



Original Article

# The investigation of pharyngeal airway space by cephalogram landmarks in primary school children in Taiwan



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## KEYWORDS

Pharyngeal airway;  
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Tongue;  
Epiglottis

**Abstract** *Background/purpose:* Proper breathing is essential to healthy growth and development of children. The present study aimed to investigate changes in the pharyngeal airway space in primary-school children.

*Materials and methods:* Cephalometric radiographs were obtained from 93 primary-school children, who were divided into three age groups (Group I, aged 7–8 years; Group II, aged 9–10 years; and Group III, aged 11–12 years). Landmarks identified on each cephalogram included the tip of the uvula (U), hyoid bone (H), and epiglottis (E). Linear and angular measurements comprised nasopharyngeal airway (NP); PS (shortest distance from the soft palate to the pharyngeal wall); UP (distance from the tip of the uvula to the pharyngeal wall); TS (shortest distance from the posterior tongue to the pharyngeal wall); EP (distance, parallel to the X-axis, from the epiglottis to the pharyngeal wall). Statistical analysis was performed using one-way analysis of variance and Pearson correlation tests.

*Results:* Group III had the highest values for all the variables. The three groups exhibited significant differences for all pharyngeal airway variables, except for EP. The three groups had significantly different vertical U, H, and E. There were positive correlations between age

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and NP, PS, UP, and TS; however, no significant correlation was observed between age and EP. Age significantly correlated with the vertical U, E, and H. Correlations between age and the horizontal U, E, and H were nonsignificant.

**Conclusion:** Among primary-school children from various grades, age significantly correlated with all pharyngeal airway variables, except with EP.

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## Introduction

The pharynx, a part of the neck, is a conical channel that connects the mouth and nasal cavity to the esophagus and trachea. It is the passage through which food and air pass and the intersection of the digestive and respiratory tracts. Therefore, the pharyngeal airway plays a crucial role in breathing, swallowing, and pronunciation.<sup>1,2</sup> Clinical features of growth and development of the human body are apparently correlated with timing and sequence of tooth eruption in the primary-school children. The first permanent molars usually erupt at the age of 6 years and the central incisors erupt at the age of 8 years. The deciduous teeth are replaced by the permanent teeth in a certain sequence of teeth eruptions. The second permanent molars usually begin to erupt when children are approximately aged 12 years, and once all their deciduous teeth have been replaced by the permanent teeth, they enter into the permanent dentition period. During the ages of 7 and 12 years, primary-school children are in the mixed dentition period.

Generally, puberty in girls starts at the age of 10–11 years and ends at the age of 15–17 years, whereas puberty in boys starts at the age of 11–12 years and ends around the age of 16–17 years.<sup>3–7</sup> The growth of the pharyngeal airway increases with age during the primary-school period. Moreover, facial growths considerably differ in each stage of primary-school children, and the pharyngeal airway also apparently undergoes changes. In Taiwan, primary-school children are aged 7–12 years. Therefore, we divided primary-school children into three groups (group 1 [1st and 2nd grades], group 2 [3rd and 4th grades], and group 3 [5th and 6th grades]), according to their body and face considerably change. On the basis of this grouping, the aim of the present study was to investigate the difference in the pharyngeal airway space in primary-school children at different age groups.

## Materials and methods

The present study investigated cephalometric radiographs of 93 children (35 boys and 58 girls). The children were divided into three age groups according to their developmental characteristics. Group I comprised 20 children (5 boys and 15 girls; aged 7–8 years); Group II comprised 40 children (13 boys and 27 girls; aged 9–10 years); and Group III comprised 33 children (17 boys and 16 girls; aged 11–12 years). The exclusion criteria were as follows: (1) head or

