Original Article

Anthropometric Study of Facial Morphology in Northern Thai Population Aged 1 to 18 Years Old to Inform the Timing of Craniofacial Reconstruction

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Objective: To determine normal range of craniofacial structures, compare between male and female and establish growth curves in subjects aged 4 to 18 years old. Moreover, to determine normal range of craniofacial structures in subpopulation aged 1 to 3 years old.

Materials and Methods: The present study was a cross-sectional study including 388 healthy subjects consisted of 363 subjects aged 4 to 18 years old and 25 subjects aged 1 to 3 years old. Both groups were Northern Thai. All subjects were measured to record the craniofacial anthropometry and established the growth curves in 6 regions including head, face, orbit, nose, labio-oral and ears.

Results: In the population aged 4 to 18 years old, upper vermillion height of males was 9.03±2.92 mm. while in females was 8.45±2.38 mm (p=0.039). Left auricular length of males was 57.22±5.33 mm, while in females was 55.89±4.59 mm (p=0.011). Right auricular length of males was 57.40±5.35 mm, while in females was 55.91±4.75 mm (p=0.006). In the population aged 1 to 3 years old, left palpebral fissure of male was 10.42±2.45 mm, while in females was 8.27±1.43 mm (p=0.041). The trend in morphological face height was stable after 13 years old. The trend in physiognomical face height, binocular width, mouth width, and auricular height was stable after 16 years old. The trend in forehead height, mandible width, and nasolabial angle was stable after 18 years old.

Conclusion: Each of the parameters showed a tendency to be stable at a specific cut-off age. Therefore, craniofacial reconstruction should be carried out after the specific cut-off ages identified in the results.

Keywords: Facial anthropometry; Anthropometrics; Craniofacial; Northern Thai

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At the present, craniofacial surgery is considered as being of great importance. According to the American Society of Plastic Surgeons (ASPS) 232,676 patients underwent head and maxillofacial surgery in 2017(1). In addition, one third of all congenital defects are craniofacial anomalies, therefore, the incidence of craniofacial anomalies is 0.2 to 0.5 per 1,000 births(2). In Thailand, the incidence of frontoethmoidal meningoencephalocele (FEEM) is relatively high being 1 per 5,000 births. FEEM is a herniation of the brain and meninges through the small bone defect at the junction between the frontal and ethmoidal bones. During infancy, FEEM is considered as urgent and craniofacial reconstruction is necessary to prevent meningitis and other serious complications(3). For craniofacial surgery to be successful, facial analysis is the primary step in the treatment plan. Craniofacial anthropometry plays an important role in the establishment of the standard database in facial analysis.

Anthropometry is the scientific study of the measurements and proportions of the human body. Craniofacial anthropometry is widely used in many studies, reconstructive surgery and normal growth studies included. A patient who is about to have plastic and reconstructive surgery requires the use of anthropometric measurements together with computed tomography (CT) scans and magnetic resonance imaging (MRI) for pre-operative planning(4). Previously, Bazmi and Zahir published results which can be used to provide an effective treatment plan through soft tissue analysis in Bengali children

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aged 6 to 14 years[5]. In Thailand, there is still no reliable database of craniofacial anthropometric measurements. Therefore, the aim of the present study was to use anthropometric data specifically for the Thai race to inform and improve current treatment. The intention of the present study was to create a standard database using a Northern Thai cohort of young people aged 4 to 18 years old as representative of the overall population. The authors also decided to determine the normal range of measurements of the craniofacial structures in a population aged 1 to 3 years old as a subpopulation group. These age groups were selected following a study of data from a paper by Chowchuen et al[3] which, mentioned that craniofacial reconstruction for FEEM should be done between the age of 5 and 10 months, to minimize the risks associated with anesthesia, blood loss and disturbance of growth. However, in many situations, the patients arrive to see doctor after the age of one year old, especially in developing countries. To improve the outcomes of this type of surgery, physicians need to identify the normal parameters in a small age group for medial canthal reconstruction, instead of the western data used at present[6]. A reliable database in Thailand, craniofacial anthropometric measurements in the specified age groups are needed.

Materials and Methods

The protocol for the present cross-sectional study was approved by the Research Ethics Committee, Faculty of Medicine, Chiang Mai University, Research ID: 05590/Study code: 2561-05590. The present study was conducted with the informed consent of all participants or their guardians. Guardians were given consent forms in Baan Kingkaew for all the children and no children in their guardians were excluded. Children ages less than 7 years old and over 7 to 13 years old, used assent forms, and children ages over 13 to 18 years, used consent forms. All the children received good health care and good nutritional care by nutritionist and pediatricians with normal curve.

