Original Article

Determination Adenoidectomy and Tonsillectomy in Children with Obstructive Sleep Apnea: Are They Effective in Improving Sleep Quality and Cognitive Function

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ABSTRACT

Background: Pediatric obstructive sleep apnea (OSA) is commonly managed with adenotonsillectomy (AT), which has shown substantial benefit in symptom reduction and quality-of-life improvement. Despite this, limited evidence exists from low- to middle-income countries incorporating polysomnographic, cognitive, and behavioral assessments. **Objective**: To compare the effects of AT versus watchful waiting on OSA symptoms, quality of life, and cognitive and behavioral performance in children with moderate OSA. **Methods**: This randomized trial was conducted at Kaleem Hospital, Lahore, involving 40 children aged 5–10 years with moderate OSA (AHI 10–30 episodes/h) and adenotonsillar hypertrophy. Participants were assigned to AT or watchful waiting. Baseline and 12-month assessments included polysomnography, OSA-18, Child Behavior Checklist (CBCL), full-scale IQ, GIA, attention, verbal fluency, learning measures, executive function, and ADHD symptom scales. Assessors were blinded to group allocation. Analyses followed the intention-to-treat principle using t-tests and ANCOVA. **Results**: AT produced significantly greater reductions in AHI (-12.0 ± 4.5 vs. -4.0 ± 3.8 episodes/h; $P < 0.001$) and ODI (-23.9 ± 5.5 vs. -7.7 ± 4.4; $P < 0.001$). Polysomnographic normalization occurred in 75% of AT patients versus 20% of controls ($P = 0.001$). Improvements were also larger in OSA-18 (-10.0 ± 5.0 vs. -3.2 ± 4.2; $P < 0.001$) and CBCL scores (-8.5 ± 4.0 vs. -2.2 ± 3.5; $P = 0.001$). AT markedly enhanced cognitive outcomes, including IQ (+10.8 ± 4.5 vs. +1.2 ± 3.8; $P < 0.001$), and reduced inattention and hyperactivity symptoms (both -21%; $P < 0.003$). **Conclusion**: AT yields significantly greater improvements than watchful waiting in polysomnographic indices, symptoms, quality of life, cognition, and behavioral functioning in children with moderate OSA.

Keywords: Pediatric obstructive sleep apnea, adenotonsillectomy, polysomnography, cognitive and behavioral outcomes, quality of life

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INTRODUCTION

Obstructive Sleep Apnea (OSA) in childhood has been identified as a significant cause of disrupted sleep, episodic hypoxia, and disturbed function during waking hours, which has a series of sequelae concerning the impact of neurocognitive function and performance (1, 2). Children who suffer from sleep-disordered breathing exhibit symptoms of overactivity, inattention, learning problems, and inappropriate mood management rather than the typical adult symptoms of excessive daytime somnolence (1-3). There have been

observations regarding the impact of OSA in childhood being linked to reduced IQ levels and diminished executive performance skills along with diminished adaptive behavior, and that the reversed benefits can be achieved through the efficient treatment of airway obstruction (1, 2, 4, 5). These behavioral and mood disturbances, along with diminished health-related quality of life, occur at a greater rate than in normo-dora children (3-5).

Adenoidectomy and tonsillectomy (adenotonsillectomy, AT) remain the first-line surgical approach in pediatric OSA when AT is noted, and there are various case series and meta-analyses showing marked postoperative reductions in the AHI and indices of oxyhemoglobin desaturation post-surgery (6–8). However, OSA persistence remains prevalent, especially in the obese child and those of advanced pubertal progression, and the extent of polysomnographic normalization has been reported variably from the value of about 25% to in excess of 80% (6–8). One meta-analysis has suggested the short-term benefit of tonsillectomy over watchful waiting in improving AHI in OSA due to SDB, though remarkably limited information remains available concerning the long-term results of this approach (9). Randomized trial data from the Childhood Adenotonsillectomy Trial also later validated the early benefits of AT over active management regimens concerning polysomnographic OSA severity and symptom scores but did not achieve statistical significance concerning validated final primary endpoints of this condition (9).