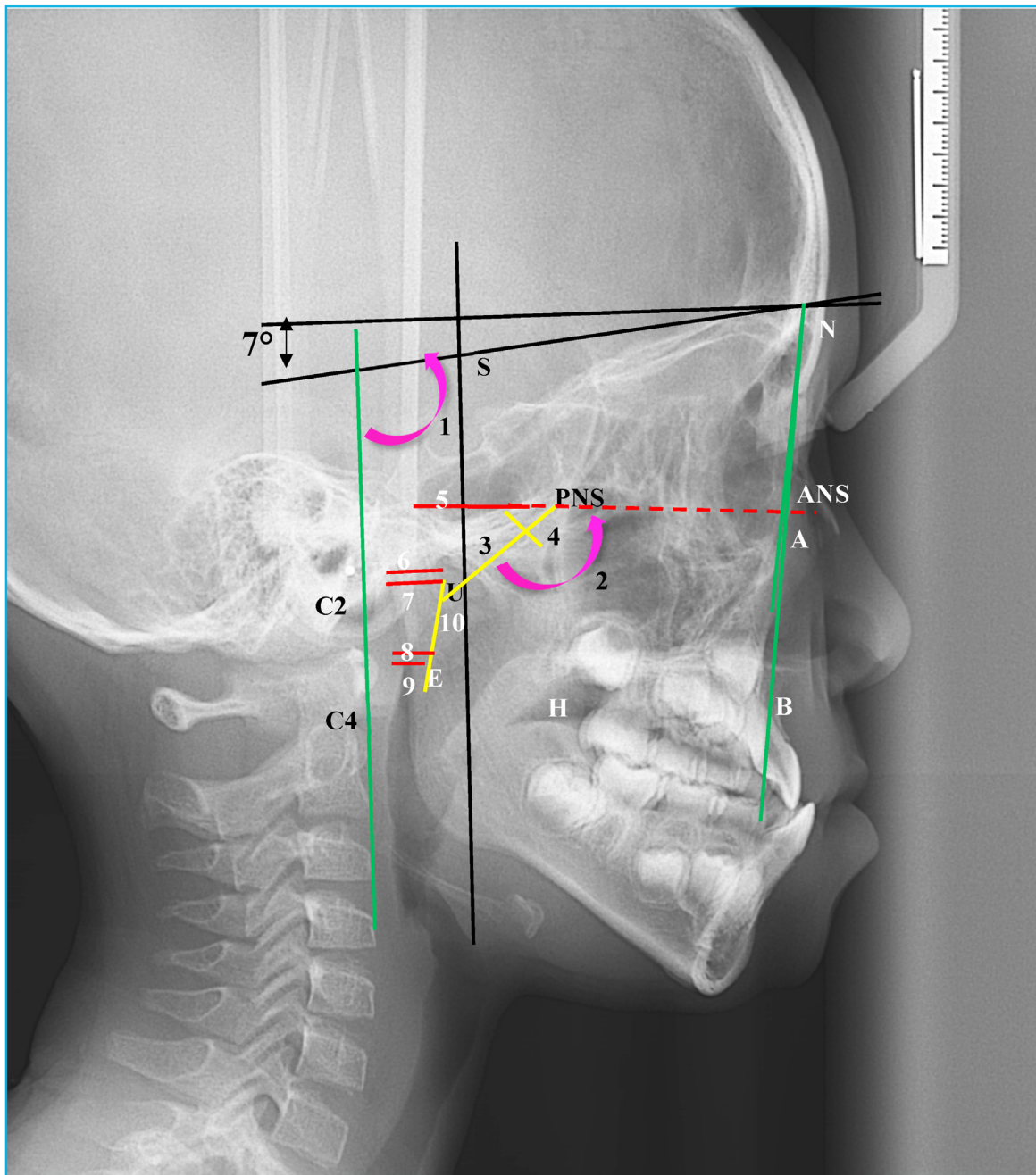
facial symptoms or deformities, (2) history of head or facial surgery, and (3) history of facial injury.