The intention of the present study was to create a standard database for Thai people, using a Northern Thai population aged 1 to 18 years old as a representation.

All subjects enrolled onto the study were generally healthy Northern Thai individuals aged 4 to 18 years old from two primary and high school, and 1 to 3 years old from Baan Kingkaew with no craniofacial abnormalities acquired either through any accidents or developmental defects and had no history of plastic or reconstructive surgery.

After obtaining the written consent forms from the participants, the authors recorded 26 anthropometric measurements pertinent to 6 regions of the craniofacial structure in the 4 to 18-year-old group. These regions included the head, face, orbit, nose, labio-oral region and ears. According to Kusumastuti et al[7], evaluation for reconstructive surgery in FEEM needed 2 measurements in particular, the medial intercanthal distance (MICD) and lateral intercanthal distance (LICD). In the present study these parameters were called intercanthal width and binocular width. In the younger subpopulation, the authors recorded 11 measurements from 2 regions, the orbit and nose. The 26 measurements of the craniofacial structure were carried out in accordance with the landmarks shown in Figure 1 and 2. Specifically the landmarks were: 1) Trichion (tr): the midpoint of the hairline; 2) Nasion (n): the midpoint on the soft tissue contour of the base of the nasal root at the level of the frontonasal suture; 3) Gnathion (gn): in the midline, the lowest point on the lower portion of the chin; 4) Subnasale (sn): the midpoint on the nasolabial soft tissue contour between the columella crest and the upper lip; 5) Stomion (sto): the midpoint of labial fissure when lips are closed naturally; 6) Labrale superius (ls): the point located in the midsagittal plane placed at the highest elevation of the upper margin of the vermilion of the upper lip; 7) Labrale Inferius (li): the point where the mucocutaneous border of the lower lip is intersected by the median sagittal plane; 8) Gonion (go): the most lateral point of the mandibular angle; 9) Endocanthion (en): the soft tissue point located at the inner commissure of each eye fissure; 10) Exocanthion (ex): the soft tissue point located at the outer commissure of each eye fissure; 11) Alare (al): most lateral point on each alar contour; 12) Pronasale (prn): the tip of nose; 13) Chelion (ch): point located at each labial commissure; 14) Super-aurale (sa): the highest point on the upper edge of the helix of the ear; 15) Subaurale (sba): the lowest point on the lobe of the ear when the head was held in the eye-ear plane; 16) Palpebrale superius (ps): the highest point in the midportion of the free margin of each upper eyelid; and 17) Palpebrale inferius (pi): the lowest point in the midportion of the free margin of each lower eyelid. Using these landmarks, 26 measurements were performed in 6 regions in the aged 4 to 18 years as shown in Figure 1[8,9].

Statistical analysis

All statistical analyses were performed using Stata Statistical Software, version 16.0 (StataCorp

