV) and their 95CI were reported at the relevant thresholds. A p value ≤ 0.05 was considered statistically significant.

Results

Children's clinical characteristics

89 children were included in this study. 8 (9%) were excluded because 4 (4%) slept less than 4 h during the night, 1 (1%) had epileptic seizures during the recording and 3 (3%) had technical issues related to the bluetooth transmission of PSG's oximetry signal.

81 children, 47 (60%) boys and 34 (40%) girls, with median [1st; 3rd quartile] age at the time of recording of 10 [7; 13] years, were finally analyzed. 25 (31%) children had obesity, 7 (9%) metabolic disorders (i.e. Prader-Willi in 4 (5%), growth hormone deficit in 2 (2%), hypothyroidism in 1 (1%)), 4 (5%) Down syndrome, 1 (1%) other genetic disorder, 6 (7%) neurological disorders (i.e. Chiari malformation in 1 (1%), spina bifida in 1 (1%), Guillain-Barré syndrome in 1 (1%), Rubinstein-Taby syndrome in 1 (1%), Silver-Russel syndrome in 1 (1%), psychomotor retardation in 1 (%)), 1 (1%) Robin syndrome, 3 (4%) bronchopulmonary dysplasia, 2 (2%) asthma, 1 (1%) Marfan syndrome, 2 (2%) neurofibromatosis type 1, 1 (1%) sickle cell anemia, 1 (1%) cardiac malformation, 1 (1%) esophageal atresia, 1 (1%) immune deficiency disorder. 25 (31%) children had no comorbidity.

Polysomnography data

Children's PSG data are presented in Table 1 for the entire group and for the children with *moderate/severe OSA*. For the entire group, the median [1st; 3rd quartile] TST was 461 [398; 507] min, the sleep efficiency0.91 [0.80; 0.95], the total arousal index 8.4 [5.9; 10.8] /h and the respiratory-related arousal index 2.8 [2.0; 4.0] /h. The median [1st; 3rd quartile] OAHI was 5.4 [4.0; 9.9] /h and AHI 6.2 [4.5; 11.3] /h. 31 (38%) children had an OAHI ≤ 5 /h (*no/mild OSA*) and 50 (62%) an OAHI > 5/h (*moderate/severe OSA*). In the *moderate/severe OSA* group, median [1st; 3rd quartile] OAHI was 8.7 [6.0; 14.8] /h and AHI 9.5 [6.6; 15.1] /h.

The oximetric parameters

The oximetric parameters obtained by the three methods, PSG, PSG's oximetry and portable oximetry, for the entire group and for the children with *moderate/severe OSA*, are presented in Table 2.

Table 1 Children's characteristics and the polysomnography data for the entire group and for the children from the *moderate/severe OSA* group

	All children	Moderate/ severe OSA group
Number of children (boys)	81 (49)	50 (27)
Age, years	10 [7; 13]	10 [7; 12]
BMI, z-score	1.04 [-0.24; 2.74]	1.04 [-0.48; 2.71]
PSG		
TST, min	461 [398; 507]	466 [399; 515]
Sleep efficiency, %	91 [80; 95]	93 [81; 95]
NREM sleep, % of TST	83 [79; 88]	83 [80; 87]
REM sleep, % of TST	17 [12; 20]	17 [13; 20]
Total arousal index	8.4 [5.9; 10.8]	9.4 [7.3; 12.7]
Respiratory-related arousal index	2.8 [2.0; 4.0]	3.8 [2.4; 6.2]
AHI	6.2 [4.5; 11.3]	9.5 [6.6; 15.1]
OAHI	5.4 [4.0; 9.9]	8.7 [6.0; 14.8]
CAI	0.4 [0.1; 0.8]	0.5 [0.2; 1.1]
Mean SpO2, %	96 [95; 97]	96 [94; 97]
Percentage of TST spent with SpO2 less than 90%	0 [0; 0.1]	0.1 [0; 0.3]
ODI	4.3 [2.1; 7.5]	6.7 [4.7; 12.7]

