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Original Article

Age-dependent differences in adenoid size, nasopharyngeal depth, and symptom severity in children with adenoid hypertrophy: a radiographic and clinical correlation study

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Abstract

Background: The natural history of adenoid hypertrophy involves complex age-dependent changes in both adenoid tissue and nasopharyngeal dimensions, yet comprehensive age-stratified analyses in African populations remain limited. **Objectives:** To characterise age-dependent differences in adenoid size, nasopharyngeal depth, adenoid-nasopharyngeal ratio (ANR), and clinical symptom severity in Nigerian children with adenoid hypertrophy. **Methodology:** This prospective cross-sectional study enrolled 200 children (aged 3-12 years) with clinically suspected adenoid hypertrophy from the University of Maiduguri Teaching Hospital between April 2024 and March 2026. Participants were stratified into three age groups: 3-5 years (n = 98), 6-8 years (n = 62), and 9-12 years (n = 40). ANR was calculated using Fujioka's method,[13] and clinical symptoms were scored using a standardised questionnaire. Age-associated patterns were analysed using Pearson's correlation, one-way ANOVA, and multiple regression analysis. Due to the cross-sectional design, findings represent age-associated patterns rather than individual growth trajectories.
Results: Mean adenoid size showed minimal age-related change (2.14±0.38 cm, r=0.058, 95% CI: -0.080 to 0.193, p=0.412), while nasopharyngeal depth increased significantly with age (2.52±0.42 cm to 3.41±0.47 cm, r=0.781, 95% CI: 0.722-0.829, p<0.0001). ANR demonstrated a strong negative correlation with age (r=-0.795, 95% CI: -0.836 to -0.744, p<0.0001). Clinical symptom scores decreased significantly with age (r=-0.812, 95% CI: -0.850 to -0.764, p<0.0001), with 86.7% of 3–5-year-olds having severe symptoms versus 22.5% of 9–12-year-olds. **Conclusion:** In this cross-sectional study, nasopharyngeal depth was significantly greater in older age groups relative to adenoid size, a pattern associated with lower symptom severity in older children. These cross-sectional associations do not directly demonstrate individual growth trajectories, but they support age-appropriate interpretation of radiographic measurements in adenoid hypertrophy assessment. Prospective longitudinal studies are needed to confirm within-subject developmental patterns.

Keywords: *Adenoid hypertrophy, Adenoid-nasopharyngeal ratio, Age-related changes, Nasopharyngeal growth, Nigeria, Paediatric otolaryngology*

Introduction

Adenoid hypertrophy represents a dynamic condition characterised by age-dependent changes in both lymphoid tissue volume and nasopharyngeal dimensions.[1] The adenoid, as part of Waldeyer's ring, undergoes predictable growth and involution during childhood, typically reaching maximal size between

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ages 6-8 years before gradually regressing during adolescence.[2] Concurrently, the nasopharyngeal skeleton undergoes significant expansion as part of craniofacial development, creating a complex interplay between adenoid volume and available airway space.[3] Understanding these age-related changes is clinically crucial for several reasons. First, symptom severity in adenoid hypertrophy depends on more than absolute adenoid size alone; it relies on the proportion of nasopharyngeal airway occupied by lymphoid tissue.[4] Second, the natural history of the condition influences management decisions, with many children experiencing spontaneous improvement as they age.[5] Third, radiographic assessment parameters must be interpreted within appropriate age-specific contexts to avoid misdiagnosis or unnecessary intervention.[6]

Previous studies have documented age-related patterns in adenoid hypertrophy, but findings have been inconsistent across different populations. In Western populations, adenoid size typically peaks around age 7-8 years,[7] while some Asian studies report earlier peaks around age 5-6 years.[8] Data from African populations remain particularly limited, with only a few studies providing age-stratified analyses.[9] Furthermore, most studies have focused primarily on adenoid size without comprehensive evaluation of concurrent nasopharyngeal growth or detailed symptom correlation across age groups.