The following landmarks were identified on each cephalogram (Fig. 1): nasion (N); sella (S); anterior nasal spine (ANS); point A; posterior nasal spine (PNS); point B; tip of uvula (U); inferoanterior point on the fourth cervical (C4); inferoanterior point on the second cervical (C2); most superior and anterior point on the hyoid bone (H); most superior point on the epiglottis (E). The X-axis was constructed by drawing a line through the nasion 7° above the SN line; the Y-axis was constructed by drawing a line through the sella perpendicular to the X-axis. Linear and angular measurements included the following: nasopharyngeal airway (NP; ANS-PNS plane intersecting the pharyngeal wall); PS (shortest distance from the soft palate to the pharyngeal wall); UP (distance from the uvula to the pharyngeal wall); TS (shortest distance from the posterior tongue to pharyngeal wall); EP (distance, parallel to the X-axis, from the epiglottis to the pharyngeal wall); UE (shortest distance from the uvula to the epiglottis); SPW (width of the soft palate); SPL (length of the soft palate); ANB angle; Palatal angle; and C2C4-SN angle (angle between the C4C2 line and SN line).

Data analysis was performed using IBM SPSS 20. The data of cephalometric measurements for hard and soft tissue landmarks were statistically analyzed. One-way analysis of variance was performed for multiple comparisons between groups, and Tukey's honestly significant difference test was used to conduct post-hoc analysis. The null hypothesis was that there were no differences among the three age groups. Pearson correlation was used to determine the correlations between variables. P value of 0.05 was considered statistically significant. Strengths of correlation were described for the absolute value of the ratio of the compared variables: very weak (0–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), and very strong (0.80–1.0). The null hypothesis was that there were no differences among the three age groups. This study was approved by the human investigation review committee (KMUHIRB-E(II)-20180,200).

## Results

Table 1 showed significant differences between the C2C4-SN angle and palatal length among the groups. However, among the three groups, no significant differences were discovered in the ANB angle (Group I: 4.2°; Group II: 4.3°; Group III: 4.6°), palatal angle (Group I: 98.5°; Group II: 102.1°; Group III: 105.4°), and soft palate width (Group I:



**Figure 1** Cephalometric landmarks and linear measurements. Landmarks: nasion (N); sella (S); anterior nasal spine (ANS); point A; posterior nasal spine (PNS); point B; tip of uvula (U); inferoanterior point on the second cervical (C2); inferoanterior point on the fourth cervical (C4); most superior and anterior point on the hyoid bone (H); most superior point on the epiglottis (E); . The X-axis was constructed by drawing a line through the N, 7° above the SN line; the Y-axis was constructed by drawing a line through S, perpendicular to the X-axis. Linear distances and angles measurements: 1: C2C4-SN angle 2: Palatal angle 3: soft palate length 4: soft palate width 5: NP 6: PS 7: UP 8: TS 9: EP 10: UE.

7.8 mm; Group II: 8.5 mm; Group III: 8.1 mm). No significant differences regarding the ANB angle, C2C4-SN angle, palatal angle, soft palate width, and palatal length were observed between Groups I and II. The three groups exhibited significant differences in all pharyngeal airway variables, except in EP (Group I: 5.1 mm; Group II: 6.0 mm; Group III: 5.5 mm). Group III had the highest values for all the variables. The pharyngeal airway variables (NP, PS, UP,

TS, and EP) did not significantly differ in Groups I and II. The null hypothesis was rejected.

Table 2 shows that the three groups did not have significantly different horizontal U, H, and E. Compared with Group I, Group III had significantly larger horizontal C2 and C4; however, the horizontal C2 and C4 of Groups I and II were nonsignificantly different. Moreover, the three groups were also compared in terms of the vertical U, H, E, C2, and

