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CLINICAL & BASIC RESEARCH

Effects of an Adenotonsillectomy on the Cognitive and Behavioural Function of Children Who Snore

A naturalistic observational study

Khalid Al-Zaabi,[1] Samir Al-Adawi,[2] *Sanjay Jaju,[3] Lakshmanan Jeyaseelan,[4] Nasser Al-Sibani,[2] Mohammed Al-Alawi,[5] Mohammed Al-Abri,[6] Rashid Al-Abri[7]

تأثير إستئصال اللوزتين ولحمية الأنف على مستوى الإدراك والسلوك لدى الأطفال الذين يعانون من الشخير أثناء النوم

دراسة مبنية على الملاحظة

خالد الزعابي، سمير العدوي، سانجاي جاجو، لاكشمانن جياسيلان، ناصر السيباني، محمد العلوي، محمد العبري، راشد العبري

abstract: ***Objectives:*** This study aimed to evaluate cognitive and behavioural changes among 9–14-year-old Omani children with obstructive sleep apnoea (OSA) after an adenotonsillectomy (AT). ***Methods:*** This naturalistic observational study was conducted at the Sultan Qaboos University Hospital, Muscat, Oman, between January 2012 and December 2014. Omani children with adenotonsillar hypertrophy (ATH) underwent overnight polysomnography and those with confirmed OSA were scheduled for an AT. Cognitive and behavioural evaluations were performed using standardised instruments at baseline prior to the procedure and three months afterwards. ***Results:*** A total of 37 children were included in the study, of which 24 (65%) were male and 13 (35%) were female. The mean age of the males was 11.4 ± 1.9 years, while that of the females was 11.1 ± 1.5 years. Following the AT, there was a significant reduction of 56% in mean apnoea-hypopnoea index (AHI) score (2.36 ± 4.88 versus 5.37 ± 7.17; P <0.01). There was also a significant positive reduction in OSA indices, including oxygen desaturation index (78%), number of desaturations (68%) and number of obstructive apnoea incidents (74%; P <0.01 each). Significant improvements were noted in neurocognitive function, including attention/concentration (42%), verbal fluency (92%), learning/recall (38%), executive function (52%) and general intellectual ability (33%; P <0.01 each). There was a significant decrease of 21% in both mean inattention and hyperactivity scores (P <0.01 each). ***Conclusion:*** These results demonstrate the effectiveness of an AT in improving cognitive function and attention deficit hyperactivity disorder-like symptoms among children with ATH-caused OSA. Such changes can be observed as early as three months after the procedure.

Keywords: Adenoidectomy; Obstructive Sleep Apnea; Cognitive Function; Behavior; Attention Deficit Hyperactivity Disorders; Children; Oman.

