Sleep Medicine 16 (2015) 1077–1083

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

Predicting poor school performance in children suspected for sleep-disordered breathing

Pablo E. Brockmann [a,b,*], Martin Schlaud [c], Christian F. Poets [a], Michael S. Urschitz [a,d]

[a] Working Group on Pediatric Sleep Medicine, Department of Neonatology, University Children's Hospital, Tuebingen, Germany
[b] Department of Pediatrics, School of Medicine, Pontificia Universidad Catolica de Chile, Santiago, Chile
[c] Department of Epidemiology and Health Monitoring, Robert Koch Institute, Berlin, Germany
[d] Institute of Medical Biostatistics, Epidemiology, and Informatics, University Medical Center, Johannes Gutenberg University, Mainz, Germany

ARTICLE INFO

Article history:
Received 7 January 2015
Received in revised form 27 March 2015
Accepted 30 March 2015
Available online 4 May 2015

Keywords:
Obstructive sleep apnea
Questionnaire
Oximetry
polysomnography
School performance
Child

ABSTRACT

Objective: Habitually snoring children are at a greater risk of poor school performance (PSP). We investigated the ability of conventional sleep-disordered breathing (SDB) measures for predicting PSP in habitually snoring children.
Methods: The dataset of Hannover Study on Sleep Apnea in Childhood (HASSAC), a large community-based study in primary school children, was retrospectively analyzed. All habitual snorers were included. Based on their grades, children were grouped into good and poor school performers. SDB measures obtained by a parental questionnaire, a home pulse oximetry, and a home polysomnography were evaluated for their accuracy in predicting poor school performance by calculating receiver operating characteristic curves and area under this curve (AUC). The most predictive single factors were identified and entered into a prediction model.
Results: Of 114 habitual snorers (mean age 9.6 years, 51 boys), 59 had PSP. All investigated SDB measures showed low accuracy (ie, AUC <0.8). The highest AUC observed was 0.686 for a questionnaire score, 0.565 for an oximetry factor, and 0.624 for a polysomnography factor. Of 20 single significant predictors for PSP, five were selected for inclusion into a prediction model. The model reached an unadjusted AUC of 0.826 and an adjusted AUC of 0.851.
Conclusions: Conventional SDB measures obtained with questionnaire, oximetry, or polysomnography may not be sufficiently predictive of PSP in children suspected for SDB. However, combining factors in a clinical prediction model may improve prediction. Results of such a model may be used to assess the risk of developing neurocognitive impairment and to decide whether a child suspected for SDB might benefit from treatment.

1. Introduction

Sleep-disordered breathing (SDB), among other socioeconomic and biological factors, may be associated with neurocognitive impairment (NCI) as evidenced by poor school performance (PSP) [1,2], inattentive and hyperactive behavior [3,4], and other externalizing behavioral problems in children [5,6]. In 2006, a comprehensive review showed that the overwhelming majority of published studies support a causal association between SDB and NCI [7]. However, convincing interventional data are lacking. Recently, the childhood adenotonsillectomy (CHAT) study found that children with SDB on average had largely normal results on neurocognitive tests before, and no significant improvement following, treatment. In contrast to neurocognitive tests, these children showed significantly improved functioning in their school setting on teacher ratings [8]. Thus, PSP may be an SDB-sensitive "real-world" marker of NCI in children.

SDB-associated intermittent hypoxia during sleep and sleep fragmentation has been postulated as mediating factors in the relationship between SDB and NCI [6,9]. Consequently, habitual snoring without intermittent hypoxia and sleep fragmentation (ie, primary snoring) should not be associated with NCI. There is increasing evidence, however, that NCI is more frequent in children with primary snoring compared to never-snoring controls. In these studies, primary snoring was associated with several cognitive impairments [10], problems in memory [3], language, and visuospatial areas [11]. In one study, there was no obvious difference between primary snorers and patients with obstructive sleep apnea (OSA) regarding daytime sleepiness and hyperactive behavior [12]. More recently, children with primary snoring were found to be at higher

* Corresponding author. Pediatric Pulmonologist, Sleep Medicine, Assistant Professor of the Department of Pediatric Cardiology and Pulmonology, School of Medicine, Pontificia Universidad Católica de Chile, Lira 85 5to piso, 330074 Santiago de Chile, Chile. Tel.: +56 2 23543767; fax: +56 2 2638 4307.
E-mail address: pbrockmann@med.puc.cl (P.E. Brockmann).

http://dx.doi.org/10.1016/j.sleep.2015.03.021
1389-9457/

risks for NCI than never-snoring controls, with effects being similar to those in children with upper airway resistance syndrome or OSA [13]. Hence, there is increasing evidence that primary snoring is not a benign condition.

Despite the association between SDB and NCI, there is yet no test available that can accurately predict NCI in children suspected for SDB. This includes sleep-laboratory-based polysomnography (PSG) as the current gold standard for diagnosing SDB. PSG and the PSG-based apnea–hypopnea index (AHI) identify OSA, but the AHI in particular often fails to predict NCI in children suspected for SDB. In one study, a questionnaire score showed better correlations with NCI markers such as hyperactive-inattentive behavior and daytime sleepiness than the simultaneously obtained AHI [14]. Thus, accurate predictors for NCI – PSG and non-PSG-based – are obviously needed.

Medical history, questionnaires, physical examination, oximetry, and home PSG are methods with unknown or insufficient diagnostic test accuracy for diagnosing OSA in children [15,16]. They may be used alone or combined, however, to predict NCI in subjects with SDB. We, hence, set out to identify potential predictors of PSP as one important marker of NCI in childhood. We specifically aimed to investigate the usefulness of easily available clinical information obtained by a parental SDB-questionnaire (SDB-Q), home pulse oximetry (HPO), and home PSG. By using this information, we aimed to create and validate a prediction model for PSP, based on the already published dataset of the Hannover Study on Sleep Apnea in Childhood (HASSAC) (Urschitz et al. 2011).