**Table 1** Patients characteristics in the One-way ANOVA with post-hoc Tukey HSD test.

Variables	Group I		Group II		Group III		P value	Intergroup comparison	
	Mean	SD	Mean	SD	Mean	SD		Significant	
Age	7.5	0.50	9.6	0.49	11.4	0.49	<0.0001	*	Group III > Group II > Group I
ANB	4.2	3.20	4.3	2.61	4.6	3.37	0.855	—	
C2C4-SN angle	98.5	6.66	102.1	8.03	105.4	8.50	0.011	*	Group III > Group I
Palate angle	129.8	5.40	130.2	6.59	130.2	5.32	0.959	—	
SPL	29.1	3.64	31.0	3.52	33.1	3.21	<0.0001	*	Group III > Group II; Group III > Group I
SPW	7.8	1.26	8.5	1.60	8.1	1.66	0.193	—	
Pharyngeal airway									
NP	19.1	3.90	21.0	3.35	24.4	4.51	<0.0001	*	Group III > Group II; Group III > Group I
PS	6.6	2.57	8.1	2.18	8.8	3.06	0.012	*	Group III > Group I
UP	7.8	3.28	8.9	2.30	10.2	3.22	0.015	*	Group III > Group I
TS	7.8	2.36	9.4	3.31	10.2	2.52	0.016	*	Group III > Group I
EP	5.1	1.71	6.0	2.18	5.5	1.98	0.255	—	
UE	17.0	5.35	21.0	5.31	21.3	5.19	0.011	*	Group III > Group II > Group I

Group I: age 7 and 8; Group II: age 9 and 10; Group III: age 11 and 12.

SPL: Soft palate length; SPW: Soft palate width.

NP: Nasopharyngeal airway; PS: shortest distance from the soft palate to the pharyngeal wall; UP: distance from the uvula to the pharyngeal wall.

TS: shortest distance from the posterior tongue to pharyngeal wall; EP: distance from the epiglottis to the pharyngeal wall.

UE: shortest distance from the uvula to the epiglottis.

\*: Intergroup comparison: Statistically significant,  $P < 0.05$ .

—: Not significant.

**Table 2** Patients landmarks in the One-way ANOVA with post-hoc Tukey HSD test.

Variables	Group I		Group II		Group III		P value	Intergroup comparison	
	Mean	SD	Mean	SD	Mean	SD		Significant	
Vertical									
U	67.3	5.21	71.6	5.53	76.3	5.49	<0.0001	*	Group III > Group II > Group I
E	83.7	6.77	91.0	6.24	95.0	8.25	<0.0001	*	Group III > Group I
H	94.8	7.54	103.5	7.65	108.2	7.07	<0.0001	*	Group III > Group II > Group I
C2	75.9	5.24	82.7	5.69	87.0	5.32	<0.0001	*	Group III > Group II > Group I
C4	100.9	6.09	110.6	7.40	117.8	7.15	<0.0001	*	Group III > Group II > Group I
Horizontal									
U	-3.0	5.03	-3.5	5.15	-3.2	4.05	0.898	—	
E	-7.0	5.63	-9.0	6.64	-10.1	7.65	0.278	—	
H	12.4	6.49	10.4	8.13	9.6	7.58	0.433	—	
C2	-15.7	5.06	-18.7	6.02	-20.1	6.02	0.034	*	Group III > Group I
C4	-16.8	6.99	-21.8	8.38	-25.1	9.09	0.003	*	Group III > Group I

Group I: age 7 and 8; Group II: age 9 and 10; Group III: age 11 and 12.

U: tip of uvula; E: most superior point on the epiglottis; H: most superior and anterior point on the hyoid bone.

C2: inferoanterior point on the second cervical; C4: inferoanterior point on the fourth cervical.

\*: Intergroup comparison: Statistically significant,  $P < 0.05$ .

—: Not significant.

C4, and significant differences were observed. Group III had the highest values for all variables; however, compared with Group I, Group II had significantly larger vertical U, H, C2, and C4.