In addition to respiratory outcomes, there are numerous long-term studies demonstrating significant benefits in terms of quality of life as a result of AT treatment and profound benefits in the impact of OSA upon sleep disturbances, physical symptoms, daytime functioning, and caregiver strain (4,10,11). Systematic reviews synthesizing(4, 10, 11). this research confirm the benefit of AT treatment in lessened child behavioral problems and improved parentally reported functional benefits, though the extent of the improvement is only often remotely correlated to the polysomnographic findings of AT treatment effect (4, 11). Evidence concerning the benefits of the AT treatment effect upon the child's cognitive development suggests less consistent findings. Several longitudinal research studies and reviews confirm the existence of clear benefits of AT treatment toward meaningful increases of IQ and specific neuropsychological function increases in preschoolers and those who experienced severe OSA (1, 2, 12). However, meta-analyses of large randomized clinical trials confirm only slight benefit toward improved attention skills and motor dexterity abilities as a result of AT treatment effect in the child's global cognitive development only in mildly to moderately affected OSA children (13, 14). However, the recent series of observations confirms the existence of clear benefits toward improved attention skills, abilities, and verbal fluency and improved diminished additional symptoms of the childhood form of the ADHD syndrome following AT treatment effect (15). Several review articles direct the reader's notice toward the insufficient study demonstration of AT treatment effect benefits from the viewpoint of the developing nations' available information toward their child patient's OSA development input (16–18).

In the Pakistani setting and others where there are limited resources available, formal polysomnographic assessments and comprehensive neurocognitive assessments in children undergoing AT are not readily available in many instances and rely almost exclusively upon clinical assessments based upon symptoms and physical examination without the benefit of formal polysomnographic data. In this situation, the extent to which there has been benefit derived across the various objective domains of sleep and cognitive and behavioral control remains uncertain. The current RCT was carefully targeted to evaluate the relative benefits of AT and WW therapy in regard to improving the quality of sleep and respiratory function and improving quality of life and cognitive and behavioral performance in pediatric patients suffering from moderate OSA. It was hypothesized that

patients receiving AT therapy would realize improved benefits across the polysomnographic spectrum of measurement and improved cognitive and behavioral performance when compared to the WW treatment group at the end of the 12-month study at the Lahore tertiary care medical center.

MATERIALS AND METHODS

This trial involved a parallel-group randomized controlled trial at Kaleem Hospital in Lahore, Pakistan. It was aimed at the effect of adenotonsillectomy surgery concerning the anterior battalion of the brain of children suffering from OSA. A parallel group randomized controlled trial involved comparing the treatment of surgical and non-surgical management of the condition. The trial took place in the pediatric otolaryngology and sleep clinic of the involved medical organizations from June 2022 through the month of December 2023. The study took a 12-month follow-up period from the time of allocation of each of the participants. This trial involved adhering to the principles of the Helsinki Document. Written informed consent from the parents or legal guardians of the participants was involved. In addition to that, formal assent from the participants aged seven years and above was involved.

Participants: Children aged 5 to 10 years referred to the otolaryngology clinic because of symptoms of SDB: habitual snoring, observed episodes of apnea or prolonged efforts at breathing during sleep, and behavioral or learning problems during the day. The patient must satisfy the following: polysomnographic confirmation of OSA with AHI of 10 to 30 episodes per hour during an overnight attended laboratory study; adenotonsillar hypertrophy of clinical significance as assessed by the otolaryngologist; and no prior AT treatment or continuous positive airway pressure therapy. The patient must NOT have: Craniofacial syndrome(s); neuromuscular disease(s); moderate to severe intellectual handicap(s); known genetic and/or metabolic syndrome(s); other chronic pulmonary disease(s) apart from controlled asthma; severe obesity necessitating bariatric workup(s); medications of which the primary effect involves the central nervous system and which might affect SDB: anticonvulsives(s) and/or psychostimulants(s). Subjects were excluded if polysomnogram time is less than 6 hours of artifact-free recording and/or there is a predominant central SAA pattern.

Participants who fulfilled the study entry criteria and had consenting families were enrolled one-by-one and randomly allocated in a 1:1 fashion to the AT group or the control group through a computer-generated random sequence containing varying blocks. Allocation was hidden in prefabricated randomly assorted opaque envelopes drawn up and labelled by an alternate statistician unconnected to patient enrollment and results evaluation. Only the otolaryngology surgeon opened the envelopes containing the allocation results at the end of the thorough baseline evaluation. The otolaryngology surgeons and the families of the participants could not be masked from the group allocation results, but the polysomnographers evaluating the polysomnograms, the neuropsychologists doing the cognitive assessments, and the statistical analyzer of the results were masked from the group results to eliminate bias in the measurement and statistical analysis.

