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The effect of adenoidectomy on pulmonary function in children: prospective controlled study

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ABSTRACT

Objectives: Adenotonsillar hypertrophy (AH) is a prevalent condition in children that can cause significant complications if left untreated. In this study, we investigated the impact of adenoidectomy on pulmonary function tests (PFTs) and explored the relationship between spirometric parameters in affected children. By evaluating these factors, we can better understand the post-surgical outcomes and the potential benefits of surgical intervention.

Methods: The present study utilized a prospective controlled design to conduct a before and after clinical trial involving 23 children diagnosed with upper airway obstruction resulting from AH. Five specific spirometric parameters were selected to evaluate pulmonary function before and 1-3 months following the adenoidectomy procedure. Additionally, adenoid grade scores and gender differences were recorded for each patient to assess their effect on the lung.

Results: Peak expiratory flow (PEF) ($p = 0.002$), the first second of expiration (FEV1) ($p < 0.001$), and the ratio of FEV1/FVC ($p = 0.001$) significantly increased postoperatively. However, no significant correlations were found between the forced vital capacity (FVC) ($p = 0.39$) and mid-expiratory forced expiratory flow (FEF25-75) ($p = 0.2$). Rising of the FVC, PEF, FEV1, and FEV1/FVC was observed in AH grade III patients compared to AH grade IV patients following the surgical intervention, in comparison to the preoperative baseline, especially statistical significance was FEV ($p = 0.047$), indicating a noteworthy change in lung function.

Conclusions: These findings emphasize the beneficial effects of adenoidectomy on PFTs and highlight that adenoidectomy positively affects the upper and lower airways.

Keywords: Adenotonsillar hypertrophy, pulmonary function tests, adenoidectomy, spirometric parameters, upper airway obstruction

Adenoid hypertrophy (AH) is a common condition characterized by the enlargement of the adenoid tissues. This condition primarily affects children and can result in upper airway obstruction, leading to a range of clinical manifestations and potential systemic effects [1-5]. AH can obstruct the nasal passage and impede the smooth flow of air through the upper respiratory tract. Upper airway obstruction caused by AH

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can significantly impact pulmonary and cardiovascular function in children, leading to symptoms such as nasal congestion, mouth breathing, snoring, and disturbed sleep patterns [6, 7]. Impaired oxygen exchange and increased carbon dioxide retention may contribute to hypoxemia, hypercarbia, and respiratory acidosis [8-10].

The cardiovascular system can also be affected by AH-related upper airway obstruction. The compromised airflow and increased respiratory effort in affected children impose an additional workload on the heart. This increased cardiac demand can lead to heart rate, blood pressure, and cardiac output changes. Over time, these alterations may contribute to cardiovascular complications such as hypertension, right ventricular dysfunction, and cardiac arrhythmias [2, 11-15].

Understanding the complex interactions between AH, upper airway obstruction, and the various physiological systems involved is crucial for appropriate diagnosis and management. Timely recognition of AH allows for targeted interventions, such as adenoidectomy, to alleviate upper airway obstruction and improve respiratory function, cardiovascular health, and overall well-being in affected children [6, 16, 17].

Spirometry, a widely utilized technique, is a noninvasive method that assesses lung function by measuring volumes above the residual volume and flow volume rates. This study obtained spirometric values using a spirometer (P.K. Morgan Ltd., UK). Spirometry is a valuable tool for evaluating lung function and diagnosing various respiratory conditions in children [18, 19]. Spirometry is recommended in several clinical scenarios for children with symptoms suggestive of obstructive airway disease, such as recurrent wheezing, coughing, or shortness of breath. It aids in assessing airway obstruction and can assist in distinguishing between asthma, chronic bronchitis, or other respiratory disorders [20, 2].

Additionally, spirometry helps monitor disease progression and response to treatment in children with known respiratory conditions. Regular spirometric measurements can provide objective data on lung function over time, allowing healthcare professionals to assess the effectiveness of interventions and adjust treatment plans accordingly. Spirometry can be valuable in preoperative evaluations for children undergoing surgical procedures that may impact lung function, such as adenoidectomy or tonsillectomy. Baseline spirometric measurements provide a reference point for postoperative comparisons and can help identify any changes in pulmonary function following the procedure [18-21]. In this study, our primary objective is to investigate the effects of adenoidectomy on PFTs in children with AH.

