Developmental Changes in Pharyngeal Airway in the Male Population From Adolescence to Adulthood

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Abstract

Aim During adolescence, there is a significant surge in height and total body mass of males. Consequently, they simultaneously experience enhancements in their circulatory and respiratory systems, which adapt to these physiological transformations. The purpose of present study was to investigate the developmental changes in male pharyngeal airway from adolescence to adulthood.

Study Design This is a cross-sectional research using cephalometric analysis.

Methods Lateral cephalograms of 192 males were obtained and divided into 5 groups: early adolescence (age 10–13 years), middle adolescence (age 14–17 years), late adolescence (age 18–21 years), early adulthood (age 22–30 years), and middle adulthood (ages 31–50 years). The dimensions of pharyngeal airway spaces and the related anatomical structures were investigated. The one-way analysis of variance and Pearson correlation analysis were employed for statistical analysis.

Results The ANB angle was found to be notably greater in the early adolescence group (3.91°) compared to the middle adolescence (0.81°), late adolescence (0.90°), and early adulthood (2.12°) groups. The lengths of soft palate airway space (SPS), pharyngeal airway space (TPS) and epiglottis pharyngeal airway space (EPS) in early adolescence were significantly shorter than those in the other four groups. A correlation between the pharyngeal airway spaces and the horizontal orientation of the hyoid bone was not found.

Conclusions During middle adolescence, the pharyngeal airway seems to be nearly completed in males. A significant negative correlation was found between the ANB angle and SPS, TPS, and EPS values.

KEYWORDS Male, Pharyngeal Airway space, ANB angle, Hyoid bone, Adolescence, Adulthood.

Introduction

Adolescence is a crucial period characterised by substantial physical and psychological transformations as individuals transition from childhood to adulthood. This phase encompasses changes in height and weight, notable developments in brain structure and function, and the progressive maturation of sexual organs. Additionally, there is an increase in the size and efficiency of the circulatory and respiratory systems, enabling increased physical activity, particularly in males. The adolescent stage involves significant endocrine, psychological, and cognitive shifts. Following infancy, adolescence represents the second major peak in human growth and development [Chulani and Gordon, 2014; Rosen, 2004].

The pharynx is a muscular tube characterised by a broader upper section and a more constricted lower portion, extending from the base of the skull to around the lower edge of the sixth cervical vertebra. It serves as a conduit connecting the oral and nasal cavities to the esophagus and trachea. The pharynx can be divided into tree parts: nasopharynx, oropharynx, and laryngopharynx. The soft palate is present at the boundary between the nasopharynx and oropharynx, and the oropharynx and laryngopharynx are separated by the epiglottis. The pharynx serves as a vital passageway for both air and food, establishing a crucial connection between the digestive and respiratory systems. Consequently, the pharynx plays a significant role in essential functions such as swallowing and breathing [Berkovitz and Moxham, 1988].

Ning et al. [2022] investigated the morphological changes of the pharyngeal airway and the position of the hyoid bone in hyperdivergent adults with different mandibular lengths after premolar extraction. They found that adults with higher mandibular lengths possess the capacity to ameliorate the position of the hyoid bone. Consequently, this leads to increase in the volumes of the glossopharyngeal and hypopharyngeal regions, as well as an increase in the minimum cross-sectional area of the pharynx. In the study of Patano et al. [2023], a significant enhancement of the pharyngeal airway was observed among patients diagnosed with skeletal Class II malocclusion who underwent treatment with functional elastodontic appliances, in contrast to the untreated group.

Due to the substantial growth and development observed in adolescence, especially the increased physical activity in boys during this phase, it is crucial to understand the physiological regulation of pharyngeal airway development. Motivated by the limited information concerning developmental changes in the pharyngeal airway in Asian men, we aimed to explore the developmental aspects of the male pharyngeal airway. Our research focused on measuring the changes in pharyngeal airway dimensions and related anatomical structures from adolescence to adulthood in males. Additionally, we examined how the position of the hyoid bone