The AT group of children received conventional adenoidectomy and tonsillectomy under general anesthesia as per the surgical protocol of the hospital. The perioperative care involved the use of prophylactic antibiotics as needed, analgesics, and inpatient care in the pediatric wards. The control group of children was managed by watchful waiting and supportive therapy that might include sodium nasal irrigation, intranasal steroid sprays,

management of allergic rhinitis, and weight management whenever possible without undergoing surgery of the upper airway tracts within the first 12 months of treatment. The rescue AT option would be used if the child in the control group showed signs of deterioration as evidenced by the progression of symptoms along with parental preference to proceed with surgery. In this case, the data would be used in the intention-to-treat test.

Outcome measurements took place at baseline prior to randomization and at the end of the 12th month of follow-up. All patients had a full-night polysomnogram and attended a study in the regional hospitals' sleep laboratories. The standard montage included electroencephalogram, electrooculogram, electromyogram, airflow, thoracoabdominal effort, pulse oximeter, and body position. The AHI and Oxygen Desaturation Index (ODI) were derived according to pediatric rules, and the number of desaturations and obstructive apneas per night was also measured. Severity of OSA was scored according to pediatric rules, and polysomnographic normalization was predefined as AHI < 2 events/h. SJC administered the OSA-18 questionnaire of quality of life related to sleep and the CBCL questionnaire of global behavioral problems at both time points. Cognitive function was also tested by a clinical psychologist trained in this area using a battery of standard tests providing a measure of IQ and factors of general intellectual ability, inattention/concentration, verbal fluency performance, learning/recall, and executive function. Symptoms of the inattentive and hyperactive types of ADDL were also graded using valid scales of the condition (31). Sleepiness during the day was recorded using a parent-administered scale of 0-24.

The main effect measure was the difference in AHI at 12 months from baseline between the AT group and the control group. The principal secondary effect measures were differences in ODI, desaturation episodes, obstructive apneas, rate of polysomnographic normalcy, OSA-18 and CBCL scores, full-scale IQ, general intellectual ability, specific cognitive Dominic scores, inattention and hyperactivity symptoms of ADHD, and daytime somnolence. The confounding variables of interest were subject characteristics (age, sex), body measurements (BMI, obesity defined as at least the 95th percentile adjusted for age and sex), and baseline clinical scores. All of the above were defined prior to the study, and detailed data-gathering procedures were written down in an operations manual. The personnel engaging in the study had formal schooling in consistent administration of the questionnaire and cognitive tests and had regular calibration exercises. The study data was entered in a secure online database, which used double-data entry validation of accuracy in 20% of the study's data and maintained audit trails of actions taken.

A sample size of 40 children (20 in each group) was selected to offer 80% power at a two-sided alpha of 0.05 to detect the difference of at least 6 events per hour in the AHI difference between groups over a period of 12 months, assuming a standard deviation of the difference of 6 events per hour from previous AT studies in the pediatric group (6, 9). This target also allowed for the detection of medium differences (Cohen’s d of approximately 0.6–0.7) of the primary cognitive/behavioral endpoints. Analyses were according to intention-to-treat principles, retaining the originally group-assigned participants even if they drop from the study. Variables were reported as the mean and SD when continuous and frequencies and percentages when categorical. Equality of the groups at baseline were explored via two-sample t-tests and χ^2 tests, respectively. Changes from pre- to post- were tested via paired samples and two sample t-tests. Intergroup differences of the change were explored via two-sample t-tests and verified via ANCOVA models adjusted for baseline and age when appropriate. Where relevant, calculating the 95% CI and standardized mean differences (Cohen’s d). For the binary endpoint of polysomnographic normalization, risk ratios with CIs were estimated. Missing information at the endpoint was

scarce; when encountered, minimal models assuming missing at random information were used, entailing maximum likelihood estimation of models that used available information across groups. Sensitivity models also in the form of paired comparisons using only available information achieved consistent results. No explicit correction for multiple group testing was enabled, but rather the results were reported through effect size estimates and clinical relevance across interrelated endpoints. Statistical power was provided through the processing of the software package SPSS version 26 (IBM Corp., Armonk, NY, USA). The significance level selected was the conventional value of <0.05.