Data are expressed as median [1st; 3rd quartile]. The indexes are expressed as the total number of events per hour of sleep. *Abbreviations* BMI = body mass index; TST = total sleep time; NREM = non rapid eye movement; OAHI = obstructive apnea-hypopnea index; CAI = central apnea index; AHI = apnea-hypopnea index; SpO2 = pulse oxygen saturation; ODI = ≥ 3% oxygen desaturation index

Table 2 The oximetric parameters obtained by the three methods: polysomnography (PSG), PSG's oximetry and portable oximetry for the entire group and for the children with *moderate/severe OSA*

	All children	Moderate/ severe OSA group
Number of children (boys)	81 (49)	50 (27)
PSG		
Mean SpO2, %	96 [95; 97]	96 [94; 97]
Percentage of TST spent with SpO2 less than 90%	0 [0; 0.1]	0.1 [0; 0.3]
ODI, /h of sleep	4.3 [2.1; 7.5]	6.7 [4.7; 12.7]
PSG's oximetry		
Mean SpO2, %	96 [95; 97]	96 [95; 97]
Percentage of TST spent with SpO2 less than 90%	0 [0; 0.1]	0.1 [0; 0.3]
ODI, /h of sleep	5.7 [3.0; 11.2]	8.9 [5.2; 14.9]
McGill score	1 [1; 1]	1 [1; 2]
Portable oximetry		
Mean SpO2, %	96 [96; 97]	96 [95; 97]
Percentage of TRT spent with SpO2 less than 90%	0 [0; 0.03]	0.01 [0; 0.2]
ODI, /h of recording	6.0 [3.9; 10.2]	8.2 [4.9; 14.3]
McGill score	1 [1; 1]	1 [1; 2]

Data are expressed as median [1st; 3rd quartile]. *Abbreviations* TST = total sleep time; SpO2 = pulse oxygen saturation; ODI = ≥ 3% oxygen desaturation index; TRT = total recording time

In the entire group, ODI was significantly lower in PSG compared to PSG's oximetry or portable oximetry ($p < 0.0001$ for both). There was no statistical difference in ODI or McGill score between PSG's oximetry and portable oximetry.

In the *moderate/severe OSA* group, ODI was significantly lower in PSG than in PSG's oximetry ($p < 0.0001$) and tended to be lower in PSG compared to portable oximetry. There was no difference in ODI or McGill score between PSG's oximetry and portable oximetry.

Area under the curve, sensitivity, specificity, and predictive values for oximetric indexes

The AUC's, sensitivity, specificity, PPV and NPV and their 95CI for ODIs and McGill scores for diagnosing a *moderate/severe OSA*, are presented in Table 2 and in Fig. 2.

The optimal threshold for ODI by PSG to predict *moderate/severe OSA* was 4.3/h with an AUC of 0.92, sensitivity of 0.84, specificity 1.0, PPV of 1.0 and NPV of 0.79.

The optimal threshold for ODI by PSG's oximetry to predict *moderate/severe OSA* was 5.8/h with an AUC of 0.86, sensitivity of 0.72, specificity 0.90, PPV of 0.92 and NPV of 0.67.

The optimal threshold for ODI by portable oximetry to predict *moderate/severe OSA* was 7.5/h with an AUC of 0.78, sensitivity of 0.60, specificity 0.87, PPV of 0.88 and NPV of 0.57.

The McGill scores by PSG's oximetry and portable oximetry showed a low AUC with high specificity and PPV and low sensitivity and NPV.

Altogether, the best pattern of sensitivity– specificity was shown by ODI by PSG, followed by ODI by PSG's oximetry and ODI by portable oximetry.

Discussion

This prospective study was conducted in a group of children and adolescents who were typical of a tertiary sleep clinic. The participants included both those with and without comorbidities, who were referred for suspicion of OSA for a routine PSG evaluation. In this population, all ODI's, performed by PSG, PSG's oximetry or portable oximetry, demonstrated a significant diagnostic ability in distinguishing *moderate/severe OSA*, with high AUC values. The specificity and positive predictive value were high for all