METHODS

Patients

From October 2016 to January 2020, in a university hospital, we conducted a prospective trial enrolling a total of 23 children (8 boys and 15 girls) between the ages of 4 and 16. They were scheduled for adenoidectomy due to adenoid hypertrophy. The study received approval from the institutional review board (IRB), and written informed consent was obtained from the parents of the participating children, following the guidelines outlined in the Declaration of Helsinki.

All patients underwent a comprehensive evaluation, including detailed medical history, clinical examination, and laboratory tests. Patients with grade 3 (adenoid obstructions 51% to 75% of posterior choana) and grade 4 (adenoid obstructions 76% to 100% of posterior choana) were included in the study and scheduled for adenoidectomy. Patients with chronic adenoiditis and tonsillitis and who have cardiopulmonary diseases, neurological involvement, obesity (body mass index [BMI] > 30 kg/m^2), other causes of nasal obstruction such as polyps, nasal septal deviations, thoracic skeletal deformity, hypertrophic tonsils (grade 2 or 3), subglottic or secondary airway stenosis resulting from previous surgeries, cleft palate, and children unable to perform PFTs were excluded.

During the study, we recorded several parameters related to pulmonary function, including vital capacity (VC), forced vital capacity (FVC), forced expiratory volume during the first second of expiration (FEV1), the ratio of FEV1 to FVC (FEV1/FVC), and mid-expiratory forced expiratory flow (FEF25-75). PFTs were performed one week before the surgery and continued until 1-3 months after the procedure, allowing us to assess the changes in pulmonary function over the postoperative period.

Spirometry

Spirometry is a fundamental tool for diagnosing and monitoring lung function in children. It plays a critical role in assessing respiratory abnormalities, determining the severity of respiratory diseases, and guiding clinical decision-making. By conducting PFTs through Spirometry, we focused specifically on flow rates in accordance with the guidelines established by the American Thoracic Society (ATS) [19-22]. During the spirometry tests, the patients were comfortably seated, with their noses clipped, and there were no restrictions on chest expansion, such as tight clothing or orthodontic braces. To ensure accurate results, the patients were encouraged to perform the test up to five times, and the highest recorded value was considered for analysis. The spirometry values were then compared to age, gender, and height-specific reference values, expressed as a percentage ratio. A minimum of three adequate measurements were recorded to ensure accuracy, following the reference values provided by Knudson *et al*. All measurements were completed within a maximum 2-minute interval [23]. The same trained operator performed all the respiratory tests throughout the study to maintain consistency and reliability. The operator provided consistent support and encouragement to the children during the testing process, ensuring their comfort and cooperation.

Statistical Analysis

In this study, descriptive statistics were used for continuous variables, and frequency analysis was used for categorical variables. Whether the variables fit the normal distribution was tested with Kolmogorov-Smirnov and Shapiro-Wilk tests. The dependent sample t-test was applied for the variables obtained from the dependent sample groups with normal distribution, and the Wilcoxon test was applied for the variables obtained from the dependent sample groups without the normal distribution. Independent sample t-test and Mann-Whitney U test were used to determine the differences between independent groups for the normal and non-normally distributed variables. The significance level was accepted as $p < 0.05$. Statistical analyses were made in the IBM SPSS 26 program.

RESULTS

The study enrolled a total of 23 children, consisting of 15 females and 8 males, with an age range between 5 and 16 years and a mean age of 9,43 ± 3,01 years. All participants demonstrated nasopharyngeal obstruction, evidenced by an adenoid-nasopharyngeal (A/N) ratio exceeding 0.85. Seven participants (30.4%) had grade III enlarged tonsils, while the remaining 16 cases