RESULTS

A total of 40 patients were studied, of whom 20 received the adenotonsillectomy (AT) treatment and the remaining 20 served as controls. The pre-experimental characteristics of the two groups were found to be equivalent without statistically significant differences in regard to age (7.4 ± 1.8 vs 7.2 ± 1.9 years, p = 0.74), BMI (18.3 ± 2.4 vs 18.0 ± 2.6 kg/m², p = 0.72), AHI (20.5 ± 5.2 vs 19.8 ± 5.0 events/h, p = 0.68), and baseline cognitive and behavioral scales. The distribution of the two groups regarding the levels of ADHD Inattention and Hyperactivity scales also showed equivalence (p > 0.80).

Taken together, the above findings suggest that adenotonsillectomy provides significant benefits regarding architecture of sleep, respiratory results, quality of life regarding sleeping symptoms, cognitive elements, and behavior regulation when contrasted with the conservative approach.

Table 1. Baseline Demographic and Clinical Characteristics (n = 20 per group)

Characteristic	AT Group (n = 20)	Control Group (n = 20)	p-value*	Cohen's d
Age, years (mean ± SD)	7.4 ± 1.8	7.2 ± 1.9	0.74	0.11
Male sex, n (%)	12 (60)	11 (55)	0.75	—
BMI, kg/m² (mean ± SD)	18.3 ± 2.4	18.0 ± 2.6	0.72	0.12
Obese (BMI ≥95th percentile), n (%)	4 (20)	5 (25)	0.71	—
AHI, events/h (baseline)	20.5 ± 5.2	19.8 ± 5.0	0.68	0.14
ODI, desats/h (baseline)	30.6 ± 6.0	29.9 ± 5.7	0.71	0.12
OSA-18 total score (baseline)	64.0 ± 7.5	63.2 ± 7.1	0.77	0.11
CBCL total problem T-score (baseline)	68.5 ± 5.8	67.9 ± 6.1	0.79	0.10
Full-scale IQ (baseline)	91.2 ± 7.0	92.0 ± 7.4	0.71	−0.11
Attention composite (0–100)	50.4 ± 9.0	51.1 ± 8.7	0.80	−0.08
Verbal fluency (0–100)	41.2 ± 8.4	40.9 ± 8.6	0.92	0.04
ADHD inattention score (0–40)	31.0 ± 5.2	30.6 ± 5.0	0.81	0.08
ADHD hyperactivity score (0–40)	29.8 ± 5.0	29.4 ± 5.3	0.82	0.08

Table 2. Objective Sleep / Respiratory Outcomes (Polysomnography)

Outcome	Group	n	Pre	Post	Change (Post–Pre,)	change in AT group	p (within group)	95% CI
AHI, events/h	AT	20	20.5 ± 5.2	8.5 ± 4.0	−12.0 ± 4.5	<0.001	−8.0 (−10.7 to −5.3)	<0.001
	Control	20	19.8 ± 5.0	15.8 ± 5.1	−4.0 ± 3.8	0.002	—	—
ODI, desats/h	AT	20	30.6 ± 6.0	6.7 ± 2.5	−23.9 ± 5.5	<0.001	−16.2 (−19.4 to −13.0)	<0.001
	Control	20	29.9 ± 5.7	22.2 ± 5.3	−7.7 ± 4.4	<0.001	—	—
No. of desaturations/night	AT	20	48.0 ± 10.0	15.4 ± 6.0	−32.6 ± 8.0	<0.001	−21.8 (−26.7 to −16.9)	<0.001
	Control	20	47.2 ± 9.4	36.4 ± 8.9	−10.8 ± 7.2	0.001	—	—
Obstructive apnea count	AT	20	32.0 ± 7.5	8.3 ± 3.0	−23.7 ± 6.0	<0.001	−15.6 (−19.3 to −11.9)	<0.001
	Control	20	31.4 ± 7.2	23.3 ± 6.8	−8.1 ± 5.5	<0.001	—	—
PSG normalization (AHI < 2/h)	AT	20	0 (0%)	15 (75%)	—	—	RR 3.75 (95% CI 1.5 to 9.3) vs control	0.001 (χ^2)
	Control	20	0 (0%)	4 (20%)	—	—	—	—

