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ORIGINAL ARTICLE

Neurocognitive and behavioural abnormalities in paediatric sleep-related breathing disorders

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KEYWORDS
Sleep-related breathing disorders;
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Abstract
Introduction: Behavioural and neurocognitive abnormalities in children may be a consequence of sleep-related breathing disorders. The effectiveness of assessments based on questioning parents is dubious and objective assessment tools are therefore required.
Aim: To ascertain the impact of these abnormalities in children with sleep-related breathing disorders and compare the reliability of questioning parents in relation to validated psychological tests.
Method: A prospective study was performed on 20 children with sleep-related breathing disorders and 20 healthy control children between 3 and 12 years of age. Both groups were subjected to a battery of validated psychological tests. The results of both groups were compared with each other and with the response to clinical questionnaires given to parents in the problem group.
Results: More than 75% of the cases in the problem group presented abnormalities with regard to attention, anxiety, memory, and spatial structuring. The percentage involvement in all concepts was higher in the problem group. Comparisons of attention (40% of children affected in the control group and 80% in the problem group), memory (50% and 84.2%), and spatial structuring (45% and 75%) were statistically significant. More abnormality was observed in the parameters assessed with psychological tests than the equivalent concept obtained from interviewing the parents. Comparison of abnormal concentration assessed from the questionnaires (40% of children affected) with attention during the psychological test (80%), memory (15% and 84.21%), and delayed language development (10%) compared to spatial structuring (75%) was statistically significant.
Conclusions: A high prevalence of behavioural and neurocognitive abnormalities was observed in children with sleep-related breathing disorders compared to a control group o healthy children. The use of objective assessment such as psychological tests revealed more abnormalities than were expressed by parents in response to clinical interviews.

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PALABRAS CLAVE
Trastornos respiratorios del sueño;
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Tests psicológicos

Alteraciones neurocognitivas y conductuales en los trastornos respiratorios del sueño infantil

Resumen
Introducción: Las alteraciones de conducta y neurocognitivas en los niños pueden ser consecuencia del trastorno respiratorio del sueño. Los medios de evaluación basados en el interrogatorio a los padres tienen una eficacia dudosa y por ello se requieren herramientas objetivas de valoración.
Objetivo: Averiguar el impacto de estas alteraciones en niños con trastornos respiratorios del sueño y comparar la fiabilidad del interrogatorio a los padres respecto a los tests psicológicos validados.
Método: Estudio prospectivo de 20 niños con trastornos respiratorios del sueño y 20 controles sanos entre 3 y 12 años de edad. Se sometió a ambos grupos a una batería de tests psicológicos validados. Se comparan los resultados entre ambos grupos y los resultados de estos tests con la respuesta a los cuestionarios aplicados a los padres en el grupo de casos.
Resultados: En el grupo de casos, más del 75% presentaba alteraciones de atención, ansiedad, memoria y estructuración espacial. Los porcentajes de afección en todos los conceptos fueron superiores en el grupo de casos. Resultan estadísticamente significativas las comparaciones de la atención (el 40% de niños afectados en el grupo control y el 80% en el grupo de casos), la memoria (el 50 y el 84,2%) y la estructuración espacial (el 45 y el 75%). Se observa mayor alteración de los parámetros valorados con los tests psicológicos que en los conceptos equivalentes obtenidos del interrogatorio de los padres. Resultaron estadísticamente significativas las comparaciones entre alteración de concentración valorada en el interrogatorio (el 40% de niños afectados) con la atención en el test psicológico (80%), la memoria (el 15 y el 84,21%) y retraso en el lenguaje (10%) comparado con la estructuración espacial (75%).
Conclusiones: Se observa una alta prevalencia de alteraciones de conducta y neurocognitivas en los niños con trastornos respiratorios del sueño comparados con un grupo equivalente de niños sanos. Con la utilización de tests psicológicos se observa mayor afección por estas alteraciones respecto a lo expresado por los padres en los interrogatorios clínicos.

Introduction

Sleep-disordered breathing (SDB) in children requires increasing attention from the specialists involved, among other reasons, due to the negative consequences that may arise if it is not treated or is treated with delay.[1-3]

We know that it is not frequent to detect in children the excessive daytime sleepiness[1,4,5] that is typical of SDB in adults, but it is possible to notice behavioural changes such as irritability and aggression, as well as neurological and cognitive disorders.[3,6-8] It is clear that these neurocognitive and behavioural disorders observed with SDB in children may condition both the evolution of the affected child and our approach to the disease.