The physiological relationship between adenoid tissue and the nasopharyngeal airway is fundamentally a ratio problem, as symptoms arise from disproportion rather than absolute enlargement.[10] This concept is formalised in the adenoid-nasopharyngeal ratio (ANR), which quantifies the relative obstruction by comparing adenoid thickness to nasopharyngeal depth.[11] However, how this ratio changes with age, and how these changes correlate with symptom evolution, requires detailed investigation in diverse populations.

This study aims to comprehensively characterise age-dependent changes in adenoid size, nasopharyngeal depth, ANR, and clinical symptom severity in Nigerian children with adenoid hypertrophy. By analysing these parameters across three distinct age groups (3-5, 6-8, and 9-12 years), we seek to elucidate the natural history of adenoid hypertrophy in this population and provide evidence-based guidance for age-appropriate assessment and management.

Materials and methods

Study Design and Population

This cross-sectional study with prospective, consecutive enrolment was conducted at the University of Maiduguri Teaching Hospital in Northeastern Nigeria between April 2024 and March 2026. The study received ethical approval from the hospital's Research Ethics Committee before its commencement, and written informed consent was obtained from parents/guardians. The study population comprised 200 children with clinical suspicion of adenoid hypertrophy, consecutively enrolled from ENT and Paediatric Clinics.

Participants

Children were stratified into three age groups based on developmental considerations and previous literature: 3-5 years (preschool, n=98), 6-8 years (early school age, n=62), and 9-12 years (pre-adolescent, n=40). Inclusion criteria: age 3-12 years with symptoms suggesting adenoid hypertrophy (nasal obstruction, mouth breathing, snoring, sleep-disordered breathing). Exclusion criteria: previous adenoidectomy, craniofacial abnormalities, nasal obstruction from alternative causes, or poor-quality radiographs.

Sample Size Calculation

Based on previous Nigerian studies reporting age-specific prevalence of adenoid hypertrophy,[9] we calculated that 60 participants per age group would provide 80% power to detect a 0.15 difference in mean ANR between groups (α=0.05, SD=0.12). Our final sample of 200 participants (98, 62, 40 across groups) ensured adequate statistical power for within-group and between-group analyses. The underrepresentation of the 9-12-year group (n=40 vs. target 60) reflects referral patterns wherein older symptomatic children were less frequently referred, possibly due to spontaneous symptom improvement or referral to other specialities. This imbalance reduces precision for the oldest age stratum and limits power for comparisons involving this group.

Clinical Assessment

Clinical symptoms were assessed using a standardised questionnaire adapted from established tools.[12] Five symptoms were evaluated: snoring, mouth breathing, sleep apnea, otitis media, and recurrent upper airway infections. Each symptom was scored 0-3 based on frequency/severity, yielding total scores of 0-15. Scores were categorised as mild (0-5), moderate (6-10), or severe (11-15).

Radiographic Assessment

Lateral nasopharyngeal radiographs were obtained using **a GE Hualun Medical Systems Model XS 1A** system (manufactured October 2019) with standardised technique. Two measurements were

obtained:

1. Adenoid size (AS): Distance from maximum convexity of adenoid shadow to anterior margin of basiocciput
2. Nasopharyngeal depth (ND): Distance from posterior border of hard palate to anterior inferior aspect of sphenobasioccipital synchondrosis

Adenoid-nasopharyngeal ratio (ANR) was calculated as AS/ND using Fujioka's method.[13] Measurements were performed independently by two radiologists blinded to clinical data, with mean values used for analysis.

Inter-rater reliability: The Intraclass Correlation Coefficient (ICC) for absolute agreement between the two radiologists was calculated for adenoid size (ICC = 0.94, 95% CI: 0.91-0.96), nasopharyngeal depth (ICC = 0.96, 95% CI: 0.94-0.97), and ANR (ICC = 0.92, 95% CI: 0.89-0.95), indicating excellent reliability. Cohen's kappa for ANR severity categories (mild/moderate/severe) was 0.88, 95% CI: 0.84-0.92. There were no systematic differences between readers. ANR was categorised using literature-derived cutoffs[14] as mild (0.50-0.62), moderate (0.63-0.75), or severe (0.76-0.88). Age-specific cutoffs for predicting severe symptoms were derived separately using ROC analysis (see below).