2. Methods

2.1. The Hannover study on sleep apnea in childhood

2.1.1. Study design

HASSAC was a community-based cross-sectional study on several aspects of SDB in school-aged children conducted between February and December 2001. Methods and main results have been outlined in detail elsewhere [17,18]. HASSAC incorporated a two-phase sequential screening procedure. Participants were screened twice for symptoms and signs of SDB using an SDB-Q and HPO. Children with outlying results on either screening method subsequently underwent home PSG for a final diagnosis of OSA.

2.1.2. Subjects

Twenty-seven of 59 public primary schools located within the city limits of Hannover, Germany, were randomly selected. After approval by the institutional review board and the regional directorate of education, all children attending third-grade classes in these schools were identified and contacted in their classrooms. Of 1760 eligible third graders in classes of the sampled schools, 1144 individuals (65.0%, mean age 9.6 ± 0.7 years) provided parental informed consent, and they were enrolled. Comparisons to the target population of all children of the same grade living in Hannover city ($n = 4109$) revealed good to excellent representativeness of the study sample in terms of gender distribution, parental education, and the prevalence of childhood asthma [17].

2.1.3. Questionnaire

Detailed descriptions of the questionnaire are given elsewhere [17,19]. Briefly, the SDB-Q by Gozal [1] was adjusted to enable the calculation of the OSA score according to Brouillette [20], and it was extended with items on demographic, socioeconomic, and anthropometric characteristics [17], daytime behavior [21], frequent sleep problems [22], and current health status. The OSA score according to Brouillette [20], the SDB score according to Gozal [1], the Snore score according to Gozal [23], and an adapted SDB score according to Paditz [21] were calculated. Details on the calculation of the scores are given elsewhere [17,24]. In short, for the calculation of scores, arbitrary numerical values were assigned to each of the answers ranging from 0 (never), 1 (rarely), 2 (occasionally), 3 (frequently) to 4 (always/almost always). Missing answers were scored as 0. The adapted SDB score according to Paditz consisted of the items 1–14 and 20–21 of the SDB-Q. In contrast to Gozal's SDB score (13 items), the adapted Paditz score comprised 16 items (including questions on hyperactive behavior, attention deficits, and frequency of respiratory tract infections). In a first comparison, the correlation coefficient for the original Gozal score and the adapted Paditz score was $r = 0.931$ [17]. The Paditz score was subsequently validated concerning its accuracy in predicting OSA on home PSG [24]. Snoring was assessed with the question "Does your child snore?" and it was rated on a four-point Likert scale. Children were classified as habitual snorers if the answers were "frequently" or "always."

2.1.4. Home pulse oximetry

A detailed description of HPO is presented elsewhere [25,26]. Briefly, recordings of arterial oxygen saturation measured by pulse oximetry (SpO_2) were performed overnight in the child's home. Data analysis software was used to determine artifact-free recording time and to calculate the mean, standard deviation, median, fifth, and 10th centile SpO_2, as well as the number of desaturation events of ≥4% SpO_2, the average distance from the optimum of 100% SpO_2, and a cumulative hypoxemia score [26]. Recordings with artifact-free recording time <5 h were excluded. The nadir SpO_2, the number of desaturation events to ≤92% and to ≤90% SpO_2, as well as desaturation event clusters [27] were manually determined using information on signal quality, low perfusion, and pulse waveform. Desaturation indices, defined as events per hour of artifact-free recording, were calculated for desaturation events of ≥4% SpO_2, desaturation events to ≤92% and to ≤90% SpO_2 as well as desaturation event clusters.

2.1.5. Home PSG

A detailed description of the home PSGs is presented elsewhere [13,28]. Briefly, home PSG was performed overnight in the children's homes. The montage comprised chest and abdominal wall movements, nasal pressure and linearized nasal airflow estimation, oral airflow, snoring, SpO_2, pulse rate, pulse waveform, body movements and position, and user events. Corrected estimated total sleep time was calculated according to published criteria [28]. Recordings with corrected estimated total sleep time <4 h were excluded. Recordings were manually analyzed for central, mixed and obstructive apneas, hypopneas, and flow limitations based on a guideline by the American Academy of Sleep Medicine [29]. Flow limitations were defined as a reduction of the nasal airflow amplitude by >50% for more than two breathing cycles, not associated with desaturation events of ≥4% SpO_2 [13]. Respiratory event indices, as number of events per hour of corrected estimated total sleep time, were calculated for (i) central, obstructive, and mixed apneas (apnea index); (ii) mixed and obstructive apneas and hypopneas (mixed obstructive apnea–hypopnea index (MOAHI)); (iii) central, obstructive, and mixed apneas and hypopneas (AHI); (iv) central, obstructive and mixed apneas, hypopneas, and flow limitations (respiratory disturbance index); and (v) obstructive and mixed apneas, hypopneas, and flow limitations (obstructive respiratory disturbance index).

2.1.6. Assessment of school performance

With parental consent, last term's report form was obtained from the school archive. As usual for the German educational system, the report forms included written ratings on a six-point scale (1 for "outstanding," 2 for "good," 3 for "satisfactory," 4 for "sufficient," and 5 and 6 for "failed") for mathematics, science, spelling, reading, handwriting, ability to study, and attitude toward peers. On an empirical basis, previous studies of this group had suggested that performance in mathematics, science, and spelling may be particularly affected by SDB [2,13]. Thus, PSP was defined for the current study