The frequency of behavioural and attention alterations is multiplied by 3 in children with SDB.[9] It has been shown that attention deficit and hyperactivity in children are clearly related to symptoms attributable to SDB. These parameters are important, since the capacity for attention is important in learning and, therefore, in social and academic development.[10]

As reported in the literature, the different alterations in children with SDB in relation to the field of knowledge range from changes in general intelligence and memory to verbal intelligence and executive cognitive disorders.[11-13]

A recent publication presented a prospective study of 73 children, based on a clinical questionnaire which was passed to parents and included questions about sleep quality, respiratory problems, and behaviour and neurocognitive alterations.[14] Of the 73 children tested, only 28% referred to excessive daytime sleepiness. However, over 50% of cases related aggression or hyperactivity; 41%, difficulty in concentration; 36%, speech alterations; 18%, memory deficit; and 20%, school performance below the average of their classmates. The lack of correlation between clinical alterations and the responses in the questionnaires with the objective parameters measured by nocturnal polysomnography (PSG) were highlighted. Therefore, the need for measuring behavioural and knowledge disorders with more objective tools that enable them to be compared with a control group of healthy children was stressed.

This publication presents the first data from a prospective study comparing children with SDB against a group of control children using validated psychological tests. The objective is to determine the true impact of these disorders in children with SDB, the reliability of parent interviews and, lastly, the long-term evolution after adenotonsillar surgery.

Methods

This is a prospective study initiated in January 2007 and still active. All children between 3 and 12 years attending the otolaryngology clinic with a clinical presentation compatible with SDB and potential candidates for adenotonsillectomy, were invited to participate in this study. The study was approved by the hospital's Clinical Trials Committee; the contents were explained and confidentiality was ensured for all parents agreeing to participate through the signing of an informed consent form.

The parents of all the children agreeing to take part in this study were given a questionnaire[14] that includes questions on their children's sleeping, breathing problems, and behavioural or neurocognitive disorders. A complete otolaryngology examination was also carried out, including in most cases a flexible endoscopy of the upper airway. Tonsillar hypertrophy was graded into four levels using the Friedman classification.[15]

All cases were tested by a complete night-time PSG prior to surgery. The record taken lasted for 8 hours, and one parent was allowed to stay in a bed next to the child. The recording was done under the child's normal conditions, after dinner at the usual time and without medication to induce sleep.

Cases meeting the criteria for surgery after physical examination, questioning, and/or PSG were informed of the surgical indication for tonsillectomy. Surgical indication is based on at least 2 of the following criteria being met: apnoeas observed by parents every night along with snoring, grade 3 or 4 tonsillar hypertrophy on the Friedman scale and an apnoea-hypopnoea index (AHI) >3 in the PSG. In cases where only the clinical or polysomnographic criterion was satisfied, follow-up monitoring at the clinic was proposed. Those cases with evident tonsillar hypertrophy but which do not satisfy the other two criteria are not, in our centre, candidates for surgery or follow-up.

The technique employed was traditional tonsillectomy, with bilateral tonsillar dissection under general anaesthesia. This was combined with adenoidectomy in all cases.

Psychological tests[16-24]

Both the patients in the group of cases and the control group underwent a battery of validated psychological tests, at baseline time, before surgery for the case group and 0 time for the control group, and 1 year after the intervention. The parameters evaluated with these tests were attention, spatial structure, concepts related to alterations of reading and writing, memory, anxiety, and the assessment of parents regarding hyperactivity and attention deficit.

The WPPSI (Wechsler Preschool and Primary Scale of Intelligence), an intelligence scale, was used to analyze cognitive ability. It is subdivided into 10 subtests plus 2 more optional ones. It analyzes several areas which are important to the development of the skills needed for learning.

It has 6 verbal tests (information, vocabulary, arithmetic, similarities, comprehension, and sentence memory) and 5 other manipulative tests (animal house, incomplete figures, mazes, geometric design, and cubes). The tests of arithmetic, figures, and incomplete sentences are considered as indicators of potential problems with attention and concentration.

The WISC (Wechsler Intelligence Scale for Children) assesses cognitive skills; it is similar to WPPSI but adapted to children aged 6 and older. There is also a verbal part: information, similarities, arithmetic, vocabulary, comprehension, and digits and a manipulative part: incomplete figures, stories, blocks, puzzles, and keys. The following sub-tests are considered as indicators of potential problems with attention and concentration: arithmetic, digits, and keys.