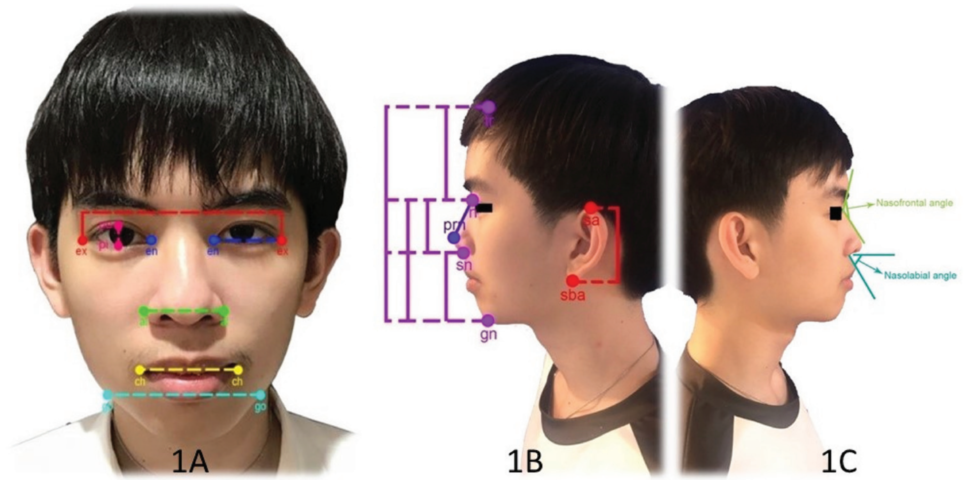

Figure 1. Measurements of the craniofacial structure. 1A-1C: 1) Head region, tr-n: forehead height; 2) Face region, tr-gn: physiognomical face height, n-gn: morphological face height, sn-gn: lower face height, go-go: mandible width, sn-sto: upper lip height; 3) Orbit region, en-en: intercanthal width, en-ex (left): left eye fissure length, en-ex (right): right eye fissure length, ex-ex: binocular width, ps-pi (left): left palpebral fissure height, ps-pi (right): right palpebral fissure height; 4) Nose region, n-sn: nose height, al-al: morphological nose width, n-prn: nasal bridge inclination, sn-prn: nasal tip protrusion, nasofrontal angle: angle that is defined from the glabella to radix to nasal tip, nasolabial angle: angle between the upper lip and the base of the columella; 5) Labio-oral region, ch-ch: mouth width, sn-ls: philtrum length, ls-li: mouth height, ls-sto: upper vermillion height, sto-li: lower vermillion height; 6) Ear region, sa-sba (left): length of the left auricle, sa-sba (right): length of the right auricle.

In the younger group, using the same landmarks, 11 measurements were performed in 2 regions as shown in 1A and 1C. Specifically: 1) Orbit region, en-en: intercanthal width, en-ex (left): left eye fissure length, en-ex (right): right eye fissure length, ex-ex: binocular width, ps-pi (left): left palpebral fissure height, ps-pi (right): right palpebral fissure height; 2) Nose region, al-al: morphological nose width, n-prn: nasal bridge inclination, sn-prn: nasal tip protrusion, nasofrontal angle: angle that is defined from the glabella to radix to nasal tip, nasolabial angle: angle between the upper lip and the base of the columella. In a study by Farkas et al[8] 113 measurements are referred to which are tr-n, tr-gn, n-gn, sn-gn, go-go, en-en, en-ex, ex-ex, n-sn, al-al, n-prn, ch-ch, and sa-sba. Two measurements are referred to in a study by Rohrich[9] which are nasolabial angle and nasofrontal angle.

LLC, College Station, TX, USA). Compared between sex group were using Student's t-test and reported by mean and standard deviation (SD). Descriptive analysis statistically significant was at p-value less than 0.05

Results

The present study group consisted of 388 healthy subjects, including 363 subjects aged 4 to 18 years old and 25 subjects aged 1 to 3 years old. All subjects were of Northern Thai extraction. Three hundred and sixty-three subjects aged from 4 to 18 years, included 159 males and 204 females, were selected by stratified sampling from Wattanothaipayap School and Chiang Mai Kindergarten School. The 25 subjects aged from 1 to 3 years consisted of 18 males and 7 females were selected by convenient sampling from Ban Kingkaew Chiang Mai Orphanage Foundation. The Normal Range of Measurements of Head regions is shown in Table 1. There was no statistically significant different between male and female in the Head region which is forehead height in all 5 age ranges between 4 to 18 years old.

Table 1. Normal range of measurement of head regions of North Thai population aged 4 to 18 years old

Age (year)	Sex (n=363)	Head regions	
		tr-n (mm)	
		Mean±SD	p-value
4 to 6	Male	67.15±11.79	0.443
	Female	64.56±12.28	
7 to 9	Male	65.81±9.95	0.087
	Female	70.02±10.80	
10 to 12	Male	67.32±10.32	0.609
	Female	68.46±10.46	
13 to 15	Male	72.06±10.84	0.670
	Female	71.09±8.92	
16 to 18	Male	73.96±14.05	0.983
	Female	74.04±10.62	

SD=standard deviation

The normal range of measurements of face regions were shown in Table 2. The length of the

Table 2. Normal range of measurement of face regions of North Thai population aged 4 to 18 years old

Age (year)	Sex (n=363)	Face regions									
		tr-gn (mm)		n-gn (mm)		sn-gn (mm)		go-go (mm)		sn-sto (mm)	
		Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value
4 to 6	Male	166.80±11.92	0.271	99.53±7.86	0.578	51.36±6.16	0.867	92.09±7.28	0.284	22.11±3.82	0.937
	Female	162.50±14.58		97.94±11.66		51.11±4.84		90.22±5.41		22.01±5.06	
7 to 9	Male	168.40±11.72	0.116	102.60±8.42	0.814	55.42±6.19	0.089	95.12±7.43	0.629	22.07±4.18	0.396
	Female	173.13±13.73		103.10±10.12		53.08±5.24		94.29±7.08		21.26±3.79	
10 to 12	Male	179.70±12.98	0.382	112.38±7.97	0.042	57.94±6.87	0.751	105.52±9.26	0.006	23.85±5.16	0.648
	Female	177.10±14.61		108.64±8.91		58.39±6.45		99.73±9.89		24.34±4.67	
13 to 15	Male	193.82±15.08	0.088	121.77±11.39	0.052	62.84±7.12	0.065	113.58±12.82	0.103	25.33±5.35	0.343
	Female	187.65±15.91		116.56±11.59		60.23±5.12		109.46±9.08		24.27±4.48	
16 to 18	Male	199.73±19.16	0.507	117.77±12.92	0.301	63.49±5.53	0.129	117.79±0.89	0.001	25.30±4.62	0.256
	Female	188.64±15.01		114.61±9.69		60.88±5.89		107.11±10.92		23.63±5.11	