الملخص: *الهدف:* هذه الدراسة تهدف إلى تقييم تأثير استئصال اللوزتين ولحمية الأنف على مستوى الإدراك والسلوك لدى الأطفال العمانيين بمتوسط عمر 14-9 سنة والذين يعانون من انقطاع النفس الإنسدادي النومي. ***الطريقة:*** أجريت هذه الدراسة المبنية على الملاحظة بمستشفى جامعة السلطان قابوس بمسقط، عمان في الفترة الممتدة من شهر يناير 2012 الى شهر ديسمبر 2014. تم إخضاع جميع الأطفال العمانيين المشاركين في الدراسة والذين يعانون من تضخم اللوزتين ولحمية الأنف الى دراسة للنوم وتم اخضاع الأطفال الذين ثبت لديهم انقطاع النفس الانسدادي النومي الى تدخل جراحي متمثل في استئصال للوزتين ولحمية الأنف. تمت دراسة مستوى الادراك والسلوك لدى هؤلاء الأطفال قبل وبعد ثلاثة أشهر من التدخل الجراحي. ***النتائج:*** بلغ عدد الأطفال المشاركين في الدراسة 37 منهم 24 (65%) ذكور و 13 (35%) إناث. بلغ متوسط اعمار المشاركين الذكور 1.9 ± 11.4 سنة والإناث 1.5 ± 11.1 سنة. بعد التدخل الجراحي انخفض مؤشر انقطاع التنفس أثناء النوم بمعدل 56% (4.88 ± 2.36 مقارنة ب 7.17 ± 5.37؛ P <0.01). كما أشارت النتائج أيضا إلى انخفاض ملحوظ في المؤشرات الفرعية لمؤشر انقطاع النفس أثناء النوم متضمنا مؤشر تشبع الأكسجين (78%) ومؤشر عدد التشبع (68%) وعدد مرات انقطاع النفس(74%؛ P <0.01 لكل منهما). كما لاحظ الباحثون تحسنا كبيرا في مستوى الإدراك لدى الأطفال متضمنا مستوى الانتباه والتركيز (42%) وطلاقة اللسان (92%) والتعلم/الذاكرة (38%) ومهارات التنفيذ (52%) ومعدل الذكاء العام (33%؛ P <0.01 لكل منهما). أشارت الدراسة أيضا الى انخفاض معدل عدم الانتباه وفرط الحركة بنسبة (21%؛ P <0.01 لكل منهما). ***الخلاصة:*** هذه النتائج توضح فعالية التدخل الجراحي (استئصال اللوزتين واللحمية) في تحسن مستوى الإدراك والسلوك لدى الأطفال الذين يعانون من أعراض فرط الحركة وقلة الانتباه بسبب انقطاع النفس الإنسدادي النومي بسبب تضخم اللوزتين ولحمية الأنف. من الممكن ملاحظة هذه التغيرات خلال ثلاثة أشهر بعد التدخل الجراحي.

الكلمات المفتاحية: استئصال لحمية الأنف؛ انقطاع النفس الإنسدادي النومي؛ مستوى الإدراك؛ السلوك؛ قصور الانتباه وفرط الحركة؛ أطفال؛ عمان.

Departments of [1]Surgery and [5]Behavioural Medicine, Sultan Qaboos University Hospital; Departments of [2]Behavioural Medicine, [3]Family Medicine & Public Health, [6]Physiology and [7]Surgery, College of Medicine & Health Sciences, Sultan Qaboos University, Muscat, Oman; [4]Department of Biostatistics, Christian Medical College, Vellore, India

**Corresponding Author's e-mail: dr.sanjayjaju@gmail.com*

Advances in Knowledge

- *The findings of this study indicate that an adenotonsillectomy (AT) has beneficial effects on cognition and attention deficit hyperactivity disorder-like symptoms among children with obstructive sleep apnoea (OSA).*
- *Such changes can be determined as early as three months after the procedure.*
- *Previous research has focused on 3–10-year-old children; however, this study observed similar results among 9–14-year-olds.*

Application to Patient Care

- *An AT may improve cognitive and behavioural function among older paediatric patients with OSA.*

Obstructive sleep apnoea (OSA) is estimated to affect between 1.2–5.7% of the paediatric population.[1,2] The condition is characterised by intermittent partial or complete obstruction of breathing during sleep.[3] Among children, adenotonsillar hypertrophy (ATH) can cause narrowing of the airway, leading to symptoms such as snoring, cessation of breathing and sleep fragmentation.[4] This in turn reduces oxygen delivery to the terminal *alveoli*, thus affecting the gas exchange process and leading to tissue hypoxia.[5] The neuropsychological *sequelae* of childhood OSA may include compromised cognitive, emotional and social function.[6,7]

An adenotonsillectomy (AT) is considered the first line of treatment for paediatric OSA.[8,9] Findings from the Childhood Adenotonsillectomy Trial (CHAT) suggest that the procedure has the potential to attenuate certain behavioural problems and enhance cognitive function.[10–12] However, to the best of the authors' knowledge, no studies have yet been conducted among Arab children with OSA. Furthermore, previous studies on this topic have focused on younger children (3–9-year-olds) and longer follow-up periods (≥6 months).[13,14] As such, the present study aimed to explore pre- versus post-AT changes in cognitive function, attention deficit hyperactivity disorder (ADHD)-like symptoms and OSA indices among Omani children aged 9–14 years. This study also aimed to determine whether a re-evaluation of cognitive and behavioural measures at three months post-AT could provide similar evidence to that noted at 6–12 months.