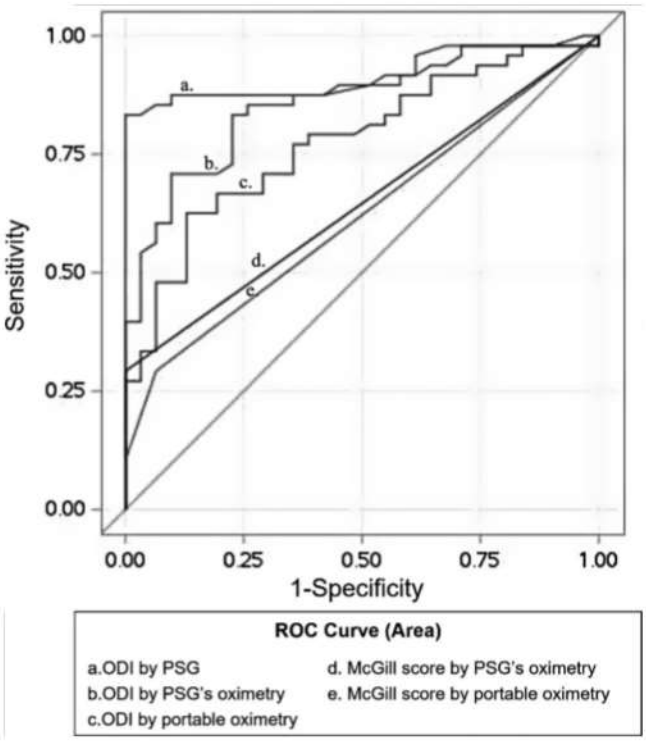

Fig. 2 ROC curves for the oxygen desaturation indexes (ODI) and the McGill scores to discriminate between children with *moderate/severe* obstructive sleep apnea (*OSA*) and children with *mild/no OSA*. Abbreviations: PSG = polysomnography

ODIs and McGill scores, whereas the sensitivity and negative predictive values were moderate for ODIs and low for McGill scores.

Portable oximetry may be performed in either a home or hospital setting, requiring just the placement of a sensor on the child's finger. This method is much simpler and comfortable for both the child and their family compared to the PSG. Prior studies have identified oximetric parameters that differentiate children with *moderate/severe OSA* from those with *no/mild OSA*. The McGill score, a qualitative measure, obtained in our study from PSG's oximetry and portable oximetry tracings, showed good specificity and PPV in diagnosing *moderate/severe OSA*. However, it had low specificity and NPV, with lower AUC values compared to ODIs (Table 3). The results of our study align with those of a previous retrospective study that involved children with numerous coexisting medical conditions. These children had either hospital-based or home-based nocturnal oximetry, as well as a PSG within three to four months of their initial oximetry [10]. The McGill score exhibited comparable specificity and PPV to that observed in our children. However, the sensitivity and NPV were slightly higher, with a sensitivity of 0.59 compared to 0.30 in our study, and a NPV of 0.78 compared to 0.47 in our study [10]. These findings were confirmed in a prospective study that included children referred for adenotonsillar hypertrophy or obesity with a positive sleep clinical record [20], suggesting that a PSG should be conducted in children with a McGill score of 1 or 2 [10, 20].

In our study, ODI was determined using three different methods: PSG, PSG's oximetry, and portable oximetry. All ODIs had a significant diagnostic value, as assessed by the AUC, with a high specificity and PPV in diagnosing *moderate/severe OSA*. The optimal thresholds for diagnosis varied according to the device utilized. The variations in thresholds can be attributed to the fact that the ODI by PSG is more precise as it is computed on the TST after manual scoring of the PSG. On the other hand, the ODI by PSG's oximetry and portable oximetry were computed on either the TST or TRT, both of which were manually scored by an experienced sleep physician using charts filled out by sleep technologists and parents. These charts may include instances of awakening, which could affect the accuracy of the calculations. However, the sensitivity and NPV of ODIs were higher compared to McGill scores (Table 3). Among the three methods, ODI by PSG had the highest AUC, sensitivity and NPV, followed by ODI by PSG's oximetry and ODI by portable oximetry. Our findings indicate that ODI might be employed as a standard procedure in a real-world setting to assess patients for *moderate/severe OSA*.