Tables 3 and 4 shows the positive correlations between age and C2C4-SN angle, NP, PS, UP, TS, SPL, and UE. Age and NP moderately positively correlated (0.467). However, no significant correlation existed between age and ANB angle, palatal angle, EP, and SPW. Age had moderate–strong correlations with the vertical U (0.529), E

(0.497), H (0.546), C2 (0.597), and C4 (0.664). The correlations between age and the horizontal U, E, and H were nonsignificant. The ANB angle and pharyngeal airway nonsignificantly correlated. The C2C4-SN angle moderately negatively correlated with the horizontal E (-0.483) and C2 (-0.557). The correlation between the C2C4-SN angle and horizontal H was strongly negative (-0.742), and that between the C2C4-SN angle and horizontal C4 was strongly negative (-0.831). Moderately negative correlations existed between the palatal angle and horizontal U, E, H, C2,

**Table 3** Pearson's correlation coefficient (R) test in the linear distances and angles.

	Age	ANB	C2C4-SN angle	Palatal angle	NP	PS	UP	TS	EP	SPL	SPW	UE
Age	1	0.058	0.309*	0.028	0.467*	0.299*	0.297*	0.290*	0.056	0.398*	0.037	0.264*
ANB	0.058	1	0.095	0.130	-0.047	-0.135	-0.118	-0.029	-0.178	0.084	-0.15	0.071
C2C4-SN angle	0.309*	0.095	1	0.332*	0.154	0.258*	0.274*	0.355*	0.170	0.14	-0.300*	0.319*
Palatal angle	0.028	0.130	0.332*	1	0.330*	0.098	0.091	0.082	0.073	-0.065	-0.203	0.324*
NP	0.467*	-0.047	0.154	0.330*	1	0.480*	0.455*	0.172	0.213*	0.096	0.157	0.231*
PS	0.299*	-0.135	0.258*	0.098	0.480*	1	0.890*	0.514*	0.397*	-0.300*	-0.028	0.315*
UP	0.297*	-0.118	0.274*	0.091	0.455*	0.890*	1	0.571*	0.396*	-0.367*	-0.027	0.257*
TS	0.290*	-0.029	0.355*	0.082	0.172	0.514*	0.571*	1	0.618*	-0.098	-0.181	0.04
EP	0.056	-0.178	0.170	0.073	0.213*	0.397*	0.396*	0.618*	1	0	-0.093	-0.021
SPL	0.398*	0.084	0.140	-0.065	0.096	-0.300*	-0.367*	-0.098	0.000	1	0.025	-0.052
SPW	0.037	-0.150	-0.300*	-0.203	0.157	-0.028	-0.027	-0.181	-0.093	0.025	1	-0.293*
UE	0.264*	0.071	0.319*	0.324*	0.231*	0.315*	0.257*	0.04	-0.021	-0.052	-0.293*	1

NP: Nasopharyngeal airway; PS: shortest distance from the soft palate to the pharyngeal wall; UP: distance from the uvula to the pharyngeal wall.

TS: shortest distance from the posterior tongue to pharyngeal wall; EP: distance from the epiglottis to the pharyngeal wall.

SPL: Soft palate length; SPW: Soft palate width; UE: short distance from the uvula to the epiglottis.

\*: Statistically significant,  $P < 0.05$ .