Methods

This naturalistic observational study was conducted at the Sultan Qaboos University Hospital (SQUH), Muscat, Oman, between January 2012 and December 2014. A total of 150 Omani children consecutively referred from local health centres with a history of snoring, mouth breathing and sleep disturbance suggestive of OSA due to ATH were targeted. However, 47 children with craniofacial or neurological abnormalities, a history of persistent and pervasive allergies or asthma, a body mass index not between the 5th and 85th percentile and those on psychotropic medications or deemed clinically unfit for surgical intervention were excluded from the study. The remaining 103 subjects underwent overnight polysomnography; of these, 60 were excluded as their symptoms did not fulfil the criteria for OSA. A final sample of 37 subjects were included in the study. The minimum sample size required was calculated to be 35 subjects at a two-sided alpha value of 0.5, power of 80% and expected effect size of 0.5.

All of the children underwent in-hospital sleep studies using a portable level 3 sleep machine with an air flow sensor, chest and abdominal effort belt and oximeter.[15] During the sleep study, the following five variables were monitored: (1) apnoea-hypopnoea index (AHI) score; (2) oxygen desaturation index (ODI) score; (3) the number of desaturations (NOD); (4) the number of obstructive apnoea (OA) incidents; and (5) the number of central apnoea (CA) incidents. AHI scores were calculated based on the guidelines of the American Academy of Sleep Medicine (AASM), wherein 0–1 obstructive events per hour was considered normal, 2–5 was classified as mild OSA, 6–10 was considered moderate OSA and >10 was indicative of severe OSA.[15,16] All children who fulfilled the criteria for mild-to-severe OSA were scheduled for an AT. Those who underwent an AT also took part in another sleep study three months after the procedure to document any changes in OSA indices. Data were manually scored at baseline and three months post-AT by a sleep technologist who was blinded to the stage of research and in accordance with the AASM guidelines.[15]

The children were also evaluated at baseline and three months post-AT for ADHD indices and cognitive function (i.e. intellectual capacity, verbal fluency, attention/concentration, learning/recall and executive function). A board-certified psychologist who was blinded to the findings of the sleep study conducted cognitive evaluations of the subjects. Each child's parents or caregivers were asked to take a checklist of ADHD symptoms from the short version of Conners' Teacher Rating Scale (CTRS) to their child's school so that their teacher could assess the frequency of certain behaviours associated with ADHD.[17] The psychometric properties of the CTRS have been previously established among Omani children, with a cut-off value of >15 denoting ADHD cases.[18]

The Raven's Coloured Progressive Matrices test was used to establish the intellectual capacity of the participants. This test has been previously validated in the Omani population and consists of 36 items grouped into three sets.[19] Each item contains a pattern with one part removed and between six and eight pictured inserts, of which the participant must choose the one with the correct pattern. The Controlled Oral Word Association Test was used to determine verbal fluency by examining lexical ability, executive control and the speed of verbal responses. The score was calculated based on the total number of acceptable words produced in three 30-second periods.[20]

The Digit Span Test, a subscale of the Wechsler Intelligence Scale for Children, was used to measure verbal/auditory attention and short-term memory. The score was based on the participant's ability to recall seven pairs of random number sequences read aloud by the examiner, with the numbers read both forwards and backwards.[21] The respondents' ability to learn and remember was gauged using the Buschke Selective Reminding Test; this consists of lists of 12 words which are read aloud to the participant at the rate of approximately one word every two seconds. The total score was based on the number of words recalled over three trials.[22] The Tower of London neuropsychological test was used to determine deficits in planning and temporal organisation, which are important constituents of executive function.[22] The participants were asked to realign coloured beads stacked on poles to three adjacent poles in a minimum number of moves during five trials. After two consecutive failures, the test was stopped. The total score was the sum of all correctly solved trials up to a maximum of 25 moves.[23]

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), Version 20.0 (IBM Corp., Armonk, New York, USA). A paired t-test or Wilcoxon test (paired samples) was used to compare the differences between pre- and post-AT indices of OSA and neurocognitive and behavioural function. Percentage changes were reported separately.