The test of Bender is a gestalt and visual-motor test. It evaluates viso-constructive and graphical perception capacities. It also assesses spatial structuring values.

The CAS test (Cognitive Assessment System) is a self-assessment questionnaire which reveals the degree of anxiety. It can be done by children from 6 to 9 years.

The STAIC (State-Trait Anxiety Inventory for Children) provides values of anxiety state (at the time of the test) and anxiety trait (anxiety that the child lives with normally in other situations). It can be done from age 9.

The Rey test is based on copying complex figures. It evaluates the maturity of graphic activity and immediate visual memory. It has 2 phases: copying and memory.

The face test measures perception of differences. It assesses the skills required to perceive differences and similarities quickly, with stimulation patterns which are partially ordered. It provides attention values.

The Toulouse-Pieron test assesses sustained attention and concentration. It is a test of differences for children over 9 years of age.

The diagnostic criteria of DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, 4th edition) for attention deficit and hyperactivity disorder (ADHD), from age 5, assess the presence of hyperactive or attention behaviour or both.

The CONNERS Parent Questionnaire is a specific behaviour scale that measures impulsiveness, inattention, and hyperactivity.

All data is given in percentiles, except those related to attention deficit and hyperactivity, which are numbered from 0 to 10. Percentiles below 50 are considered affected. In tests where the score given ranges from 0 to 10, a result of 6 or more is considered pathological or altered.

A control group was recruited comprising children between 3 and 12 years of age who specifically deny suffering clinical conditions compatible with SDB, significant nasal obstruction or neurocognitive and behavioural alterations problems. All children in this control group underwent a tonsillar hypertrophy oropharyngoscopy to rule out tonsillar hypertrophy above grade 2 in the Friedman scale and underwent the same battery of psychological tests as the case group.

One year after surgery, patients in the case group were again questioned by the same clinical questionnaire and the PSG and the battery of psychological tests were repeated. The cases included in the control group were again subjected to the battery of psychological tests.

Statistical analysis

Statistical analysis was performed with SPSS 15.0 software. A first section offers the summary of descriptive statistics; for quantitative variables the mean (standard deviation) is shown and for quantitative variables, the frequency, and percentage.

We have proceeded to compare the variables age, height and weight between the control group and the group of cases with the Mann-Whitney *U* test and the variables of gender and those relating to psychological tests with the ^{2} test. Regarding the calculation of the correlation between data of the clinical questionnaire and the psychological tests in the case group, this has been conducted with a McNemar test.

Results

Description of the population groups

The sample consisted of 20 children in the case group and 20 in the control group. The various epidemiological and anthropometric data for the 2 groups showed no statistically significant differences. The ages ranged between 45 and 107 months (mean, 71.1 [20.37] months) in the case group and between 42 and 144 months (mean, 93.85 [34.33] months) in the control group. In both groups there were 12 males (60%). The overall average weight was 24.3 (8.48) kg and the height, 117.95 (12.86) cm; in the case and control groups the averages were, respectively, 28.05 (12.06) and 124.35 (20.43).

The most prominent pre-operative clinical data in the group of 20 children with SDB and operated on for adenotonsillectomy are shown in Table 1. The mean level of snoring, present in all cases and determined through a visual analogue scale between 0 and 10, was 7 (1.78) (range, 3-10). Parents reported apnoeas observed in 89% of cases and nasal obstruction in 85%. They reported excessive daytime sleepiness in only 25% of cases. The tonsillar volume measured by the Friedman scale was an average of 2.9 (0.4) (2-4). Finally PSG was performed in all cases and the average AHI was 5.85 (5.07) (0.27-21.73).

Table 1 Description of the pre-operative symptoms in the cases with SDB (n=20)

Clinical signs of SDB	
Snoring (AVS), mean (SD) (interval)	7 (1.78) (3-10)
Apnoeas observed	17[a] (89.47)
Nasal obstruction	17 (85)
Daytime drowsiness	5 (25)
Quality of sleep	
Enuresis	4 (20)
Agitated sleep	14 (70)
Painful legs	5 (25)
Teeth-grinding	11 (55)
Night terrors	7 (35)
Night sweating	14 (70)
Sleepwalking	2 (10)
Behaviour and learning	
Aggressiveness	8 (40)
Hyperactivity	9 (45)
Delay in speech acquisition	2 (10)
Concentration	8 (40)
Memory	3 (15)

AVS indicates analogue visual scale from 0 to 10; SD, standard deviation; SDB, sleep disordered breathing.
Unless otherwise indicated, the data express n (%).
[a]In 1 of the 20 cases, the parents replied that they did not know.