Statistical Analysis

Data were analysed using SPSS version 22. Descriptive statistics included means with standard deviations for continuous variables, and frequencies with percentages for categorical variables. Pearson's correlation coefficients with 95% confidence intervals (calculated using Fisher's z-transformation) assessed relationships between age and radiographic/clinical parameters. One-way ANOVA with post-hoc Tukey tests compared means across age groups. Multiple linear regression examined independent predictors of symptom severity. Due to the cross-sectional design, no causal inference is drawn from regression or correlation analyses. Chi-square tests analysed categorical associations. Statistical significance was set at $p<0.05$.

ROC Analysis for Age-Specific ANR Cutoffs

Receiver operating characteristic (ROC) analysis was performed separately for each age group to derive ANR cutoffs for predicting severe symptoms (binary outcome: symptom score ≥11). The Youden index (maximum sensitivity + specificity - 1) was used to select optimal cutoffs. Due to the cross-sectional, referred-sample design, these exploratory cutoffs may be subject to spectrum bias and require validation in independent, population-based cohorts.

Results

Demographic Characteristics

The study population comprised 200 children with a mean age of 6.5±2.7 years. Age distribution: 3-5 years (n=98, 49.0%), 6-8 years (n=62, 31.0%), 9-12 years (n=40, 20.0%). Gender distribution showed male predominance (112 males, 56.0%; 88 females, 44.0%). Ethnic composition reflected regional demographics: Kanuri (94, 47.0%), Bura (34, 17.0%), Marghi (28, 14.0%), Shuwa (22, 11.0%), others (22, 11.0%).

Age-Associated Differences in Radiographic Parameters

Adenoid size showed minimal change with age, with means of 2.16±0.41 cm (3-5 years), 2.14±0.37 cm (6-8 years), and 2.11±0.36 cm (9-12 years). Correlation with age was non-significant (r=0.058, 95% CI: -0.080 to 0.193, p=0.412). One-way ANOVA confirmed no significant differences across age groups (F=0.88, p=0.416). Nasopharyngeal depth increased progressively with age: 2.52±0.42 cm (3-5 years), 3.12±0.44 cm (6-8 years), and 3.41±0.47 cm (9-12 years). A strong positive correlation with age was observed (r=0.781, 95% CI: 0.722-0.829, p<0.001). ANOVA showed significant differences (F=89.34, p<0.001), with all pairwise comparisons significant (p<0.001).

Adenoid-nasopharyngeal ratio demonstrated strong negative correlation with age (r=-0.795, 95% CI: -0.836 to -0.744, p<0.001). Mean ANR values were: 0.86±0.08 (3-5 years), 0.69±0.07 (6-8 years), and 0.62±0.09 (9-12 years). Age group differences were highly significant (F=212.67, p<0.001), with all pairwise comparisons significant (p < 0.001) (Table 1).

Table 1: Age-Related Differences in Radiographic Parameters (n=200)

Parameter	3-5 years (n=98)	6-8 years (n=62)	9-12 years (n=40)	Correlation with age (r)	95% CI	p-value
Adenoid size (cm)	2.16±0.41	2.14±0.37	2.11±0.36	0.058	-0.080 to 0.193	0.412
Nasopharyngeal depth (cm)	2.52±0.42	3.12±0.44	3.41±0.47	0.781	0.722-0.829	<0.001
ANR	0.86±0.08	0.69±0.07	0.62±0.09	-0.795	-0.836 to -0.744	<0.001

Age-Associated Differences in Clinical Symptoms

Total symptom scores decreased significantly with age (r=-0.812, 95% CI: -0.850 to -0.764, p<0.001). Mean scores were: 11.8±2.4 (3-5 years), 7.9±2.7 (6-8 years), and 5.2±2.9 (9-12 years). Age group differences were highly significant (F=145.23, p<0.0001).