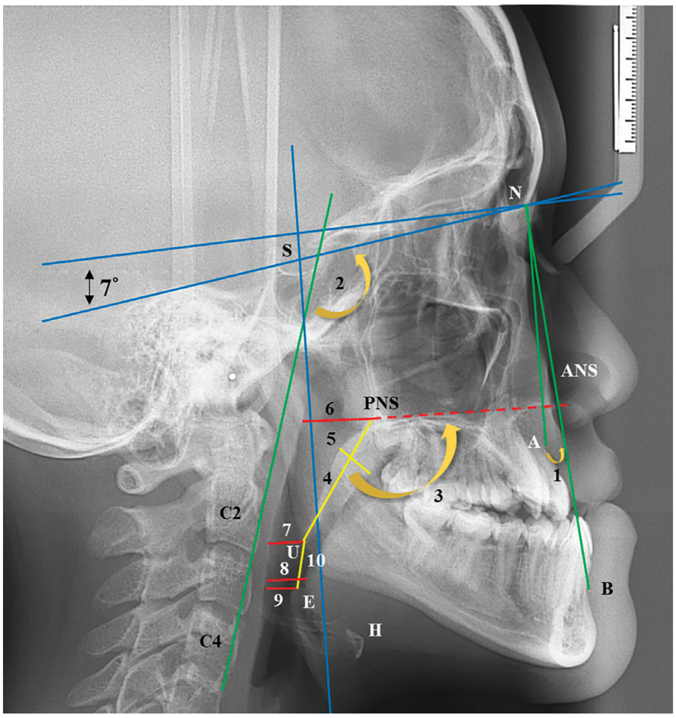

FIG. 1 Cephalometric landmarks.
S:sella; N: nasion; A point; B point; ANS: anterior nasal spine; PNS: posterior nasal spine; H: hyoid bone; C2: The most anterior inferior point of the second cervical vertebra; C4: The most anterior inferior point of the fourth cervical vertebra; U: uvula; E: epiglottis.
Reference lines: The X axis in the X-rays was set as 7° upward of the line connecting the S and N, using N as the fulcrum. The line passing through S perpendicular to the X axis was regarded as the Y axis.
Angular and linear measurements. 1: ANB angle; 2. C2C4-SN angle; 3: Palatal angle; 4: SPL (soft palate length); 5: SPW (soft palate width); 6: NPS (nasal pharyngeal airway space); 7: SPS (soft palate pharyngeal airway space); 8: TPS (Tongue pharyngeal airway space); 9: EPS (epiglottis pharyngeal airway space); 10: UE distance.

could influence the relative positioning of the tongue, thereby affecting airway space. Consequently, we explored the factors influencing the dimensions of pharyngeal airway spaces and their correlations in a male population.

Materials and Methods

For this study we obtained the male lateral cephalograms from the department of dentistry of Kaohsiung Medical University, Keohsiung, Taiwan. The inclusion criteria were: (1) healthy male; (2) at least 10 years old; and (3) no orthodontic treatment. Exclusion criteria were presence of craniofacial symptoms or deformities, history of craniofacial surgery, or history of facial trauma. In order to determine the sample size, the G*Power (version 3.1.9.2; Dusseldorf University, Dusseldorf, Germany) was utilised. With a power (1-β) of 90% and an α of 0.05, our study enrolled 192 male participants in order to attain a sufficient power (≧ 90%). On the basis of the growth and development from puberty to adulthood, the male population was divided into 5 groups: Group 1 (early adolescence; age 10 to 13 years), Group 2 (middle adolescence; age 14 to 17 years), Group 3 (late adolescence; age 18 to 21 years), Group 4 (early adulthood; age 22 to 30 years), and Group 5 (middle adulthood; age 31 to 50 years).

Using a 0.3-mm pencil, Dr. CM Chen conducted the manual identification of cephalometric landmarks on tracing paper. Twenty radiographs were randomly selected and double-verified with a time interval of one week by Dr. CM Chen. The landmarks and angles used in the X-ray analysis were defined as follows:

- A: the most concave point on the anterior border of the maxilla.
- B: the most concave point on the anterior border of the mandibular symphysis.
- ANS: the anterior nasal spine, which is the most anterior and superior point of the maxilla.
- PNS: the posterior nasal spine, which is the most posterior and superior point of the maxilla.
- H: the most anterior and superior point of the hyoid bone.
- C2: the most anterior and inferior point of the second cervical vertebra.
- C4: the most anterior and inferior point of the fourth cervical vertebra.
- U: the lowest point of the uvula.
- E: the highest point on the epiglottis.
- ANB angle: angle between points A, N, and B.
- Palatal angle: angle formed by the length of the soft palate and the line connecting ANS and PNS.
- C2C4-SN angle: angle formed by the line passing through the most anterior and inferior points of C2 and C4 and the SN line.