**Table 4** Pearson's correlation coefficient (R) test in the landmarks.

	Age	ANB	C2C4-SN angle	Palatal angle	NP	PS	UP	TS	EP	SPL	SPW	UE
Vertical												
U	0.529*	-0.135	-0.103	-0.285*	0.236*	-0.064	-0.120	0.027	0.134	0.719*	0.211*	-0.129
E	0.497*	-0.059	-0.021	-0.128	0.257*	0.026	-0.062	-0.097	0.036	0.596*	0.05	0.469*
H	0.546*	-0.055	0.095	-0.132	0.194	0.080	0.030	0.039	0.155	0.553*	0.056	0.411*
C2	0.597*	-0.077	0.127	-0.032	0.261*	0.063	-0.003	0.157	0.106	0.614*	0.011	0.130
C4	0.664*	-0.072	0.137	-0.047	0.369*	0.161	0.082	0.140	0.090	0.586*	0.102	0.166
Horizontal												
U	-0.010	-0.261*	-0.263*	-0.437*	0.051	0.223*	0.290*	0.168	0.123	-0.318*	0.217*	-0.118
E	-0.164	-0.268*	-0.483*	-0.436*	-0.180	-0.184	-0.157	-0.054	0.090	-0.087	0.349*	-0.362*
H	-0.130	-0.214*	-0.742*	-0.512*	-0.081	-0.248*	-0.252*	-0.239*	-0.108	-0.006	0.397*	-0.369*
C2	-0.261*	-0.183	-0.557*	-0.523*	-0.224*	-0.304*	-0.323*	-0.271*	-0.154	-0.131	0.289*	-0.300*
C4	-0.341*	-0.160	-0.831*	-0.493*	-0.234*	-0.340*	-0.348*	-0.366*	-0.205*	-0.181	0.323*	-0.338*

U: tip of uvula; E: most superior point on the epiglottis; H: most superior and anterior point on the hyoid bone.

C2: inferoanterior point on the second cervical; C4: inferoanterior point on the fourth cervical.

NP: Nasopharyngeal airway; PS: shortest distance from the soft palate to the pharyngeal wall; UP: distance from the uvula to the pharyngeal wall.

TS: shortest distance from the posterior tongue to pharyngeal wall; EP: distance from the epiglottis to the pharyngeal wall.

SPL: Soft palate length; SPW: Soft palate width; UE: short distance from the uvula to the epiglottis.

\*: Statistically significant,  $P < 0.05$ .

and C4. SPL was moderately correlated with vertical E, H, and C4 and strongly correlated with vertical U. UE was moderately correlated with vertical E and vertical H.

## Discussion

The upper respiratory tract comprises the nasopharynx, oropharynx, and laryngopharynx. The nasopharynx and oropharynx are separated by the soft palate at the posterior maxilla, whereas the oropharynx and laryngopharynx

are separated by the tip of the epiglottis. The nasopharynx, the upper part of the pharynx, is located at the intersection of the nose, ear, and throat. It is located above the soft palate and posterior to the nasal cavity and is a space above the oral cavity, including the space between the nostril and soft palate. The longitudinal study conducted by Jeans et al.<sup>8</sup> reported that the size of the nasopharyngeal airway decreases slightly from age 3–5 years because compared with the nasopharyngeal airway, the nasopharyngeal soft tissue grows more rapidly during this period. After the age of 5, the growth of the nasopharyngeal soft tissue remains



steady; therefore, the nasopharyngeal airway steadily enlarges up to the age of 9 years. The nasopharyngeal airway rapidly grows from 9 to 13 years and then, gradually grows until 19 years. The present study discovered that NP of Group II was 1.9 mm greater than that of Group I, whereas NP of Group III was 3.4 mm greater than that of Group II; therefore, the result of the present study is consistent with that of Jeans et al.<sup>8</sup> The nasopharyngeal airway undergoes rapid growth during the age of 11–12 years.

Mislik et al.<sup>9</sup> examined the cephalograms of 880 children aged between 6 and 17 years and found that PS (the shortest distance between the soft palate and posterior pharyngeal wall) increased from 8.1 to 9.2 mm with the increase in age from 6 to 17 years. They indicated that PS is mostly determined during early childhood and remains stable afterward. The present study found that PS of Group II (8.1 mm) was 1.5 mm larger than that of Group I (6.6 mm), and PS of Group III (8.8 mm) was 0.7 mm larger than that of Group II. This result is consistent with that of Mislik et al.;<sup>9</sup> therefore, the growth of PS is 95% complete by early childhood (9–10 years old). An Iranian researcher reported that the pharyngeal space does not significantly change at the age of 9–11 years; Akcam et al.<sup>10</sup> also reported that the pharyngeal space at the uvula level does not significantly change. The results of the present study are consistent with those of the aforementioned studies; Groups II and III did not have significantly different UP.