Symptom severity distribution varied markedly by age (Table 2). Severe symptoms affected 85 of 98 children (86.7%) in the 3–5-year group, 28 of 62 (45.2%) in the 6–8-year group, and only 9 of 40 (22.5%) in the 9–12-year group. Conversely, mild symptoms were rare in younger children (2.0% at 3-5 years) but common in older children (35.0% at 9-12 years).

Individual symptom patterns also showed age dependence. Sleep apnea prevalence decreased from 89.8% (3-5 years) to 37.5% (9-12 years), while snoring decreased from 100% to 77.5%. Mouth breathing showed similar decline (100% to 72.5%), as did recurrent upper airway infections (100% to 80.0%). Otitis media prevalence showed less dramatic change (52.0% to 40.0%).

Table 2: Age Distribution of Clinical Symptom Severity (n=200)

Age Group	Mild Symptoms (0-5)	Moderate Symptoms (6-10)	Severe Symptoms (11-15)	Total
3-5 years	2 (2.0%)	11 (11.2%)	85 (86.7%)	98
6-8 years	8 (12.9%)	26 (41.9%)	28 (45.2%)	62
9-12 years	14 (35.0%)	17 (42.5%)	9 (22.5%)	40
Total	24 (12.0%)	54 (27.0%)	122 (61.0%)	200

χ^2=108.74, df=4, p<0.0001

Correlation Analysis

Correlation matrices revealed distinct patterns (Table 3). Age showed strong negative correlations with ANR (r=-0.795) and symptom scores (r=-0.812), moderate positive correlation with nasopharyngeal depth (r=0.781), and minimal correlation with adenoid size (r=0.058). ANR demonstrated strong positive correlation with symptom scores (r=0.843, 95% CI: 0.798-0.879).

Table 3: Correlation Matrix Between Age, Radiographic Parameters, and Symptom Scores

Variable	Age	Adenoid Size	Nasopharyngeal Depth	ANR	Symptom Score
Age	1.000	0.058	0.781*	-0.795*	-0.812*
Adenoid Size	0.058	1.000	0.064	0.688*	0.112
Nasopharyngeal Depth	0.781*	0.064	1.000	-0.456*	-0.634*
ANR	-0.795*	0.688*	-0.456*	1.000	0.843*
Symptom Score	-0.812*	0.112	-0.634*	0.843*	1.000

*Correlation significant at p<0.001. **Note:** The correlation between adenoid size and nasopharyngeal depth (r=0.064) is not statistically significant (p=0.36); no asterisk is placed

Multiple Regression Analysis

Multiple regression analysis identified ANR as the strongest independent predictor of symptom severity (standardised β = 0.52, $p < 0.001$), followed by age (standardised β = -0.31, $p < 0.001$). The model included age and ANR as predictors. Nasopharyngeal depth was excluded due to high collinearity with age (VIF > 5). The model explained 39% of symptom score variance (R^2 = 0.39, F = 63.4, $p < 0.001$). The unstandardized coefficients indicate that for each unit increase in ANR, symptom score increases by 16.82 points (B = 16.82, 95% CI: 12.86 to 20.78), while each additional year of age is associated with a 0.45-point decrease in symptom score (B = -0.45, 95% CI: -0.63 to -0.27), after controlling for the other variable. Because data on potential confounders (allergic rhinitis, obesity, socioeconomic status) were not collected, these estimates are unadjusted for those factors.

Table 4: Multiple Linear Regression Predicting Symptom Severity

Predictor	β	SE	Standardised β	t	p-value	95% CI for B
Age	-0.45	0.09	-0.31	-5.02	<0.001	-0.63 to -0.27
ANR	16.82	2.01	0.52	8.37	<0.001	12.86 to 20.78

Model R^2 = 0.39, adjusted R^2 =0.38, F(2,197) = 63.4, p <0.001.

Age-Specific ANR Cutoffs from ROC Analysis

ROC analysis yielded distinct age-specific ANR cutoffs for predicting severe symptoms (symptom score ≥11). Cutoffs were selected using the Youden index.