The X-ray coordinate axis (horizontal axis) was established by connecting the sella (S point) and nasion (N point) and tilting it upward by 7°, with N taken as the pivot point for the X-axis. The Y-axis (vertical axis) was established perpendicular to the X-axis, passing through the S point. Positive values were assigned to the right of the X-axis and downward on the Y-axis.

Pharyngeal airway and soft palate lengths:

1. NPS: nasal pharyngeal airway space; the distance from PNS (ANS-PNS line) to the posterior pharyngeal wall.
2. SPS: soft palate pharyngeal airway space; the shortest distance from the U to the posterior pharyngeal wall.
3. TPS: tongue pharyngeal airway space; the shortest distance from the dorsum of the tongue to the posterior pharyngeal wall.
4. EPS: epiglottis pharyngeal airway space; the shortest distance from the tip of the E to the posterior pharyngeal wall.
5. SPL: soft palate length; posterior nasal spine to tip of soft palate.
6. SPW: soft palate width; maximum thickness of soft palate.
7. UE length: distance between U and E.

Statistical analysis was conducted using IBM SPSS 20 (SPSS Inc., Chicago, IL, USA) software. One-way analysis of variance test was employed for statistical comparisons between groups, and a post hoc test was performed using the least significant difference method. Pearson correlation analysis was used to investigate the correlations among several variables within groups. A significance level of P < .05 was applied. The factors influencing the dimensions of pharyngeal airway spaces and the correlations were investigated. This study was approved by the human investigation review committee (KMUHIRB-E(II)-20180200).

Results

As shown in Table 1, the study included 29 male patients in Group 1 (mean age: 11.17 ± 0.97 years), 27 in Group 2 (mean age: 15.85 ± 0.77 years), 39 in Group 3 (mean age: 19.87 ± 0.86 years), 69 in Group 4 (mean age: 24.99 ± 2.64 years), and 28 in Group 5 (mean age: 37.04 ± 5.84 years). In Table 1, the ANB angle in Group 1 (3.91°) was significantly greater than in Group 2 (0.81°), Group 3 (0.90°), and Group 4 (2.12°). The palatal angle in Group 1 (128.41°) was significantly higher than in Group 2 (122.04°), Group 3 (121.35°), and Group 4 (122.89°). However, no significant differences were found in the C2C4 angle among the five groups. As shown in Table 2, the SPL was significantly greater in Group 2 (36.28 mm), Group 3 (34.77 mm), Group 4 (36.50 mm), and Group 5 (38.13 mm) than in Group 1 (32.09 mm), whereas the SPW did not significantly differ among the five groups. The vertical position of the hyoid bone was significantly superior in Group 1 than in the other four groups. The horizontal position of the hyoid bone in Group 1 and Group 2 was significantly posterior than in Group 3, Group 4, and Group 5. The NPS of Group 5 was significantly greater than in the other four groups (Table 3). The SPS (7.88 mm), TPS (10.38 mm), and EPS (5.74 mm) of Group 1 were significantly smaller than those in the other four groups. After early adolescence, pharyngeal airway lengths (SPS, TPS, and EPS) showed no statistically significant differences among the four groups. In Table 4, age showed a significant positive correlation with the NPS and EPS. The ANB angle displayed a significant negative correlation with the SPS, TPS, and EPS. The C4C2-SN angle demonstrated a significant negative correlation with the NPS and a significant positive correlation with the TPS. The palatal angle revealed a significant positive correlation with the NPS and a significant negative correlation with the SPS and EPS. The SPL exhibited a significant positive correlation with the NPS and a significant negative correlation with the SPS. The vertical position of the hyoid bone showed a significant positive correlation with the SPS, EPS, and UE.