SD=standard deviation

Table 3. Normal range of measurement of orbits regions of North Thai Population aged 4 to 18 years old

Age (year)	Sex (n=363)	Orbits regions											
		ex-ex (mm)		en-en (mm)		en-ex (left) (mm)		en-ex (right) (mm)		ps-pi (left) (mm)		ps-pi (right) (mm)	
		Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value
4 to 6	Male	83.77±6.98	0.018	31.60±3.55	0.642	25.92±2.65	0.009	26.25±3.75	0.019	8.22±1.73	0.592	8.08±1.42	0.686
	Female	79.29±6.93		32.04±3.30		23.28±3.85		23.89±34.02		7.97±1.59		7.91±1.49	
7 to 9	Male	86.48±6.39	0.828	33.49±5.43	0.082	26.80±3.21	0.491	26.64±3.25	0.345	8.72±1.58	0.441	8.28±1.39	0.118
	Female	86.16±5.89		31.49±3.85		27.33±3.27		27.34±3.00		9.00±1.44		8.78±1.27	
10 to 12	Male	89.55±9.16	0.428	34.24±5.04	0.490	27.73±5.25	0.628	27.58±5.15	0.867	8.35±1.83	0.523	8.06±1.54	0.549
	Female	88.15±6.85		33.50±4.80		27.23±4.17		27.41±4.04		8.59±1.47		8.27±1.54	
13 to 15	Male	100.02±10.42	0.029	36.56±7.56	0.719	31.74±4.93	0.062	31.42±4.88	0.93	8.61±2.34	0.331	8.32±2.46	0.493
	Female	95.68±6.63		36.04±4.96		29.72±4.39		29.92±4.43		9.12±2.17		8.67±2.08	
16 to 18	Male	97.61±6.33	0.462	38.27±6.51	0.143	29.25±5.19	0.332	30.09±4.81	0.943	8.49±2.46	0.326	8.35±1.74	0.363
	Female	96.15±6.93		35.99±4.92		30.37±4.14		30.18±3.95		9.04±1.81		8.84±2.09	

SD=standard deviation

morphological face height (n-gn) of males aged 10 to 12 years was significantly longer than that of females and the mandible width (go-go) of males aged 10 to 12 and 16 to 18 years was significant longer than those of females. All other measurements of face regions showed no statistically significant differences between male and female.

The normal range of measurements of the orbit region were shown in Table 3. The length of some orbital regions [binocular width (ex-ex), right eye fissure length (en-ex (right)], and left eye fissure length [en-ex (left)] of males aged 4 to 6 years were significantly wider than those of females. The length of ex-ex of males aged 13 to 15 years was also significantly wider than that of females. Other measurements of orbital regions and other age groups showed no statistically significant different between genders.

The normal range of measurement of nose regions was shown in Table 4. The length of al-al in males aged 4 to 6, 13 to 15, and 16 to 18 years were significantly wider than that of females. The length of nose height (n-sn) in males aged 10 to 12 years was significantly wider than that of females. The length of nasal bridge inclination (n-prn) in males aged 16 to 18 years were significantly wider than that of females. Other measurements of nose regions and other aged groups showed no statistically significant difference between genders.

The normal range of measurement of labio-oral

Table 4. Normal range of measurement of nose regions of North Thai population aged 4 to 18 years old