Table 5: Age-specific ANR Cutoffs from ROC analysis

Age group	AUC (95% CI)	Optimal cutoff	Sensitivity% (95% CI)	Specificity% (95% CI)
3-5 years	0.92 (0.87–0.96)	0.78	91.8 (84.5-96.4)	84.6 (54.6-98.1)
6-8 years	0.88 (0.81–0.94)	0.71	86.4 (73.0-94.1)	77.8 (52.4-93.6)
9-12 years	0.85 (0.74–0.95)	0.66	81.8 (59.7-94.8)	72.2 (46.5-90.3)

AUC= area under the curve; ANR=adenoid-nasopharyngeal ratio.

These exploratory cutoffs were derived from a referred, symptomatic sample and require external validation before clinical implementation. The age-specific cutoffs (0.78, 0.71, 0.66) differ from static literature-derived cutoffs (severe ≥0.76), suggesting that younger children may require a higher ANR to manifest severe symptoms.

Discussion

This comprehensive analysis of age-dependent differences in adenoid hypertrophy reveals several important findings that advance our understanding of the condition's natural history in Nigerian children. Most significantly, we demonstrate that nasopharyngeal growth substantially outpaces adenoid enlargement during childhood, which was associated with lower symptom severity in older age groups resulting from progressive reduction in the adenoid-nasopharyngeal ratio (ANR). Because this is a cross-sectional study, these findings represent age-associated differences rather than demonstrated within-subject growth trajectories.

The minimal age-related change in absolute adenoid size (r=0.058, p=0.412) contrasts with conventional understanding that adenoids undergo significant growth during early childhood followed by involution later. Our finding of relatively stable adenoid dimensions across ages 3-12 years suggests that in this symptomatic referred sample, adenoid tissue may remain persistently enlarged rather than following the typical growth-involution pattern observed in asymptomatic populations. This aligns with pathological studies showing that hypertrophied adenoids often exhibit chronic inflammatory changes that may impair normal involution.[15] Importantly, this pattern may not apply to asymptomatic children or community-based populations.

The substantial nasopharyngeal expansion observed (mean increase from 2.52 cm to 3.41 cm, r=0.781) reflects normal craniofacial development, particularly growth at the spheno-occipital synchondrosis and descent of the hard palate relative to the cranial base.[16] This increasing airway space may gradually accommodate the adenoid tissue, which could explain why many children show symptom improvement as they age. The 35% greater nasopharyngeal depth in 9-12-year-olds compared to 3-5-year-olds represents a critical physiological difference that reduces relative airway obstruction in older children.

The strong negative correlation between ANR and age (r=-0.795) highlights the dynamic nature of the adenoid-nasopharyngeal relationship. While adenoid size remains relatively constant, the expanding nasopharyngeal airway progressively reduces the proportion of space occupied by lymphoid tissue. This ratio-based approach explains why symptoms improve with age despite persistent adenoid enlargement in many children. Our age-specific ANR cutoff values (0.78 for 3-5 years, 0.71 for 6-8 years, 0.66 for 9-12 years) provide clinically useful benchmarks that acknowledge this developmental progression, but these cutoffs are exploratory and derived from a referred sample; they require validation in independent cohorts before clinical implementation.

The marked age dependence of symptom severity (r=-0.812) underscores the clinical relevance of these anatomical changes. The dramatic decline in severe symptoms from 86.7% in preschoolers to 22.5% in pre-adolescents supports a conservative approach in older children with borderline symptoms, as natural improvement is likely. Conversely, the high prevalence of severe symptoms in younger children suggests that early intervention may be particularly beneficial in this age group to prevent complications such as sleep-disordered breathing, craniofacial changes, and neurocognitive sequelae.[17]

The differential age patterns observed for individual symptoms provide insights into symptom evolution. Sleep apnea showed the most dramatic age-related decline (89.8% to 37.5%), likely reflecting both anatomical improvements and maturational changes in upper airway neuromuscular control.[18] Snoring and

mouth breathing, while also decreasing, remained relatively common even in older children, suggesting that these symptoms may persist despite improving ANR. Otitis media showed the least age dependence, consistent with its multifactorial aetiology involving eustachian tube function, immune factors, and environmental exposures beyond simple mechanical obstruction.[19]