Prior studies have found varying thresholds for ODIs and various sensitivity-specificity patterns. However, these studies differed from our own in terms of methodology and generally included children without comorbidities. The threshold for ODI by PSG was considerably lower than in our study, 1/h, with lower sensitivity, of 0.78, compared to 0.84 in our study, and specificity of 0.57 compared to 1.0 in

Table 3 Area under the receiver operating curves (AUC), sensitivity, specificity, positive (PPV) and negative (NPV) predictive values and their 95% confidence interval for the oxygen desaturation indexes (ODI) and McGill scores to predict *moderate/severe OSA* at the optimal threshold obtained by the ROC curves

	Threshold	AUC	Sensitivity	Specificity	PPV	NPV
PSG	ODI ≥ 4.3/h	0.92 (0.85; 0.98)*	0.84 (0.71; 0.93)*	1.0 (0.89; 1.0)*	1.0 (0.92; 1.0) *	0.79 (0.64; 0.91) $
PSG's oximetry	ODI ≥ 5.8/h	0.86 (0.77; 0.94)*	0.72 (0.58; 0.84)^	0.90 (0.74; 0.98) *	0.92 (0.79; 0.98) *	0.67 (0.50; 0.80) °
	McGill score ≥ 2	0.65 (0.58; 0.71)*	0.30 (0.18; 0.45)	1.0 (0.89; 1.0) *	1.0 (0.78; 1.0) *	0.47 (0.35; 0.60)
Portable oximetry	ODI ≥ 7.5/h	0.78 (0.67; 0.88)*	0.60 (0.45; 0.74)	0.87 (0.70; 0.96) *	0.88 (0.73; 0.97) *	0.57 (0.42; 0.72)
	McGill score ≥ 2	0.62 (0.54; 0.69)#	0.30 (0.18; 0.45)	0.94 (0.79; 0.99)*	0.88 (0.64; 0.99)#	0.45 (0.33; 0.58)

*$p < 0.0001$; $^{\$}p = 0.0003$ (0.0002 for AUX delta 12s; $^{\wedge}p = 0.003$; $^{\#}p = 0.002$;° $p = 0.044$ *Abbreviations* PSG = polysomnography

our study [8]. The inclusion of clinical indicators in addition to the ODI by PSG resulted in a considerable improvement in both sensitivity and specificity [8]. ODI by PSG's oximetry was previously computed in a retrospective study that involved a population different from ours. This study included children, with more than one third of them having obesity and about two-thirds being otherwise healthy. The ODI by PSG's oximetry had also a higher AUC compared to the AUC of the McGill score [14]. Furthermore, employing modern approaches, such as an automated neural network algorithm based on overnight oximetry recordings, the diagnostic value of oximetry enhanced, as demonstrated by the high AUC value in identifying a *moderate/severe OSA* in snoring, otherwise healthy, children [21].

There was only a limited number of research that focused on children who had comorbidities. Children with Down syndrome had a significantly high AUC value of 0.83 for ODI by portable oximetry, with high sensitivity of 0.92, but a low specificity of 0.63 [22]. In obese children, ODI by portable oximetry has shown a high sensitivity of 0.84 with high NPV of 0.81 in identifying *moderate/severe OSA* [23]. On the other hand, ODI by PSG's oximetry has shown a moderate specificity of 0.73 in identifying m*ild OSA* [13]. The high specificity of ODIs in our study might be the results of the presence of comorbidities in more than two-thirds of our children leading to a more severe OSA. This indicates that if children have negative oximetry results, i.e. low ODI, and there is a strong suspicion of OSA, they should be referred for a more thorough evaluation with a comprehensive sleep exam in a sleep lab. One limitation of utilizing oximetry for diagnosing OSA is that partial airway obstructions, or hypopneas, are not necessarily accompanied by desaturations, but by micro-arousals, and hence are not identified by oximetry [11].

There are numerous oximetry devices available, each with different characteristics in terms of sampling time, response time, and analysis algorithm of different parameters. The device used in our study is particularly effective at accurately removing periods of movement, which might explain the disparity in threshold values observed between studies. The inclusion of population, whether with or without comorbidities, may be an additional factor that impacts the threshold and the diagnostic value of ODI.