Results of psychological tests in both groups

In the case group, the parameters of attention, anxiety, memory, and spatial structuring were affected in more than 75%. Direct attention was impaired in 45.5%, attention deficit disorder according to the Conners test passed to parents, in 53.8%, and hyperactivity, in 30.8%.

The comparative analysis of different behavioural and cognitive concepts altered between the case and control groups is summarized in Table 2. It shows that the group of cases presented greater impairment, with statistically significance, in attention, memory, and spatial structuring. The rest of the variables studied showed no statistically significant differences, probably due to the small number of cases, although all of them presented greater impairment in the group of children with SDB.

Comparison of clinical data with psychological tests in the case group (Table 3)

We compared the psychological concepts of attention, anxiety, memory, and spatial structure with equivalent clinical concepts in the questionnaire and corresponding to the level of attention or concentration of the child with respect to classmates or children of the same level in their environment, if the child is considered too aggressive or hyperactive compared with children of their milieu and, finally, if the child has a delay in language acquisition. All the parameters compared showed greater alteration when assessed with objective measures than when considering the perceptions of parents. Three of the six comparisons were statistically significant: concentration in the questionnaire (40% of affected children) versus attention in psychological tests (80% of the affected tests), memory (15 vs 84%) and comparison between language delay (10%) and spatial structuring (75%).

Discussion

Patients with SDB, if not diagnosed and treated early, may suffer further complications that will condition their future. SDB in children has different distinctive features than in the adult population, but this statement is equally valid. In this age group, cardiovascular complications and those related to weight-height growth are especially relevant and behavioural disorders and neurocognitive development are especially characteristic.[1,3]

This last group of complications has been the subject of many international studies and publications.[8,25,26] Gotlieb et al,[27] for example, studied a group of more than 60 children with SDB and an average age of 5 years compared with a control group of 140 individuals. Using standardized neurocognitive tests they showed that cases with SDB presented worse results, with statistical significance, in

Table 2 Comparison of psychological test results between the case and control groups

Concept	Control group, n/No. (%)	Case group, n/No. (%)	*P*
Attention	8/20 (40)	16/20 (80)	.010
Anxiety	5/13 (38.5)	9/12 (75)	NS
Memory	10/20 (50)	16/19 (84.2)	.023
Spatial structuring	9/20 (45)	15/20 (75)	.05
Direct attention	4/13 (30.8)	5/11 (45.5)	NS
Hyperactivity	1/10 (10)	4/13 (30.8)	NS
Attention deficit	2/10 (20)	7/13 (53.8)	NS

NS indicates without statistical significance.

Table 3 Correlation between concept in questionnaire and equivalent concept in psychological test

Test versus questionnaire	Psychological test	Clinical questionnaire	*P*
Attention versus concentration	16/20 (80)	8/20 (40)	.008
Direct attention versus concentration	5/11 (45.45)	8/20 (40)	1
Anxiety versus aggressiveness	9/11 (81.82)	8/20 (40)	.219
Anxiety versus hyperactivity	9/11 (81.82)	9/20 (45)	.375
Memory versus memory	16/19 (84.21)	3/20 (15)	<.001
Spatial structuring versus delay in language	15/20 (75)	2/20 (10)	<.001

The data express n/No. (%).

tests of executive function, memory and general intellectual ability. Other authors such as Beebe et al[28] have reached similar conclusions. Their data indicate that there is a relationship between SDB and behavioural and cognitive alterations, especially with regard to the regulation of behaviour and some aspects of attention and executive function.

As was shown in a previous study, based exclusively on clinical questionnaires,[14] neurocognitive, and behaviour disorders occur in a significant percentage of the populations analyzed. These findings are important, as they can significantly condition the intellectual and social future of children with SDB.

In this publication, despite the low number of cases collected so far, the data indicate that the rates of behavioural and cognitive impairment in children with SDB are higher than those of a control group of similar age and without upper respiratory involvement. Of particular significance are those relating to attention, memory and spatial structuring.