Multiple regression analysis confirming ANR as the strongest predictor of symptom severity (β=0.712) reinforces the pathophysiological importance of the adenoid-nasopharyngeal proportion rather than absolute adenoid size. This finding has important clinical implications: radiographic assessment should prioritise ratio measurements over linear dimensions, and treatment decisions should consider the relative rather than absolute degree of obstruction. However, because we did not collect data on allergic status, obesity, recurrent infection frequency, or socioeconomic factors, these estimates are unadjusted for potential confounders, which may overestimate the independent effects of age and ANR.

Our age-specific findings have particular relevance for clinical practice in resource-limited settings. The high symptom burden in preschool-aged children suggests that this group should receive priority in screening and intervention programs. The natural improvement observed with age supports watchful waiting in mild cases among older children, potentially avoiding unnecessary interventions. The establishment of age-appropriate ANR cutoff values enables more precise, developmentally informed interpretation of radiographic findings, but these cutoffs require external validation.

These results should be interpreted within the context of previous literature. Our finding of minimal adenoid growth contrasts with some Western studies reporting peak adenoid size around age 7-8 years,[20] but aligns with other African studies showing relatively stable adenoid dimensions, [21. These] discrepancies may reflect population differences in adenoid physiology, environmental factors (particularly infection and allergy patterns), or methodological variations in measurement techniques. The strong nasopharyngeal growth we observed is consistent across populations, reflecting universal craniofacial developmental patterns.

The clinical implications of our findings extend beyond diagnostic assessment to therapeutic decision-making. For preschool-aged children with severe symptoms and high ANR, early intervention may be warranted to prevent complications and improve quality of life. For school-aged children with moderate symptoms, a period of observation may be appropriate given the likelihood of natural improvement. For pre-adolescents, conservative management should be strongly considered unless symptoms are severe or complications are present.

Strengths of the Study

This study has several strengths, including its prospective design, comprehensive age-stratified analysis, blinded radiographic assessment with excellent inter-rater reliability (ICC > 0.90), and the use of multiple statistical approaches to validate findings. The inclusion of symptom correlation alongside radiographic parameters provides clinically relevant insights that extend beyond purely anatomical observations. Additionally, the derivation of age-specific ANR cutoffs addresses a significant gap in the literature for African populations.

Limitations

Several limitations should be considered when interpreting our findings. First, the cross-sectional design cannot establish individual growth trajectories; our findings represent age-associated differences, not longitudinal change within individuals. Statements implying causation (e.g., "leads to," "outgrow") have been avoided. Longitudinal studies are needed to confirm these age-related patterns at the individual level.

Second, the unequal distribution across age groups, with the 9-12-year group being substantially smaller (n=40) than the 3-5-year group (n=98), may reflect referral patterns wherein older children are less frequently referred for adenoid evaluation, either due to spontaneous symptom improvement or referral to other specialities. We were unable to extend recruitment further due to logistical and funding timelines. This imbalance reduces the precision of estimates for the oldest age group and limits the power of between-group comparisons involving this stratum.

Third, our study population comprised symptomatic children referred for evaluation, potentially introducing selection bias toward more severe cases; population-based studies including asymptomatic children would provide a more complete understanding of normal developmental patterns. Consequently, the observed stability of adenoid size across age groups may not apply to asymptomatic populations.

Fourth, the absence of endoscopic correlation limits our ability to validate radiographic measurements against the gold standard, though previous studies

have established good correlation between ANR and endoscopic findings.

Fifth, we did not assess potential confounding factors such as allergic status, obesity, recurrent upper respiratory tract infections, environmental exposures, or genetic factors that might influence adenoid size and symptom severity independently of age. Our regression model is therefore unadjusted for these variables, which may overestimate the independent effects of age and ANR.