Discussion

Puberty is the developmental phase is marked by sexual maturation, typically occurring in males between the ages of 12 and 18, although the onset can vary among individuals. During adolescence, boys undergo several changes, and this stage is characterised by the development of secondary sexual characteristics. Changes may include deepening of the voice and enlargement of the Adam's apple, but the extent of maturity in these features can differ. Assessing physical development in adolescents is commonly done using sexual maturity ratings, also known as the 5 Tanner stages, which span from prepuberty to adulthood [Chulani and Gordon, 2014; Rosen, 2004; Tanner, 1981]. The Tanner scale serves as a widely accepted tool to assess the degree of maturation of secondary sexual characteristics in individuals across different age groups, ranging from children to adults. This scale aids in the measurement of the development of primary and secondary external sexual attributes, including breast size, genitalia, testicular volume, proliferation of pubic hair, and growth of hair in the armpit region. The emergence of facial hair in males typically occurs during the latter phases of puberty, generally between 15 and 19 years of age. During puberty, the release of growth stimulation factors, including growth hormones, thyroid hormones, and androgens, results in rapid increases in height and weight among adolescents [Benyi and Sävendahl, 2017; Farr et al., 2014]. In light of the distinct stages of development observed in male patients, it is imperative to acknowledge that the dimensions of the pharyngeal airway space may display variances across diverse ethnic groups.

Buschang et al. [1988] conducted a study on 209 French-Canadian children aged 10 to 15 years, revealing that the growth curve for boys reached the mean minimum prepubertal velocity at the age of 10.8 years and the maximum pubertal velocity at the age of 14.1 years. In contrast, girls reached the maximum pubertal velocity at 12.1 years. Another study by Farkas et al. [1992] analysed 1,594 healthy North American, White individuals aged 1 to 18 years. At the age of 15, boys attained maturity in terms of face height, mandible height, face width, and depth of the mandible, while girls tended to reach facial maturity approximately 2 years earlier than boys. Generally, the onset of puberty manifests in male adolescents approximately two years

	Age (year)		ANB angle (degree)		C2C4-SN angle (degree)		Palatal angle (degree)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1 (n= 29)	11.17	0.97	3.91	3.17	104.52	7.46	128.41	5.99
Group 2 (n= 27)	15.85	0.77	0.81	4.15	107.04	6.71	122.04	7.38
Group 3 (n= 39)	19.87	0.86	0.90	4.60	107.17	6.69	121.35	8.43
Group 4 (n= 69)	24.99	2.64	2.12	3.50	104.91	7.37	122.89	6.75
Group 5 (n= 28)	37.04	5.84	2.84	5.05	103.23	8.26	123.91	7.27
p value	< 0.001*		0.013*		0.149		0.001*	
Multiple comparisons	5>4>3>2>1		1>2,1>3,1>4		NS	❑	1>2,1>3,1>4	

n: number of participants
Group 1: early adolescence; Group 2: middle adolescence; Group 3: late adolescence;
Group 4: early adulthood; Group 5: middle adulthood
**: Statistically significant, p< 0.05; NS : not significant*

TABLE 1 Male characteristics from adolescence to adulthood in the one-way analysis of variance test with least significance difference post-hoc comparison.

	SPW(mm)		SPL(mm)		Hyoid H(mm)		Hyoid V(mm)		UE(mm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1 (n= 29)	8.55	1.72	32.09	4.12	11.53	7.53	108.31	10.26	21.14	6.06
Group 2 (n= 27)	9.20	1.83	36.28	3.92	13.84	13.43	126.95	8.41	29.96	5.78
Group 3 (n= 39)	9.49	2.02	34.77	4.14	17.96	8.27	130.30	7.94	30.10	7.28
Group 4 (n= 69)	9.12	2.37	36.50	4.53	18.56	9.74	129.38	8.03	31.81	24.26
Group 5 (n= 28)	9.77	2.06	38.13	4.07	21.78	10.35	132.42	6.61	29.43	6.31
p value	0.229		< 0.001*		0.001*		< 0.001*		0.044*	
Multiple comparisons	NS		5>1,4>1,3>1,2>1		5>1,4>1,3>1		5>1,4>1,3>1,2>1		5>1,4>1,3>1,2>1	
❏	❏	❏	4>3, 5>3	❏	3>2,4>2,5>2		5>2	❏	❏	❏

n: number of participants
Group 1: early adolescence; Group 2: middle adolescence; Group 3: late adolescence;
Group 4: early adulthood; Group 5: middle adulthood; SPW: soft palate width; SPL: soft palate length
Hyoid H (Horizontal); Hyoid V (Vertical); UE: distance between uvula and epiglottis
**: Statistically significant, p< 0.05; NS : not significant*