SPL increases most rapidly when children are 1.5–2 years old, but this growth rate slows down by the age of 5 years, following which SPL steadily increases until adolescence.<sup>11</sup> Consistent with this observation, the present study found that SPL of Groups II and III was 1.9 and 4.0 mm longer, respectively than that of Group I. Another study noted that SPW increases most rapidly at the age of 1 year, following which the increase becomes small.<sup>11</sup> SPW reaches its peak at 14–16 years. The result of the present study is consistent with this description; SPW between Groups I and III showed a nonsignificant difference of only 0.3 mm.

Taylor et al.<sup>12</sup> examined longitudinal cephalograms of 32 children (16 boys and 16 girls; aged between 6 and 18 years) to investigate the growth of the oropharynx and identified two periods of accelerated change (6–9 and 12–15 years) and two periods of quiescent change (9–12 and 15–18 years). Additionally, Mislik et al.<sup>9</sup> found that TS increased from 10.6 to 11.2 mm from the age of 6–17 years; the present study found that TS of Group II (9.4 mm) was 1.6 mm larger than that of Group I (7.8 mm), whereas TS of Group III (10.2 mm) was only 0.8 mm larger than that of Group II. These results are consistent with those of Mislik et al.<sup>9</sup> and Taylor et al.<sup>12</sup> The change in TS at the age of 9–12 years is stable because the development of TS is 90% complete at the age of 9–10 years.

Fathi et al.<sup>13</sup> reported that the craniocervical inclination and cervical inclination to the horizontal plane are stable in children aged 9–11 years. This is consistent with the results of our study, which found no significant difference in the C2C4-SN angle between Groups II and III. In this study, C2 and C4 were considerably moved backward horizontally at the age of 11–12 years, which is related to the extension of the C-spine and head with the growth of children. Moreover, PA of the three age groups did not significantly differ, which may be because PA growth remains stable

substantially only after children enter the rapid growth period of puberty. The growth of the tongue is associated with the intermaxillary space and changes with age. When the mandible grows downward and forward, the tongue descends in the oral cavity, which compensates for the increase in tongue size and maintains tongue functionality during the growth period.<sup>14</sup> During the growth of the tongue, the hyoid bone descends as the mandible and vertebrae descend. Its superoinferior position is relatively stable and maintained between the third and fourth vertebrae.<sup>15,16</sup> The findings of the present study confirmed these observations. All pharyngeal airway landmarks (i.e., U, E, H, C2, and C4) were significantly lower in the older children; therefore, the distance between U and E considerably increased.

In this study, a moderately positive correlation between age and NP was found, whereas no significant correlation between age and EP was found. Moreover, significant moderate to strong correlations between age and U, E, H, C2, and C4 were found. However, this study found no significant correlation between ANB and any pharyngeal airway variable in terms of the relationship between the maxilla and mandible in children. The C2C4-SN angle significantly weakly and positively correlated with PS, UP, and TS, whereas the palatal angle significantly weakly and positively correlated with only NP. The C2C4-SN angle and palatal angle did not significantly correlate with EP; SPL had a significantly weak negative correlation with PS and UP, and no significant correlation existed between SPW and any of the pharyngeal airway variables. The horizontal E had no significant correlation with any pharyngeal airway variable. The horizontal H, C2, and C4 significantly weakly and negatively correlated with the pharyngeal airway variables.

Among primary-school children from various grades, age significantly correlated with all pharyngeal airway variables, except with EP. This indicates that the growth of EP is almost complete by the age of 7–8 years, and subsequently, only slight growth occurs. Therefore, our findings provide an important recommendation that EP could be a reference point of pharyngeal airway growth. In orthodontics, pharyngeal airway must always be evaluated before treatment and it could be assessed as early as age 7 (1st grade of primary-school children).

## Declaration of competing interest

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

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