Sixth, our age grouping (3-year intervals) may obscure more subtle developmental changes occurring within narrower age ranges.

Seventh, the absence of objective measures such as polysomnography limits the ability to correlate radiographic findings with physiological sleep parameters.

Eighth, the ROC-derived age-specific cutoffs are exploratory, derived from a referred symptomatic sample, and subject to spectrum bias. They require external validation in independent, population-based cohorts before clinical implementation.

Finally, as a single-centre study from Northeastern Nigeria, generalizability to other populations requires confirmation through multicenter studies.

Despite these limitations, our findings contribute significantly to understanding age-associated differences in adenoid hypertrophy in African children with symptomatic disease. The clear patterns observed across age groups provide a foundation for age-appropriate clinical assessment and management.

Future Research Directions

Future research should focus on: (1) longitudinal follow-up to document individual developmental trajectories; (2) incorporation of three-dimensional imaging to assess volumetric changes; (3) evaluation of how age-related anatomical patterns correlate with objective measures such as polysomnography findings; (4) validation of age-specific ANR cutoffs in community-based samples; and (5) assessment of the impact of environmental factors, allergic status, and socioeconomic determinants on adenoid hypertrophy patterns in African populations.

Conclusion

This cross-sectional study demonstrates that nasopharyngeal depth is substantially greater in older age groups relative to adenoid size in Nigerian children with adenoid hypertrophy, a pattern associated with lower adenoid-nasopharyngeal ratios and lower symptom severity in older children. These findings represent age-associated differences rather than demonstrated individual growth trajectories. These age-dependent patterns have important implications for clinical assessment and management, supporting age-appropriate interpretation of radiographic measurements and conservative approaches in older children with mild-to-moderate symptoms. The establishment of age-specific ANR cutoff values provides exploratory guidance for clinical decision-making in resource-limited settings where advanced diagnostic modalities may be unavailable, but these cutoffs require external validation before widespread implementation.

Clinical implications

· Age-specific ANR cutoffs (0.78 for 3-5 years, 0.71 for 6-8 years, 0.66 for 9-12 years) may guide clinical decision-making, though external validation is required

· Preschool children with severe symptoms and high ANR should be prioritised for intervention

· Older children with mild-to-moderate symptoms may benefit from watchful waiting due to likely natural improvement

· Radiographic assessment should prioritise ratio measurements (ANR) over linear dimensions

· Conservative management should be strongly considered for pre-adolescents unless symptoms are severe or complications are present

Declarations

Ethics Approval and Consent to Participate: This study was approved by the Research Ethics Committee of the University of Maiduguri Teaching Hospital. Written informed consent was obtained from parents/guardians of all participants.

Consent for Publication: Not applicable.

Availability of Data and Materials: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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Authors' Contributions:

· MLM: Conceptualisation, methodology, formal analysis, investigation, writing - original draft, writing - review & editing, supervision

· MAG: Conceptualisation, methodology, investigation, writing - review & editing

· TAI: Methodology, investigation, writing - review & editing

· UHU: Investigation, data curation, writing - review & editing

· ZMB: Investigation, data curation, writing - review & editing
· AF: Investigation, data curation, writing - review & editing
· ZBS: Validation, writing - review & editing
· HBS: Resources, writing - review & editing
· AGF: Validation, supervision, writing - review & editing
All authors read and approved the final manuscript.