Table 1. Pulmonary function measures of all patients

Descriptive Statistics						Test Statistics[a]	
		Mean	SD	Min.	Max.	Z	Asymp. Prob
FVC	pre-operation	1.549	0.490	0.690	2.470	-0.853[b]	0.393
	post-operation	1.729	0.627	0.770	3.040		
FEV_1	post-operation	1.263	0.521	0.340	1.920	-3.681[b]	**< 0.001**
	post-operation	1.636	0.551	0.760	2.580		
FEV_1/FVC	pre-operation	80.024	19.519	30.631	105.682	-3.406[b]	**0.001**
	post-operation	96.277	14.456	80.142	146.269		
PEF	pre-operation	1.873	0.835	0.340	3.180	-3.073[b]	**0.002**
	post-operation	2.602	1.122	1.310	5.520		
FEF_{25-75}	pre-operation	3.516	7.281	0.000	27.000	-1.278[b]	0.201
	post-operation	1.766	0.560	1.080	3.020		

FVC = forced vital capacity, FEV_1 = first second expiration, PEF = peak expiratory flow, FEF_{25-75} = mid-expiratory forced expiratory flow

[a]Wilcoxon Signed Ranks Test

[b]Based on negative ranks

(69.4%) had grade IV.

Table 1 illustrates the improvements observed in various pulmonary function measures, including FVC, PEF, FEV1, FEV1/FVC, and FEF25-75, during the period of 1-3 months following the surgery in comparison to the preoperative measurements. The Wilcoxon Signed Ranks tests indicated significant improvements in three parameters: PEF, FEV1, and FEV1/FVC ($p < 0.05$).

Significant spirometric improvements followed adenoidectomy. PEF increased from 1.87 ± 0.84 preoperatively to 2.60 ± 1.12 postoperatively ($p = 0.002$), FEV1 increased from 1.26 ± 0.52 to 1.63 ± 0.55 ($p < 0.001$), and FEV1/FVC increased from 80.02 ± 19.51 to 96.28 ± 14.46 ($p = 0.001$). However, no significant correlations were found between FVC, FEF25-75, both pre and post-op ($p > 0.05$). FVC increased from 1.55 ± 0.49% pre-op to 1.73 ± 0.63% post-op ($p = 0.39$), while FEF25-75 improved, decreasing from 3.52 ± 7.28% to 1.76 ± 0.55% ($p = 0.2$). Differences in post/pre-PFTs were more pronounced in women but not statistically significant (Table 2).

The study revealed that among the variables measured, including FVC, PEF, FEV1, and the FEV1/FVC,

Table 2. Statistical Analysis of Pulmonary Functional Tests Based on Gender Differences

Descriptive Statistics						**Test Statistics[a]**		
		Mean	**SD**	**Min.**	**Max.**	**Z**	**Asymp. Prob**	**Exact Sig. [2*(1-tailed Sig.)]**
Dif. FVC Post-Pre operation	F	0.309	0.067	-0.09	1.94	-1.56	0.120	0.131[b]
	M	-0.006	0.29	- 0.43	0.44			
Dif. FEV$_1$ Post-Pre operation	F	0.52	0.72	- 0.13	2.24	-2.13	**0.033**	**0.034[b]**
	M	0.097	0.12	- 0.15	0.24			
Dif. FEV$_1$/FVC Post-Pre operation	F	19.11	18.39	-8.99	53.96	*Independent Samples Test		
	M	10.89	17.12	-19.15	40.59			
Dif. PEF Post-Pre operation	F	0.92	1.76	-0.27	5.18	-0.097	0.92	0.93[b]
	M	0.37	0.55	-0.20	1.00			
Dif. FEF$_{25-75}$ Post-Pre operation	F	-2.78	9.06	-25.92	3.00	-0.06	0.95	0.98[b]
	M	0.12	0.39	-0.49	0.57			

*Independent Samples Test

	t-test for Equality of Means						
Dif.FEV$_1$/FVC	t	Df	Prob	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Post-Pre operation (F, M) (Equal variances assumed)	1.05	21	0.308	8.23	7.87	Lower	Upper
						-8.14	24.59

FVC = forced vital capacity, FEV$_1$ = first second expiration, PEF = peak expiratory flow, FEF$_{25-75}$ = mid-expiratory forced expiratory flow, F = female, M = male

[a]Grouping variable: gender

[b]Based on negative ranks

there was a more significant increase in patients with AH grade III compared to those with AH grade IV following the surgical intervention when compared to the preoperative baseline. However, the variable FEF25-75 did not show significant differences (Table 3).