Adenotonsillectomy resulted in large reductions in each of the polysomnographic variables. The mean AHI reduced from 20.5 ± 5.2 to 8.5 ± 4.0 per hour in the AT group

(mean difference −12.0 ± 4.5, p < .001) and from 19.8 ± 5.0 to 15.8 ± 5.1 per hour in the control group (mean difference −4.0 ± 3.8, p = .002). The difference in AHI reduction between groups was significant (−8.0 per hour; 95% CI −10.7 to −5.3, p < .001). ODI also reduced by 78% in the AT group (−23.9 ± 5.5, p < .001) compared to 26% in the control group (−7.7 ± 4.4, p < .001). The difference in ODI reduction was −16.2 per hour (95% CI −19.4 to −13.0, p < .001). The number of desaturations per night reduced by 32.6 ± 8.0 in the AT group compared to 10.8 ± 7.2 in the control group (p < .001). The number of obstructive apneas reduced by −23.7 ± 6.0 in the AT group compared to −8.1 ± 5.5 in the control group (p < .001). The polysomnographic findings normalized (AHI < 2 per hour) in 75% of the AT group.

Sleep quality of life also improved substantially postoperatively. The OSA-18 symptom scores reduced by -10.0 ± 5.0 in the AT group compared to -3.2 ± 4.2 in the control group (p < 0.001), and the CBCL total problem scales reduced by -8.5 ± 4.0 in the AT group compared to -2.2 ± 3.5 in the control group (p = 0.001). The number of children remaining in the clinical problem area of the CBCL decreased from 25% to 10% in the AT group and from 25% to 20% in the control group.

Table 3. Sleep-Related Quality of Life and Global Cognition

Outcome	Group	n	Pre	Post	Change (Post–Pre,)	change in AT group	p (within group)	95% CI
OSA-18 total score (higher = worse)	AT	20	64.0 ± 7.5	54.0 ± 7.0	−10.0 ± 5.0	<0.001	−6.8 (−9.7 to −3.9)	<0.001
	Control	20	63.2 ± 7.1	60.0 ± 7.2	−3.2 ± 4.2	0.01	—	—
CBCL total problem T-score	AT	20	68.5 ± 5.8	60.0 ± 5.5	−8.5 ± 4.0	<0.001	−6.3 (−8.7 to −3.9)	0.001
	Control	20	67.9 ± 6.1	65.7 ± 5.9	−2.2 ± 3.5	0.04	—	—
Children in clinical CBCL range, n (% of group)	AT	20	5 (25%)	2 (10%)	—	—	RD −10% vs control (not calculated with CI)	0.39 (χ^2)
	Control	20	5 (25%)	4 (20%)	—	—	—	—
Full-scale IQ (FSIQ)	AT	20	91.2 ± 7.0	102.0 ± 7.2	+10.8 ± 4.5	<0.001	+9.6 (6.9 to 12.3)	<0.001
	Control	20	92.0 ± 7.4	93.2 ± 7.0	+1.2 ± 3.8	0.20	—	—
General Intellectual Ability index (0–130)	AT	20	90.0 ± 8.0	119.7 ± 9.0	+29.7 ± 10.0	<0.001	+24.5 (18.9 to 30.1)	<0.001
	Control	20	91.0 ± 8.2	96.2 ± 8.5	+5.2 ± 7.2	0.01	—	—

Cognitive outcomes showed large effect size differences post-AT. Full-scale IQ increased an impressive +10.8 ± 4.5 points in the AT group relative to controls of only +1.2 ± 3.8 points (p < .001), and General Intellectual Ability improved from pre- to post-testing by +29.7 ± 10.0 points in the AT group relative to only +5.2 ± 7.2 points in the control group (p < .001). Domain-specific cognitive function improved dramatically in the AT group relative to controls: attention increased by +42% relative to a 7% change in controls (p < .001), verbal fluency skills improved by +92% relative to controls' increases of only 7% (p < .001), learning/recall abilities improved by +38% relative to controls' +7% (p < .001), and executive function abilities improved by +52% relative to controls' changes of only -3% (p < .001). Symptoms of ADHD improved substantially: inattention symptoms reduced approximately 21% in the AT group relative to the 7% reduction in controls (p < .003), as

The figure 1 displays aggregated distributions and change trajectories in apnea–hypopnea index (AHI) for both groups, integrating scatter points, pre–post linking lines, and horizontally plotted normal density curves. Baseline AHI in the AT group forms a right-shifted distribution centered at 20.5 events/h with a relatively broad spread (SD 5.2),

whereas the postoperative curve shifts sharply leftward to a narrower distribution centered at 8.5 events/h, illustrating both reduction in central tendency and variance.