The capacity for attention is important in learning and, therefore, in social and academic development. Several studies have shown attention deficit in children with SDB compared to controls, which improves markedly after adenotonsillectomy.[29-31] As for memory, not many studies exist and some data are conflicting. Some authors believe that in children with SDB, the capacity for memory assessed by standard psychometric testing is significantly reduced compared to the controls.[32,33] Others, however, do not obtain similar results.[34,35]

With regard to broader evaluations such as intelligence, studies in children with SDB have documented reductions in the IQ obtained with the WISC-III compared with controls.[32,33] However, Ali et al[29] in 1996 did not obtain the same results with a reduced version of WISC-III.

Such differences could probably be explained, as indicated by Gozal et al,[8] by great individual variability regarding the incidence of respiratory sleep disorders in this age group, associated with environmental factors. On the other hand, it has also been widely reported in the literature that these behavioural and neurocognitive disorders are also prevalent among children with mild SDB and even in snorers without apnoeas.[7,27,32,36,37] For many of them, this could be explained by the fact that the AHI of child PSG is not a good enough indicator of what actually happens and that the distortion could be attributed more to gasometric alterations or, especially, to the sleep architecture associated with neurological age (first decade of life), very susceptible to these changes.[6,12,36-38]

In this sense, a publication by Suratt et al[39] from 2006 is very interesting. They note that the risk of alteration in the cognitive function and behaviour can be predicted fairly reliably by the history of snoring, sleep efficiency and latency. A history of snoring is more predictive than episodes of apnoea per hour.

Comparing the current findings with those provided in a previous publication based on clinical questionnaires,[14] it appears that the degree of these behavioural and neurocognitive alterations, when evaluated with validated psychological tests, is clearly superior to that obtained through simple clinical questionnaires based on the insight and subjectivity of the parents. Other authors have already pointed out the usefulness of these psychological tests as a tool for understanding the degree of alteration and even as indicators of surgery[40].

Furthermore, it is significant that the 3 statistically most affected parameters in psychological tests in the case group with respect to the control group are also those which are least perceived by parents. Especially 2 of them: the alteration of memory perceived by 15% of parents and delay in language in 10% of cases. Their equivalent concepts in psychological tests, however, show alteration in 84% and 75% respectively.

The usefulness of adenotonsillectomy to prevent and resolve these abnormalities in children with SDB cases has been mentioned extensively in literature.[7,41-44] However, some publications suggest that surgery may not be sufficient and, especially, that when these cases undergo surgery there is already a residual damage which will not be completely resolved.[45]

In this sense it is interesting to note the comments of Hallbower et al.[46] For them, since children are in a state of rapid change in knowledge and behaviour, the impact of SDB in development can have profound consequences. They also note that preliminary data indicate that these cognitive deficits can be reversed with treatment, although such factors as the age at which treatment is performed, the duration of SDB, the prior intellectual level, socio-economic status or the ineffectiveness of treatment may have adverse effects in the long term. According to these authors, it is imperative for investigators to determine whether brain development has critical periods of plasticity during which SDB could cause long-term or permanent neuropsychological alterations.

These findings confirm our view that those patients with a clinical condition compatible with SDB should be diagnosed and treated early to prevent damage in this area. The awareness of frontline physicians and society in general would be valuable to this end. The age range of the population presented here is relatively low when compared with other studies. This fact presents some difficulties when seeking applicable psychological tests but, by contrast, encourages us to continue with the line of parent awareness.

The results obtained so far and presented in this publication justify, in our view, the need to continue with the study proposed. In time, the number of cases will be increased, allowing comparisons that have not yet been possible. In particular, evaluating whether there is any correlation between neurocognitive and behavioural disorders and degrees of polysomnographic alteration or clinical alterations relating to SDB such as the level of snoring or observed apnoeas or difficulty in breathing through the nose.

Moreover, further study will also enable the evaluation of the progress of these neurocognitive and behavioural disorders one year after adenotonsillar surgery, compared, also, with the same evolution in the control group. This will avoid the evolutionary bias created by the simple neurological growth of children with SDB.

Conclusions

SDB in children may have consequences on behaviour and neurocognitive development which may condition their future. We must be attentive to the presence of these complications in this population group to begin early treatment to reduce its impact. Validated psychological tests are a useful tool for this purpose and they evaluate these changes more effectively than the subjective response of parents. The continuity of this study should allow the number of cases and long-term post-operative follow-up to increase and show, through objective assessments, the evolution and eventual resolution of these alterations after adenotonsillar surgery.

Conflict of interests

The authors have indicated there is no conflict of interest.

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