This study was approved by the Medical Research & Ethics Committee of the College of Medicine & Health Sciences, Sultan Qaboos University (MREC #749). Written informed consent was obtained from the parents or guardians of all of the participants.

Results

A total of 37 children with OSA participated in the study, of which 24 (65%) were male and 13 (35%) were female. The mean age was 11.4 ± 1.9 years and 11.1 ± 1.5 years for males and females, respectively. The mean post-AT AHI score showed a significant reduction of 56% compared to the mean pre-AT AHI score (2.36 ± 4.88 versus 5.37 ± 7.17; P <0.01). Similarly, significant reductions were observed for the other OSA indices, including ODI score (78%), NOD (68%) and the number of OA incidents (74%; P <0.01 each). Although there was a reduction in the number of CA incidents (14%), this difference was not statistically significant (P = 0.73) [Table 1].

Following the AT, significant improvements were noted in all neurocognitive function parameters, including attention/concentration (42%), verbal fluency (92%), learning/recall (38%), executive function (52%) and general intellectual ability (33%; P <0.01 each). In addition, there was a significant decrease of 21% in both ADHD inattention and hyperactivity scores (P <0.01 each); however, the mean post-AT hyperactivity score nevertheless remained above a cut-off value of >15 (15.84 ± 4.13) [Table 2].

Discussion

There is a plethora of evidence to suggest that children with cognitive and intellectual deficits and those with ADHD-like symptoms tend to have OSA.[6,7] Conversely, OSA has also been associated with cognitive and intellectual deficits as well as ADHD-like symptoms.[24] Such findings indicate that clinicians should be vigilant

Table 1: Pre- and post-adenotonsillectomy changes in obstructive sleep apnoea indices among Omani children at the Sultan Qaboos University Hospital, Muscat, Oman (N = 37)

Index	Mean ± SD		Change, unit (%)	95% CI	*P* value*
	Pre-AT	Post-AT			
AHI score	5.37 ± 7.17	2.36 ± 4.88	−3.00 (−56%)	1.16, 4.86	<0.01
ODI score	5.19 ± 8.14	1.14 ± 2.87	−4.05 (−78%)	1.72, 6.39	<0.01
Number of desaturations	31.22 ± 57.99	10.05 ± 28.81	−21.16 (−68%)	5.65, 36.67	<0.01
Number of OA incidents	16.51 ± 22.51	4.35 ± 13.69	−12.16 (−74%)	4.59, 19.74	<0.01
Number of CA incidents	3.32 ± 6.41	2.87 ± 4.93	−0.46 (−14%)	0.84, 1.76	0.73

*SD = standard deviation; AT = adenotonsillectomy; CI = confidence interval; AHI = apnoea-hypopnoea index; ODI = oxygen desaturation index; OA = obstructive apnoea; CA = central apnoea. *Using a Wilcoxon signed ranks test.*

Table 2: Pre- and post-adenotonsillectomy changes in behavioural and cognitive function indices among Omani children with obstructive sleep apnoea at the Sultan Qaboos University Hospital, Muscat, Oman (N = 37)

Index	Mean ± SD		Change, unit (%)	95% CI	*P* value*
	Pre-AT	Post-AT			
CTRS-IA score	18.76 ± 4.79	14.86 ± 3.65	−3.89 (−21%)	2.39, 5.40	<0.01
CTRS-H score	19.92 ± 6.72	15.84 ± 4.13	−4.08 (−21%)	2.19, 5.97	<0.01
DST score	6.83 ± 2.69	9.70 ± 4.51	+3.00 (+42%)	−4.16, −1.84	<0.01
COWAT score	6.07 ± 5.45	11.67 ± 8.39	+5.49 (+92%)	−7.28, −3.70	<0.01
BSRT score	18.65 ± 5.72	25.65 ± 5.49	+7.00 (+38%)	−9.23, −4.77	<0.01
TOL score	11.46 ± 4.74	17.43 ± 5.19	+5.97 (+52%)	−7.20, −4.74	<0.01
RCPM score	18.03 ± 7.47	23.97 ± 7.19	+5.95 (+33%)	−7.35, −4.54	<0.01