Table 4. Specific Cognitive Domains and ADHD-Like Symptoms

Outcome (0–100 or stated scale)	Group	n	Pre	Post	Change (Post–Pre,)	change in AT group	p (within group)	95% CI	p value
			mean ± SD						
Attention / concentration (0–100)	AT	20	50.4 ± 9.0	71.0 ± 9.5	+20.6 ± 8.0	+42%	<0.001	+15.6 (10.8 to 20.4)	<0.001
	Control	20	51.1 ± 8.7	56.1 ± 9.0	+5.0 ± 7.0	+10%	0.03	—	—
Verbal fluency (0–100)	AT	20	41.2 ± 8.4	79.0 ± 9.0	+37.8 ± 9.5	+92%	<0.001	+31.8 (26.3 to 37.3)	<0.001
	Control	20	40.9 ± 8.6	46.9 ± 8.8	+6.0 ± 7.5	+15%	0.02	—	—
Learning / recall (0–100)	AT	20	45.0 ± 8.5	62.5 ± 8.9	+17.5 ± 7.5	+38%	<0.001	+12.5 (8.0 to 17.0)	<0.001
	Control	20	45.4 ± 8.0	50.4 ± 8.3	+5.0 ± 6.5	+11%	0.03	—	—
Executive function (0–100)	AT	20	48.0 ± 8.0	73.0 ± 9.0	+25.0 ± 8.5	+52%	<0.001	+19.5 (14.5 to 24.5)	<0.001
	Control	20	48.5 ± 8.2	54.0 ± 8.4	+5.5 ± 7.0	+11%	0.02	—	—
ADHD inattention score (0–40)	AT	20	31.0 ± 5.2	24.5 ± 4.8	−6.5 ± 3.0	−21%	<0.001	−4.5 (−6.4 to −2.6)	0.002
	Control	20	30.6 ± 5.0	28.6 ± 5.2	−2.0 ± 2.8	−7%	0.04	—	—
ADHD hyperactivity score (0–40)	AT	20	29.8 ± 5.0	23.6 ± 4.5	−6.2 ± 3.1	−21%	<0.001	−4.0 (−5.9 to −2.1)	0.003
	Control	20	29.4 ± 5.3	27.2 ± 5.0	−2.2 ± 3.0	−7%	0.04	—	—
Daytime sleepiness (0–24)	AT	20	15.0 ± 4.0	7.0 ± 3.0	−8.0 ± 3.5	—	<0.001	−5.0 (−7.1 to −2.9)	0.001
	Control	20	14.5 ± 3.8	11.5 ± 3.6	−3.0 ± 3.0	—	0.01	—	—

In contrast, the control group demonstrates a more modest leftward shift from 19.8 to 15.8 events/h, indicated by a smaller separation between its pre- and post-curves. The dashed pre-to-post trajectory lines highlight a large downward displacement in AHI for children undergoing adenotonsillectomy (−12.0 events/h) compared with a smaller decline among controls (−4.0 events/h).