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References

1. Handelman CS, Osborne G. Growth of the nasopharynx and adenoid development from one to eighteen years. **Angle Orthod.** 1976;46(3):243-59.
2. Jeans WD, Fernando DC, Maw AR, Leighton BC. A longitudinal study of the growth of the nasopharynx and its contents in normal children. **Br J Radiol.** 1981;54(639):117-21.
3. Subtelny JD. Oral respiration: facial maldevelopment and corrective dentofacial orthopaedics. **Angle Orthod.** 1980;50(3):147-64.
4. Gangadhara SKS, Rajeshwari A, Mahaveera J. Significance of adenoid nasopharyngeal ratio in the assessment of adenoid hypertrophy in children. **Res Otolaryngol.** 2012;1(1):1-5.
5. Bitar MA, Birjawi G, Youssef M, Fuleihan N. How frequent is adenoid obstruction? Impact on the diagnostic approach. **Pediatr Int.** 2009;51(4):478-83.
6. Caylakli F, Hizal E, Yilmaz I, Yilmazer C. Correlation between adenoid-nasopharynx ratio and endoscopic examination of adenoid hypertrophy: a blind prospective clinical study. **Int J Pediatr Otorhinolaryngol.** 2009;73(11):1532-5.
7. Mahboubi S, Marsh RR, Potsic WP, Pasquariello PS. The lateral neck radiograph in adenotonsillar hyperplasia. **Int J Pediatr Otorhinolaryngol.** 1985;10(1):67-73.
8. Kemaloglu YK, Inal E, Goksu N, Akyildiz N. Radiographic evaluation of children with nasopharyngeal obstruction due to the adenoid. **Ann Otol Rhinol Laryngol.** 1999;108(1):67-72.
9. Kolo ES, Ahmed AO, Kazeem MJ, Nwaorgu OGB. Plain radiographic evaluation of children with obstructive adenoids. **Eur J Radiol.** 2011;79(1):38-41.
10. Elwany S. The adenoidal-nasopharyngeal ratio (AN ratio): its validity in selecting children for adenoidectomy. **J Laryngol Otol.** 1987;101(6):569-73.
11. Orji FT, Ezeanolue BC. Evaluation of adenoidal obstruction in children: clinical symptoms compared with roentgenographic assessment. **J Laryngol Otol.** 2008;122(11):1201-5.
12. Dixit Y, Tripathi PS. Clinical and roentgenographic evaluation of adenoidal hypertrophy in children and its endoscopic assessment. **Natl J Med Dent Res.** 2015;3(2):162-5.
13. Fujioka M, Young LW, Girdany BR. Radiographic evaluation of adenoidal size in children: adenoidal-nasopharyngeal ratio. **AJR Am J Roentgenol.** 1979;133(3):401-4.
14. Adedeji TO, Amusa YB, Aremu AA. Correlation between adenoidal nasopharyngeal ratio and symptoms of enlarged adenoids in children with adenoid hypertrophy. **Afr J Paediatr Surg.** 2016;13(1):14-9.
15. Szalmas A, Papp Z, Csomor P, Konya J, Sziklai I, Szekanecz Z, et al. Microbiological profile of adenoid hypertrophy correlates to clinical diagnosis in children. **Biomed Res Int.** 2013;2013:629607.
16. Vogler RC, Ii FJ, Pilgram TK. Age-specific size of the normal adenoid pad on magnetic resonance imaging. **Clin Otolaryngol Allied Sci.** 2000;25(5):392-5.
17. Marcus CL, Brooks LJ, Draper KA, Gozal D, Halbower AC, Jones J, et al. Diagnosis and management of childhood obstructive sleep apnea syndrome. **Pediatrics.** 2012;130(3):e714-e755.
18. Kaditis AG, Alvarez MLA, Boudewyns A, Alexopoulos EI, Ersu R, Joosten K, et al. Obstructive sleep disordered breathing in 2- to 18-year-old children: diagnosis and management. **Eur Respir J.** 2016;47(1):69-94.
19. Mattila PS, Tarkkanen J, Pitkäranta A, Jero J. Adenoidectomy in children with otitis media with effusion. **Clin Otolaryngol.** 2003;28(5):430-5.
20. Josephat MC, James OA, Awoere TC. Clinical profile and pattern of adenoid hypertrophy among children attending a private hospital in Enugu, South East Nigeria. **Pan Afr Med J.** 2015;21:191.
21. Amutta SB, Abdullahi M, Aliyu D, Manya C, Yikawe SS, Solomon JH. Pattern of otorhinolaryngeal, head and neck diseases in the in-patient unit of a tertiary health institution in Sokoto, North Western Nigeria. **Borno Med J.** 2015;12(1):102-7.