Our study has several strengths as the use of PSG as diagnostic exam with videorecording and sleep technologist's attendance during the night, the gold standard for diagnosing OSA in children, the computation of AHI and ODI according to recent recommendations [17], the use of portable oximetry in parallel with the PSG recording and the manual analysis of all tracings by an experienced sleep physician. We consider that inclusion of children with comorbidities is a strength of the study. Our patients' profile is typical of a tertiary sleep clinic in real life, and validating oximetry indexes in these patients may help to expedite the time it takes for a more comprehensive exam. It is important to highlight that these findings should be taken with caution and not applied universally, because in our cohort, more than two-thirds of the children had comorbidities and the results may be bias due to the increased severity of OSA in our population. Moreover, sleep devices employ varying frequencies to capture the SpO2 signal. Additional extensive research is required to validate these findings, with the manufacturers being urged to standardize and enhance the automated signal processing methods.There are several limitations in our study. The inclusion of adolescents up to the age of 18 may be regarded as a limitation, since beyond the age of 16, they may be more representative of the adult population. However, this aligns with our routine clinical practice, where pediatric guidelines apply up to the age of 18. The sleep exams were performed at the hospital, and it might be argued that the quality of the exams may differ when carried out at home due to the existence of additional artifacts that can impact the interpretation and the computation of ODI. More studies are needed to evaluate if the exams conducted at the hospital resemble those performed in a home environment in terms of quality and interpretability.

Conclusion

ODI by portable oximetry alone or by PSG's oximetry with manual scoring by an experienced sleep physician demonstrated a strong diagnostic ability for identifying *moderate/severe OSA* in children and adolescents referred for OSA, particularly in those with a pre-existing comorbidity. The specificity and positive predictive values were excellent, and the optimal thresholds varied depending on the device utilized. Oximetry can serve as an effective tool for screening patients with suspicion of OSA and for determining the priority for a comprehensive sleep exam in patients with or without comorbidities and low ODI. On the other hand, children who have a high ODI should be addressed to an ENT physician for adenotonsillectomy if necessary or to a pediatric pulmonologist for assessment and potential continuous positive airway pressure therapy. Our results may not be generalizable and should be limited mainly to children with comorbidities in the setting of a tertiary pediatric sleep center. Larger prospective studies are further required to validate the optimal thresholds for different methods and devices in identifying children with *moderate/severe OSA* with varying comorbidities, who perform simultaneously PSG and portable oximetry, with thorough manual analysis of the recordings and addition of clinical characteristics and

other simplified tools as pulse transit time or mandibular movement sensor.

Acknowledgements The authors thank Claude Bonabel, Claire Abenzoar, Lucie Kempf, Myriam Chamagne, Marie-Jeanne Arnoux, Francine Cael, and Aurelia Datin for their technical assistance, and also children and their parents.

Author contributor Conception and study design: MM, II, CS, SDM, AT, LC Patient data collection: MM, II, ER, SDM Polysomnographic analysis: MM, II, SDM Statistical analysis: MM, II, ER, SDM Interpretation of results: MM, II, ER, SDM, PF, LC, CS Manuscript preparation: MM, II, ER, AT, LC Final revision: MM, II, CS, AT, PF, LC Number of tables: 3 Number of figures: 2 Abstract word count: 231 Manuscript word count: 3711 References: 23.

Funding No external funding for this manuscript.

Declarations

Ethical approval Each author listed on the manuscript has seen and approved the submission of this version of the manuscript and takes full responsibility for the manuscript. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest The authors have indicated they have no potential conflicts of interest to disclose.