TABLE 2 Dimension and location of soft palate and hyoid bone from adolescence to adulthood in the one-way analysis of variance test with least significance difference post-hoc comparison

	NPS(mm)		SPS(mm)		TPS(mm)		EPS(mm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1 (n= 29)	22.02	4.42	7.88	2.34	10.38	3.05	5.74	1.89
Group 2 (n= 27)	23.76	3.31	12.06	3.48	14.38	3.41	8.31	2.79
Group 3 (n= 39)	23.63	3.80	11.79	3.75	14.03	5.84	8.41	3.68
Group 4 (n= 69)	24.24	3.25	10.87	3.28	12.44	3.65	7.52	2.73
Group 5 (n= 28)	25.99	3.98	11.06	3.76	13.57	4.96	8.41	3.47
p value	0.002*		< 0.001*		0.002*		0.002*	
Multiple comparisons	5>1,5>2,5>3,5>4		5>1,4>1,3>1,2>1		5>1,4>1,3>1,2>1		5>1,4>1,3>1,2>1	
	4>1	❏	❏	❏	❏	❏	❏	❏

n: number of participants
Group 1: early adolescence; Group 2: middle adolescence; Group 3: late adolescence;
Group 4: early adulthood; Group 5: middle adulthood
NPS: nasal pharyngeal airway space; SPS: soft palate pharyngeal airway space
TPS: tongue pharyngeal airway space; EPS: epiglottis pharyngeal airway space
**: Statistically significant, p< 0.05*

TABLE 3 Pharyngeal airways from adolescence to adulthood in the one-way analysis of variance test with least significance difference post-hoc comparison

after that observed in female adolescents [Chulani and Gordon, 2014; Rosen, 2004; Tanner, 1981]. The results of our study are in line with those reported by Buschang et al. [1988] and Farkas et al. [1992]. In early adolescence, we observed an ANB angle of 4.22°, reflecting ongoing maxillary development, while the mandible had not yet reached its peak development. Therefore, it is worth mentioning that the ANB angle in early adolescence exhibited a significantly greater value in comparison to the other four stages. During the period of middle adolescence, coinciding with the crucial stage of mandibular growth, the ANB angle experiences a gradual reduction and reaches 1.52°. During the period of early adulthood, the mandible undergoes full development, leading to the establishment of a steady ANB angle from the stage of late adolescence to the stage of middle adulthood. Our study revealed that there were no significant differences in the ANB angle from middle adolescence through middle adulthood. In the study conducted by Muto et al. [2002], the relationship between the inclination of the craniocervical region and the space in the pharyngeal airway was investigated. It was observed that changes in the craniocervical inclination resulting from head extension were associated with an expansion of the pharyngeal airway space. Our findings were consistent with those of Muto et al. [2002]. While the C2C4-SN angle did not show a statistically significant difference from early adolescence to middle adulthood, a noticeable trend was observed. Specifically, the C2C4-SN angle measured 104.85° in early adolescence and gradually increased to 108.48° in middle adulthood. The observed trend in the gradual increase of the C2C4-SN angle from early adolescence to middle adulthood can be attributed to several factors. These factors include the natural physiological changes associated with increases in height and body size over age, heightened physical activity, and the development and enlargement of the mandible and tongue. These changes lead to a natural tendency for the head to be raised, contributing to the rise in the C2C4-SN angle. The observed adaptation in the gradual increase of the C2C4-SN angle is essential to meet the heightened demands for physical activity and respiratory capacity during adolescence. This adaptation