In Fig. 1, the spirometry results illustrate the variation in lung capacity before (B) and after (C) surgery. The normal airflow during nasopharyngeal breathing is provided, indicating the typical breathing time of a child with adenoid hypertrophy (D) after undergoing surgery (E). Adenoid hypertrophy hinders or obstructs the airflow passage through the nasopharynx, leading to reduced or complete blockage (Fig. 1).

DISCUSSION

The relationship between AH grade and PFTs has been a subject of interest in understanding the impact of adenoid enlargement on respiratory function. AH is characterized by the excessive growth of adenoid tissues in the upper airway, leading to varying degrees of airway obstruction. This obstruction can disrupt normal airflow and potentially affect lung function parameters measured by PFTs [23-25]. In our study, we found that adenoidectomy has a positive effect on pulmonary functions, and after surgery, there were significant improvements in three spirometric parameters:

Table 3. Statistical Analysis of Pulmonary Functional Tests Parameters in Relation to Adenoid Hypertrophy Grades

		Descriptive Statistics				Test Statistics[a]		
		Mean	**SD**	**Min.**	**Max.**	**Z**	**Asymp. Prob**	**Exact Sig. [2*(1-tailed Sig.)]**
Dif. FVC Post-Pre operation	Grade III	0.32	0.72	-0.9	1.94	-0.91	0.37	0.376[b]
	Grade IV	0.12	0.53	-0.43	1.93			
Dif. FEV_1 Post-Pre operation	Grade III	0.60	0.74	0.7	2.24	-2.01	**0.05**	**0.047**[b]
	Grade IV	0.27	0.54	-0.15	2.23			
Dif. FEV_1/FVC Post-Pre operation	Grade III	25.06	14.12	9.81	53.96	*Independent Samples Test		
	Grade IV	12.40	18.56	-19.56	53.91			
Dif. PEF Post-Pre operation	Grade III	1.13	1.83	-0.14	5.18	-1.07	0.28	0.308[b]
	Grade IV	0.55	1.30	-0.27	5.18			
Dif. FEF_{25-75} Post-Pre operation	Grade III	-2.99	10.15	-25.92	2.75	-1.10	0.27	0.278[b]
	Grade IV	-1.21	6.13	-23.98	3.00			

*Independent Samples Test

	t-test for Equality of Means						
Dif.FEV_1/FVC Post-Pre operation	t	df	Prob	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
	1.60	21	0.12	12.66	7.89	Lower	Upper
						-3.74	29.06

FVC = forced vital capacity, FEV_1 = first second expiration, PEF = peak expiratory flow, FEF_{25-75} = mid-expiratory forced expiratory flow