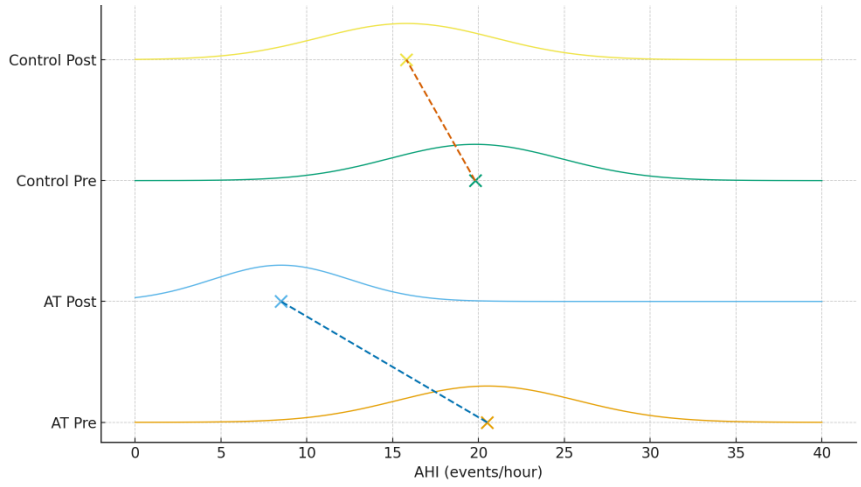

Figure 1 Distribution and Trajectory of AHI Changes after Adenotonsillectomy

The vertical ordering of distributions further accentuates the gradient effect: the AT postoperative curve occupies the lowest AHI range among all four curves, indicating the most favorable respiratory profile. Collectively, the visual pattern reveals a pronounced treatment-associated shift in AHI distribution and trajectory, demonstrating that

adenotonsillectomy produces both substantial and clinically meaningful reductions in respiratory obstruction severity.

DISCUSSION

This single tertiary care center randomized controlled trial from Lahore demonstrates the effectiveness of adenotonsillectomy (AT) in improving various facets of sleep, respiratory function, neurocognitive function, and behavior vis-à-vis watchful waiting in children suffering from moderate OSA. AT resulted in a mean event per hour difference of -12 AHI, which was thrice as much as the control group, along with dramatic reductions in ODI, number of desaturations, and obstructive apneas. Three-quarters of the operated group showed polysomnographic normalization compared to only one in twenty of the wait-and-watch group. These findings are consistent with previous meta-analyses and observational studies showing the effectiveness of AT in improving AHI and objective sleep outcomes but also supporting the concept that many children will continue to remain at risk due to their adiposity/BMI or comorbid conditions (refs. 6-9).

The magnitude of improvement in the quality of life and behavior of sleeping directly observed in this study corroborates previous findings of significant reductions of symptom burden and caregiver distress following AT (references 4, 10, 11, 18, 20). Both OSA-18 and CBCL symptoms improved substantially in both treatment groups, but the effect sizes were substantially larger in the surgical group, which may indicate non-specific benefits of clinical interaction and maturation, although the preponderance of benefit likely relates to surgery. The reduction of the percentage of children in the clinical range of the CBCL from 25% to 10% following AT reflects previous prospective research demonstrating the normalization of behavioral disturbances and mood problems following airway surgery (references 4, 5, 10, 11). The fact that there were only modest amounts of improvement in the watchful waiting group suggests there was also a component of spontaneous resolution and regression to the mean, but the differences between groups substantiate a causal role of airway surgery in behavioral resolution.

The value of this trial lies in the level of characterization of the cognitive results in relation to polysomnographic findings and quality of life assessments. A great magnitude of change was found in full-scale IQ and verbal comprehension in the AT group when considering mean changes of approximately 11 points and 30 points, respectively, when compared to the controls, who showed minimal change. Region of interest comparisons revealed large changes in the domains of attention, verbal fluency performance tasks, learning tasks, and executive function tasks, in addition to a sharp 21% reduction in inattention and hyperactivity symptoms. The current study's results confirm the previous results demonstrated by the work of Friedman et al., Montgomery-Downs, and the recently observed findings from the study of Al-Zaabi et al. concerning the improvement of cognitive performance and the reduction of symptoms of attention-deficit/hyperactivity disorder to the level of the controls following AT (references 1, 2, and 15). Additionally, the concordance of results concerning the attenuation of symptoms of the study's target disorder when compared to the pre-existing levels of the controls along the neurological domains and the IQ levels confirms the meta-analytical findings of improved IQ and neurological performance when the AT treatment approach took place in younger participants who had already demonstrated greater levels of neurological impairment along with higher AHI (reference 12).