	Age	ANB angle	C4C2-SN angle	Palatal angle	SPW	SPL	Hyoid H	Hyoid V
NPS	0.281*	0.017	-0.154*	0.309*	0.062	0.184*	0.104	0.138
SPS	0.124	-0.441*	-0.028	-0.265*	0.071	-0.218*	0.121	0.197*
TPS	0.099	-0.406*	0.144*	-0.130	0.059	0.001	0.064	0.123
EPS	0.193*	-0.275*	0.006	-0.178*	0.103	0.078	0.098	0.182*
UE	0.140	-0.024	-0.081	-0.035	0.000	-0.067	0.062	0.175*

SPW: soft palate width; SPL: soft palate length; Hyoid H (Horizontal); Hyoid V (Vertical)
NPS: nasal pharyngeal airway space; SPS: soft palate pharyngeal airway space
TPS: tongue pharyngeal airway space; EPS: epiglottis pharyngeal airway space
UE: distance between uvula and epiglottis
**: Statistically significant, p< 0.05*

TABLE 4 Pearson correlation (r) test for related angles and linear distances in all males

plays a crucial role in maintaining a patent airway, ensuring optimal functioning of the respiratory system in response to the changing physiological requirements of this developmental stage. Li et al. [2019] delved into the regulatory mechanisms governing soft palate development, emphasising its role as a shared conduit for both swallowing and breathing. In the process of chewing, the soft palate depresses to aid in closing the oropharyngeal isthmus, separating the oral cavity from the pharynx, preventing interference between normal swallowing and breathing. Conversely, during swallowing, the soft palate elevates, temporarily pausing breathing and facilitating the passage of food into the pharynx. Hence, the soft palate assumes a pivotal role in fundamental activities like breathing, eating, and speaking. The most rapid growth in soft palate length is observed in early childhood, typically between 1.5 to 2 years old, with minimal expansion during the ages of 1.5 to 4 or 5 years. Following this stage, soft palate growth stabilizes, progressing steadily until late adolescence or early adulthood. In terms of soft palate thickness, the most substantial increase takes place in the first year after birth, followed by smaller increments in subsequent stages of development. The maximum thickness of the soft palate is typically achieved between 14 and 16 years old, and the palate angle becomes acute with age [Li et al., 2019]. In our study, no significant differences were identified in the soft palate width across the five stages of development. In contrast, the elongation of the soft palate undergoes a significant increase, particularly from the stage of middle adolescence onwards. Concurrently, there is a notable decrease in the palatal angle during this same middle adolescence phase and beyond. This shift can be explained by the growth of the soft palate, influenced by gravity, leading the uvula to naturally tilt slightly forward and consequently resulting in a diminished palatal angle. Our data suggests that from the middle adolescence stage onward, there were no significant differences observed in the length of the soft palate and palatal angle, indicating the near completion of soft palate development during this period. The hyoid bone, which is horseshoe-shaped and situated between the mandible and the thyroid cartilage, lacks joints with other bones but is linked to them through muscles and ligaments. Additionally, it is connected to various structures, including the base of the tongue, epiglottis, pharynx, larynx, mandible, and styloid process of the temporal bone. Bench [1963] observed that the hyoid bone is positioned at the level between the third and fourth cervical vertebrae at the age of 3 years and undergoes a gradual descent to the level of the fourth vertebra by adulthood. There is a tendency for the hyoid bone to experience a slight descent from adolescence to young adulthood [Cotter et al., 2015]. Nejaim et al. [2008] discovered significant correlations between pharyngeal airway volume and both the mandible and hyoid bone. Cheng et al. [2020] reported no significant differences in the vertical position of the hyoid bone among the three skeletal types. These findings indicate that the position of the hyoid bone can change with alterations in mandibular position, highlighting the crucial role of the hyoid bone and its attached muscles in maintaining pharyngeal airway size. In our study, although no significant differences were observed in the horizontal distance of the hyoid bone among the five stages, the horizontal distance gradually increased as the hyoid bone moved forward. Conversely, the vertical position of the hyoid bone was significantly superior in the early adolescence stage than in the other four stages. This observation is consistent with previous reports, suggesting that the hyoid bone undergoes a descent during craniofacial growth, starting from the stage of middle adolescence. Moreover, by middle adolescence, the development of the hyoid bone reaches a near completion, resulting in insignificant difference in the vertical positioning of the hyoid bone between the middle adolescence and middle adulthood stages. In the study conducted by Hsu et al. [2021] to examine alterations in the pharyngeal airway space among