[a]Grouping variable: AH grade

[b]Not corrected for ties

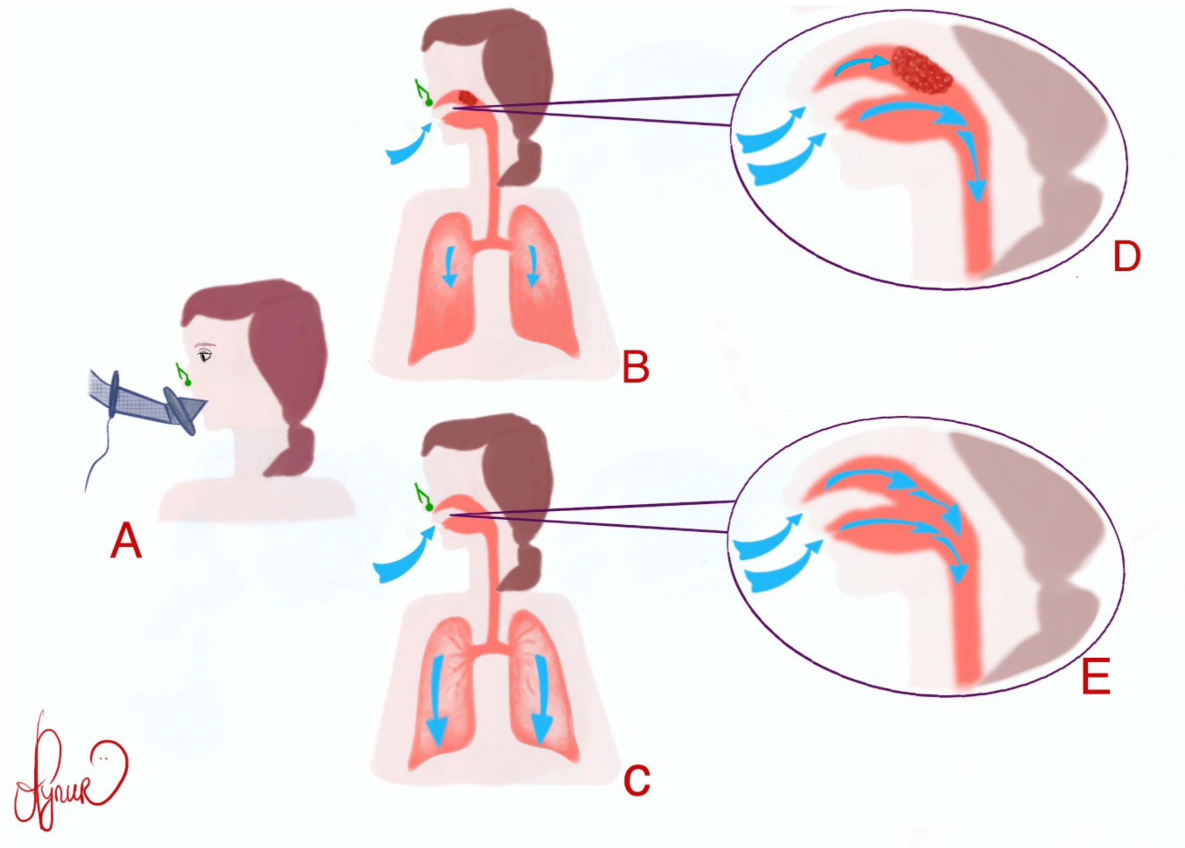

Fig. 1. **Nasopharyngeal airflow in a child with adenoid hypertrophy and after adenoidectomy. A: The spirometry procedure in a child, B: Spirometry in a child with adenoid hypertrophy, C: Spirometry after the adenoidectomy, D: Airflow from the nasopharynx in a child with adenoid hypertrophy, and E: Airflow from the nasopharynx in a child after the adenoidectomy.**

PEF, FEV1, and FEV1/FVC ($p < 0.05$).

AH notably impacts various systems, including the respiratory, cardiovascular, neurological, and other associated systems. Enlarging the adenoid tissue in the upper airway can give rise to patterns, leading to significant physiological disturbances and complications.

AH obstructs the nasal passages, causing airflow restriction during inhalation and exhalation. This obstruction results in mouth breathing as a compensatory mechanism, altering the normal breathing pattern. The restricted airflow can lead to increased respiratory effort, reduced lung volumes, and impaired gas exchange. Children with AH often experience symptoms such as snoring, sleep-disordered breathing, and recurrent respiratory infections. The compromised airflow can also disrupt sleepiness and reduce quality of life [3, 25-28].

Rogha *et al*. [28] found a significant increase in FVC after adenotonsillectomy. Removal of adenoids can alleviate upper airway obstruction, allowing for improved air movement in and out of the lungs and subsequently increasing FVC. Although the FVC parameter is not statistically significant ($p = 0.393$), our study observed a mathematical difference in the FVC parameters before and after the surgery. Initial findings hint at a potential positive link between adenoidectomy and FVC, but more data is needed for statistical significance.

FEV1 measures the air volume forcibly exhaled during forced expiration in one second. Adenoidectomy can contribute to an improvement in FEV1 by reducing airway resistance and facilitating smoother airflow. This can result in a greater volume of air expelled from the lungs within the first second of exhalation [1, 20, 23-26]. Our study observed a significant increase in FEV1, pre-op it was 1.26% ± 0.52%, post-op averaged 1.636% ± 0.551 ($p < 0.001$), showing adenoidectomy's impact on one-second forced exhalation.

FEV1/FVC ratio assesses airway function. A lower ratio suggests obstruction or airflow restriction, higher in healthy cases. Our study also detected a significant increase in FEV1/FVC (Preoperative: 80.02 ± 19.52; postoperative: 96.28 ± 14.46) (p = 0.001).

PEF measures the maximum flow of air during forced expiration. Improvement in PEF signifies better expiratory flow and respiratory efficiency [10, 28]. PEF increased significantly from 1.87% ± 0.84% preoperation to 2.60% ± 1.12% post-operation (p = 0.003), aligning with literature. After adenoidectomy, the reduction in upper airway obstruction allows for more efficient airflow, leading to an increased PEF.