References

1. Kaditis AG, Alvarez MLA, Boudewyns A et al (2016) Obstructive sleep disordered breathing in 2-to 18-year-old children: diagnosis and management. Eur Respir J 47(1):69–94
2. Marcus CL (2000) Pathophysiology of childhood obstructive sleep apnea: current concepts. Respir Physiol Feb 119(2–3):143–154
3. Franco P, Bourdin H, Braun F, Briffod J, Pin I, Challamel M-J (2017) Diagnostic Du syndrome d'apnée obstructive Du Sommeil Chez L'enfant (2–18 ans): place de la Polysomnographie et de la polygraphie ventilatoire. Médecine Du Sommeil 14(2):77–88
4. Paiva T, Attarian H (2014) Obstructive sleep apnea and other sleep-related syndromes. Handb Clin Neurol 119:251–271
5. Brouillette RT, Morielli A, Leimanis A, Waters KA, Luciano R, Ducharme FM (2000) Nocturnal pulse oximetry as an abbreviated testing modality for pediatric obstructive sleep apnea. Pediatr Feb 105(2):405–412
6. Nixon GM, Kermack AS, Davis GM, Manoukian JJ, Brown KA, Brouillette RT (2004) Planning adenotonsillectomy in children with obstructive sleep apnea: the role of overnight oximetry. Pediatr Jan 113(1 Pt 1):e19–25
7. Trucco F, Rosenthal M, Bush A, Tan HL (2020) The McGill score as a screening test for obstructive sleep disordered breathing in children with co-morbidities. Sleep Med Apr 68:173–176
8. Chang L, Wu J, Cao L (2013) Combination of symptoms and oxygen desaturation index in predicting childhood obstructive sleep apnea. Int J Pediatr Otorhinolaryngol Mar 77(3):365–371
9. Tsai CM, Kang CH, Su MC et al (2013) Usefulness of desaturation index for the assessment of obstructive sleep apnea syndrome in children. Int J Pediatr Otorhinolaryngol Aug 77(8):1286–1290
10. Jonas C, Thavagnanam S, Blecher G, Thambipillay G, Teng AY (2020) Comparison of nocturnal pulse oximetry with polysomnography in children with sleep disordered breathing. Sleep Breath Jun 24(2):703–707
11. Kaditis A, Kheirandish-Gozal L, Gozal D, Pediatric OSAS (2016) Oximetry can provide answers when polysomnography is not available. Sleep Med Rev Jun 27:96–105
12. Kirk VG, Bohn SG, Flemons WW, Remmers JE (2003) Comparison of home oximetry monitoring with laboratory polysomnography in children. Chest Nov 124(5):1702–1708
13. Van Eyck A, Lambrechts C, Vanheeswijck L et al (2015) The role of nocturnal pulse oximetry in the screening for obstructive sleep apnea in obese children and adolescents. Sleep Med Nov 16(11):1409–1412
14. Polytarchou A, Ohler A, Moudaki A et al (2023) Nocturnal oximetry parameters as predictors of sleep apnea severity in resource-limited settings. J Sleep Res Feb 32(1):e13638
15. Organization WH (1998) Obesity: preventing and managing the global epidemic: report of a WHO consultation on obesity, Geneva, 3–5 June 1997. World Health Organization, Geneva
16. Nonin Medical I (2023) Oxymètre de pouls WristOx2®modèle 3150 BLE et USB. https://www.physicor.ch/wp-content/uploads/2019/01/112864-002-02_FRE.pdf. Accessed Feb 24
17. Berry RB, Budhiraja R, Gottlieb DJ et al (2012) Rules for scoring respiratory events in sleep: update of the 2007 AASM Manual for the Scoring of Sleep and Associated events. Deliberations of the Sleep Apnea definitions Task Force of the American Academy of Sleep Medicine. J Clin Sleep Med Oct 15(5):597–619
18. Iber C, Ancoli-Israel S, Chesson A, Quan S (2007) The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications: American Academy of Sleep Medicine. *Westchester, IL*.
19. Masimo Corporation (2023) Radical-7® Pulse CO-Oximeter® Operators's Manual. https://techdocs.masimo.com/globalassets/techdocs/pdf/lab-5475j_master.pdf. Accessed Feb 20
20. Villa MP, Pietropaoli N, Supino MC et al (2015) Diagnosis of pediatric obstructive sleep apnea syndrome in settings with limited resources. JAMA Otolaryngology–Head Neck Surg 141(11):990–996
21. Hornero R, Kheirandish-Gozal L, Gutiérrez-Tobal GC et al (2017) Nocturnal oximetry-based evaluation of habitually snoring children. Am J Respir Crit Care Med Dec 15(12):1591–1598
22. Hill CM, Elphick HE, Farquhar M et al (2018) Home oximetry to screen for obstructive sleep apnoea in Down syndrome. Arch Dis Child Oct 103(10):962–967
23. Evangelisti M, Shafiek H, Rabasco J et al (2016) Oximetry in obese children with sleep-disordered breathing. Sleep Med Nov-Dec 27–28:86–91