children attending primary school, with participants divided into three distinct age groups: 7–8 years, 9–10 years, and 11–12 years. The research revealed a noteworthy correlation between age and the various aspects of the pharyngeal airway (NPS, SPS, and TPS). However, age demonstrated no significant correlation with EPS. Masoud and Alwadei [2022] conducted an investigation on the pharyngeal airway among paediatric patients aged 7 to 17 years. These subjects were classified into two distinct groups (7 to 11 years and 12 to 17 years). Upon careful analysis, it was revealed that the upper airway length exhibited the most significant association with chronological age. Schendel et al. [2012] assessed the development of the pharyngeal airway in a cohort of 1300 individuals aged 6 to 60 years. Their findings revealed a continuous increase in the size and length of the pharyngeal airway until the age of 20, after which airway development stabilised. Subsequently, the dimensions of the pharyngeal airway demonstrated a gradual reduction, and this decline became more pronounced, especially after reaching the age of 50. Jeans et al. [1981] conducted a study on the growth of the nasopharyngeal area in children with normal development. They identified that the prepubertal spurt started at 9 years for girls and 10 years for boys. Additionally, they observed that from the age of 13 years onward, the nasopharyngeal area in boys was notably larger than that in girls, and this discrepancy continued to gradually increase until the age of 19 years. Claudino et al. [2013] investigated the airway volume in individuals aged 13 to 20 years and found no significant association between the ANB angle and the nasopharyngeal airway volume. Our study also observed that the NPS length increased gradually, with no significant differences identified among the five stages. Claudino et al. [2013] reported that in the male population, velopharyngeal and oropharyngeal airway volume decreases as the ANB angle increases. Similarly, our study revealed that the SPS and TPS were significantly negatively correlated with ANB angle. The TPS showed a significant increase in size from middle adolescence onward compared to the early adolescence stage. However, there were no significant differences observed among these four stages from middle adolescence onward. This outcome suggests that beginning from middle adolescence, the TPS experiences a gradual increase, and its development corresponds to the completion of mandibular and tongue growth, indicating near completion of TPS development during middle adolescent period. The epiglottis, a leaf-shaped flap positioned at the upper part of the larynx, functions as a protective mechanism by remaining open during respiration to permit airflow into the larynx. Additionally, it plays a crucial role in preventing the entry of food and water into the trachea and lungs [Ardran and Kemp, 1967]. The laryngeal structure experiences rapid growth from birth to the age of 3 years, followed by a slower growth phase during puberty. This growth is characterised by a gradual descent towards the approximate level of the fourth or fifth cervical vertebra, which typically occurs in early adolescence [Luscan et al., 2020]. Our study observed a significant increase in the EPS from middle adolescence onward. Similarly, from middle adolescence onward, no statistically significant differences were found in the EPS, suggesting a gradual increase in its development, approaching completion. Our research offered momentous revelations regarding the anatomical and physiological alterations observed in the male pharyngeal airway as it progresses through the various stages of adolescence and adulthood. However, it must be recognized that this study has certain limitations:1) the sample distribution for the development group was not evenly distributed; 2) there was no late adulthood group (age > 50) included in the analysis; 3) due to the diverse demographics of male participates, it is worth noting that the dimensions of the pharyngeal airway space may exhibit variations among different ethnic groups.

Conclusion

Considering the results of our investigation, it has been observed that the development of pharyngeal airway spaces (specifically SPS, TPS, and EPS) in male individuals undergoes a process of near maturation during middle adolescence, typically between the ages of 14 and 17. However, the growth of NPS continues to increase until the stage of middle adulthood. The pharyngeal airway (specifically SPS, TPS, and EPS) displayed a significant negative correlation with the ANB angle and palatal angle. Based on our findings, it can be inferred that an increase in the ANB angle or palatal angle may lead to a reduction in the pharyngeal airway space. These findings have significant implications for elucidating the development of the pharyngeal airway in the male population.

Declaration of competing interest
The authors have no conflicts of interest relevant to this article.

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