FEF25-75, a Spirometry measure of mid-exhalation airflow, reflects lung function in small and intermediate airways. In our study, FEF25-75 was 3.52% ± 7.28% preoperative and 1.76% ± 0.55% postoperative, without significant change (p = 0.2).

Gender-related PFT differences linked to adenoidectomy yield insights, but findings are inconclusive [25, 29, 30]. Our study found female's post-surgery PFTs increased compared to male's, lacking statistical significance (FVC; p = 0.120, FEV1; p = 0.033, FEV1/FVC; p = 0.38, PEF; p = 0.92, and FEF25-75; p =0.95).

Our thorough spirometry provides reliable data, enhancing understanding of adenoidectomy's impact on pulmonary function in adenotonsillar hypertrophy children. Assessment of the presence and degree of reversibility of airflow obstruction is clinically significant in patients with asthma or chronic obstructive pulmonary disease. The measurement of PEF and FEV1 is a valuable method to assess the severity of obstruction and its degree of reversibility [31]. Our study showed that positive reversible changes can be observed in the lower respiratory tract after adenoidectomy.

Limitations

We only evaluated the short-term effects of adenoidectomy on pulmonary function tests. However, it will help provide valuable insights into the durability of the improvements and potential future complications that may arise over time. The study focused on five parameters of spirometry to evaluate pulmonary function. For future research, we recommended including other relevant parameters, such as lung volumes or airway resistance. Conducting multicenter studies involving a larger and more diverse population to improve the generalizability of the findings. Involving multiple centers would allow for a broader representation of different patient demographics, which could enhance the applicability of the results to a wider range of populations. Assessing parameters such as sleep quality, daytime functioning, academic performance, and behavioral outcomes can provide a more holistic understanding of the benefits of surgical intervention beyond the objective measurements of pulmonary function.

Highlights of this study

(1) Significant improvements in spirometric parameters: The study demonstrated significant improvements in spirometric parameters, including forced vital capacity (FVC), peak expiratory flow (PEF), forced expiratory volume during the first second of expiration (FEV1), and the ratio of FEV1 to FVC (FEV1/FVC), following surgical intervention for adenoid hypertrophy.

(2) Variation in improvement based on AH grade: The study observed a more substantial increase in spirometric parameters among patients with AH grade III compared to those with grade IV, indicating that the severity of AH may influence the extent of improvement in lung function following surgery.

(3) Limited impact on mid-expiratory forced expiratory flow (FEF25-75): The study found that the mid-expiratory forced expiratory flow (FEF25-75) did not show significant changes after the surgical intervention. This suggests that while other spirometric parameters improved, the FEF25-75 may be less influenced by adenoidectomy.

(4) Statistically significant improvement in FEV1: Among the spirometric variables, the FEV1 exhibited statistically significant improvement after surgery. This finding indicates a notable enhancement in the air volume forcefully exhaled during the first second of expiration, reflecting improved lung function.

(5) Clinical relevance and impact: The significant improvements observed in spirometric parameters following adenoidectomy highlight the clinical relevance of the surgical intervention in improving respiratory function. These findings can contribute to better respiratory care and enhanced overall respiratory health outcomes for patients with adenoid hypertrophy.

CONCLUSION

Compared with preoperative measurements, our study showed improvement in postoperative pulmonary function measurements (PEF, FEV1, FEV1/FVC). Gender differences were noted, more pronounced in females but not statistically significant. Grade III adenoid hypertrophy patients showed more remarkable postoperative improvement in lung function than grade IV patients, significantly in FEV1. FEV1 and PEF measurements are of clinical importance in guiding the reversibility of the lower airway. We observed positive reversible changes in the lower respiratory tract after adenoidectomy.

Authors' Contribution

Study Conception: OYA, AA; Study Design: OYA; Supervision: SK; Funding: N/A; Materials: N/A; Data Collection and Processing: OYA, AA; Statistical Analysis and Data Interpretation: OYA, AA; Literature Review: OYA; Manuscript Preparation: AA, OYA, and Critical Review: AA, OYA, SK.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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