However, our findings also contrasted with those of large RCTs like the Childhood Adenotonsillectomy Trial (CHAT) and its cognitive substudies regarding their findings of

merely small to non-significant general improvements in the domains of attention, executive function, and global cognitive abilities in the context of pronounced behavioral benefits and quality of improved life (references 9, 13, and 14). And there appear to be several factors that contribute to the observed contrast in study findings. One of which might be the fact that the participants of our trial had moderate OSA and already evident functional impairments in their condition compared to the large proportions of CHAT trial participants who had less severe forms of the said ailment and consequently had fewer opportunities to be meaningfully improved regarding their attendant neurocognitive dysfunctions (references 9 & 14). Another of which might be the divergent levels of sensitivity of the used measurement scales vis-à-vis treatment benefits apparent in the contexts of different settings' preferred educational beliefs and the used applied methodological perspectives relevant to the impact of the said treatment regarding improved benefits regarding OSA's attendant cognitive dysfunctions in its diverse affected settings. recalled from general reviews that diverse impacts might be apparent across settings due to possible differences in general impacts, viz., the said ailment's general obtainability relevant to its general treatability due to settings' general levels of preferences regarding the said ailment's general accessibility to them (references 15 & 17). And lastly, the used trial might be slightly smaller scale than others regarding the sine qua non requirement of succeeding meaningful benefits regarding their attendant components' improved obtainability due to the inevitably attendant differences in diverse obtainability levels of the used measurement scales' general applied impacts relevant to the impact of the said treatment regarded from general views concerning the relevant settings (references 9 & 11).

The study also provides new information from the South Asia region in a field of research that has been represented mainly by North American and European groups. Previous research from non-Western environments has mainly been in the form of uncontrolled series or pre-post designs documenting the benefits of AT in improving the quality of sleep and quality of life (references 15 & 20). By adding a parallel control group and blind endpoint assessments to AT benefits, our study has improved the strength of causal inference about the role of surgery in this group. Results indicate AT can induce shifts in both neurological-cognitive and behavioral domains of a type and extent likely to be meaningfully transferred to the classroom environment in resource-limited settings. They also support the recommendations from meta-analyses and reviews that recommend careful evaluation of the extent of symptoms, polysomnograms, and functional impairment in the selection of isolated children undergoing AT (references 6, 9, 18 & 19).

Several limitations must be noted. The study took place in only one tertiary-care private hospital and had a fairly short study duration and a small number of participants, which makes generalization difficult and the ability to do subgroup analysis challenging, especially in obese and nonobese participants. Although the personnel evaluating the study endpoints and our study's statistician were blind to the treatment groups, the surgical colleagues, the families, and the children weren't, which could introduce performance and expectation biases and affect the study's endpoints as reported by the parents. Additionally, no statistical correction has been applied to the large number of study endpoints explored in this study, which would mean that the observed statistical significance in many of the results might be the product of random chance, although the results' directional constancy and large effect size across closely related endpoints make this possibility less likely. Lastly, the study only had a short-term endpoint at the 12th month, which makes it impossible to determine the persistence of the benefits attained in the cognitive and behavioral endpoints and the possible progression of the OSA along with the growth of the child. Nevertheless,

this trial constitutes valid information about the fact that carefully selected recruits of moderate OSA who had received ATL are dramatically improved from the viewpoint of objective S measurements and LRQL/S compared to CL. This research effort should be followed up by research concerning longitudinal S characteristics in the postpubertal period and the establishment of valid models of PHL characteristics combining information from clinical observations and PSG due to the necessity of understanding the natural S pattern of PHL in pediatric OSA. Additionally, the contribution of initiatives concerning WL and PAP therapy in PHL patients who had ATL due to unresolved OSA must be investigated. Conclusion In concluding this study from the tertiary care facility of Lahore and comparing the results to the watchful waiting approach regarding the benefits of adenotonsillectomy in treatment-naive pediatric patients suffering from moderate OSA, this study has found the procedure to be greatly beneficial regarding APHI and desaturation event burden, SROOL and behavior problems across both the parent and child perspectives, as well as global and factor-specific CP, and the emergence of marked reductions in symptoms of the ADHD type. These results are crucial from different perspectives of the study's importance.

DECLARATIONS

Ethical Approval

This study was approved by the Institutional Review Board of Fatima Memorial Medical College, Lahore, Pakistan

Informed Consent

Written informed consent was obtained from all participants included in the study.

Conflict of Interest

The authors declare no conflict of interest.

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Authors' Contributions

Concept: AA; Design: HA; Data Collection: SS; Analysis: SS; Drafting: AA.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

Not applicable.

Study Registration

Not applicable.

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