*SD = standard deviation; AT = adenotonsillectomy; CI = confidence interval; CTRS = Conners' Teacher Rating Scale; IA = inattention; H = hyperactivity; DST = Digit Span Test; COWAT = Controlled Oral Word Association Test; BSRT = Buschke Selective Reminding Test; TOL = Tower of London; RCPM = Raven's Coloured Progressive Matrices. *Using a paired t-test.*

in excluding OSA among children with cognitive and intellectual deficits and ADHD or vice versa. A previous study conducted in Oman suggested that the prevalence rate of ADHD was 8.8% among 9–10-year-olds.[25] However, it is not clear what percentage of this population also had OSA. In the current study, although there was a significant decrease in mean inattention and hyperactivity scores post-AT, this change does not indicate a reversal of ADHD-like symptoms, as the mean post-AT score remained above the cut-off value of >15 on the CTRS scale.[25] Longer-term evaluation would perhaps shed more light on this finding.

In the current study, indices of neurocognitive and behavioural function and OSA were found to improve significantly post-AT. These findings concur with those reported in the existing literature.[26–30] Previous studies on this topic have focused on evaluating cognitive and behavioural changes between 6–12 months after the surgery.[13,14,31] In contrast, the current study evaluated cognitive and behavioural function over a much shorter follow-up period. Kaditis *et al*. recommended re-evaluation at six weeks post-AT while a 6–12-month range was used by CHAT researchers.[10–13,32] Overall, it is still unclear at exactly which point in time neuroplasticity in children with OSA is likely to occur after an AT. Further research on this topic is warranted.

In previous research, ATs were commonly performed for children between 3–9 years old.[13,14] The current study included children aged 9–14 years old; this age group was chosen to ensure the correct diagnosis of ADHD-like symptoms, which are more accurately identified in older children.[33] Additionally, more developmentally appropriate and standardised cognitive measures are available for this population.[34] Finally, the neurocognitive assessment of very young children can be logistically challenging, thus supporting the assessment of older children in the current study. Studies on younger children have been justified based on the assumption that OSA can trigger irreversible morbidity and that, therefore, the intervention should be implemented as quickly as possible.[35] However, no neurobiological or molecular mechanisms have yet been identified to suggest that the pathological processes triggered by OSA can only be reversed in specific age groups. The CHAT researchers have recommended that ATs be performed on 3–10-year-olds.[10–12]

The current study was subject to certain limitations. First, the study constituted a naturalistic observation of routine medical services provided to children referred to one tertiary care hospital in Oman and therefore did not include a control group. While naturalistic observational studies have the potential to lay the groundwork for further research with more robust methodologies, generalisation of the findings of such studies should be made with caution. Second, using a symptom checklist to diagnose ADHD is considered suboptimal compared to semi-structured interviews in which the diagnosis is based on the International Classification of Diseases and the Diagnostic and Statistical Manual of Mental Disorders.[36] Similarly, brain scans may be of some benefit to more accurately measure cognitive impairment.[37] Third, this study did not take into account variations of hypoxaemia due to complex fluctuations in the associations between hypoxaemia and cognitive variables.[38] Fourth, the study may have been affected by various confounders, such as maternal education, maturity, diet, parental supervision, socioeconomic status and spontaneous changes in cognition. Finally, a level three sleep study is considered suboptimal compared to level one. However, this type of sleep study machine is widely used in clinical practice and research and is considered an acceptable tool for diagnosing OSA.[39]

Conclusion

The results of this study indicate that an AT is effective in improving cognitive function and reducing ADHD-like symptoms among children with OSA secondary to ATH. In addition, a short follow-up period of three months is sufficient to measure such changes. This study also suggests that post-AT neurobehavioural improvements extend beyond the previously studied age range of 3–9 years.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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