Age (year)	Sex (n=363)	Nose regions											
		n-sn (mm)		al-al (mm)		n-prn (mm)		sn-prn (mm)		nasofrontal angle (mm)		nasolabial angle (mm)	
		Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value
4 to 6	Male	48.17±7.23	0.780	30.42±1.95	0.018	34.35±7.45	0.369	12.16±1.96	0.179	131.91±5.55	0.501	101.36±9.28	0.877
	Female	47.35±12.39		29.02±2.15		36.24±7.57		11.39±2.05		133.03±6.27		100.94±10.34	
7 to 9	Male	47.18±7.74	0.155	31.29±3.42	0.742	37.18±6.09	0.783	12.29±2.27	0.515	135.21±7.73	0.742	99.45±8.97	0.559
	Female	50.02±9.28		31.05±3.46		36.80±5.27		12.65±2.29		134.59±8.34		98.00±12.29	
10 to 12	Male	54.44±9.85	0.049	33.66±2.93	0.316	40.44±5.77	0.797	13.67±2.01	0.334	135.74±8.18	0.602	98.22±10.87	0.828
	Female	50.25±9.73		33.00±3.12		40.76±5.65		13.16±2.82		134.80±8.44		98.73±11.18	
13 to 15	Male	58.92±11.86	0.333	38.61±4.29	0.001	45.35±4.00	0.479	15.04±3.36	0.366	131.68±10.00	0.657	92.88±11.27	0.571
	Female	56.33±11.37		35.70±3.19		44.60±4.95		14.31±3.57		132.60±8.26		94.28±10.25	
16 to 18	Male	54.28±14.65	0.857	39.37±4.66	0.002	49.32±4.39	<0.001	13.98±3.63	0.610	133.87±8.70	0.889	98.00±13.53	0.391
	Female	53.72±9.37		35.97±3.71		43.79±4.77		14.40±2.52		134.19±7.69		95.41±9.34	

SD=standard deviation

Table 5. Normal range of measurement of labio-oral regions of North Thai population aged 4 to 18 years old

Age (year)	Sex (n=363)	Labio-oral regions											
		ch-ch (mm)		ls-li (mm)		ls-sto (mm)		sto-li (mm)		li-gn (mm)		sn-ls (mm)	
		Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value
4 to 6	Male	35.39±4.73	0.753	14.76±3.02	0.634	7.70±2.62	0.367	7.06±1.95	0.045	22.19±5.08	0.323	14.41±4.03	0.733
	Female	35.73±3.29		15.15±2.86		7.13±1.98		8.02±1.49		21.07±3.14		14.89±5.55	
7 to 9	Male	40.04±3.44	0.152	17.41±3.89	0.152	8.25±2.95	0.488	9.16±2.32	0.080	24.19±5.38	0.566	13.82±3.96	0.669
	Female	38.85±3.58		16.08±3.21		7.82±2.19		8.27±1.89		23.55±3.66		13.44±3.33	
10 to 12	Male	40.93±4.20	0.241	18.97±3.62	0.077	9.37±3.11	0.155	9.60±1.73	0.206	24.48±3.94	0.587	14.48±4.00	0.175
	Female	39.85±4.31		17.67±3.11		8.56±2.01		9.11±1.86		24.94±3.88		15.78±4.88	
13 to 15	Male	46.54±4.17	0.002	20.77±2.93	0.059	9.94±2.62	0.229	10.83±2.35	0.202	26.68±4.49	0.449	15.39±4.98	0.721
	Female	43.26±4.72		19.36±3.43		9.25±2.34		10.11±2.54		25.85±4.88		15.01±4.36	
16 to 18	Male	45.11±3.18	0.909	21.22±2.73	0.229	10.07±2.41	0.123	11.16±1.49	0.874	27.03±3.89	0.429	15.23±4.93	0.706
	Female	44.97±4.51		20.14±3.17		8.89±2.65		11.25±2.09		26.00±4.58		14.74±4.29	

SD=standard deviation

regions were shown in Table 5. The length of mouth width (ch-ch) in males aged 13 to 15 years was significantly wider than that of females. The length of lower vermillion height (sto-li) in females aged 4 to 6 years was significantly wider than that of males. Other measurements of labio-oral regions and other age groups showed no statistically significant different between genders.

The normal range of measurement of ear regions was shown in Table 6. The length of the left auricle [sa-sba (left)] in males aged 13 to 15 and 16 to 18 years were significantly wider than that of females. The length of the right auricle [sa-sba (right)] in males aged 10 to 12, 13 to 15, and 16 to 18 years were significantly wider than that of females. Other measurements of ear regions and other age groups showed no statistically significant difference between genders.

The normal range of measurement of orbit and nose regions were shown in Table 7. The length of the left palpebral fissure [ps-pi (left)] of the orbit regions in males aged 1 to 3 years was significantly wider than that of females. Other measurements of other regions of the orbit and nose showed no statistically significant different between genders.

The growth curves in each region corresponding with age were shown in Figure 2.

Discussion

Head region: there was no statistically significant difference between male and female in the head region in ages between 4 to 18 years. Forehead height (tr-n)

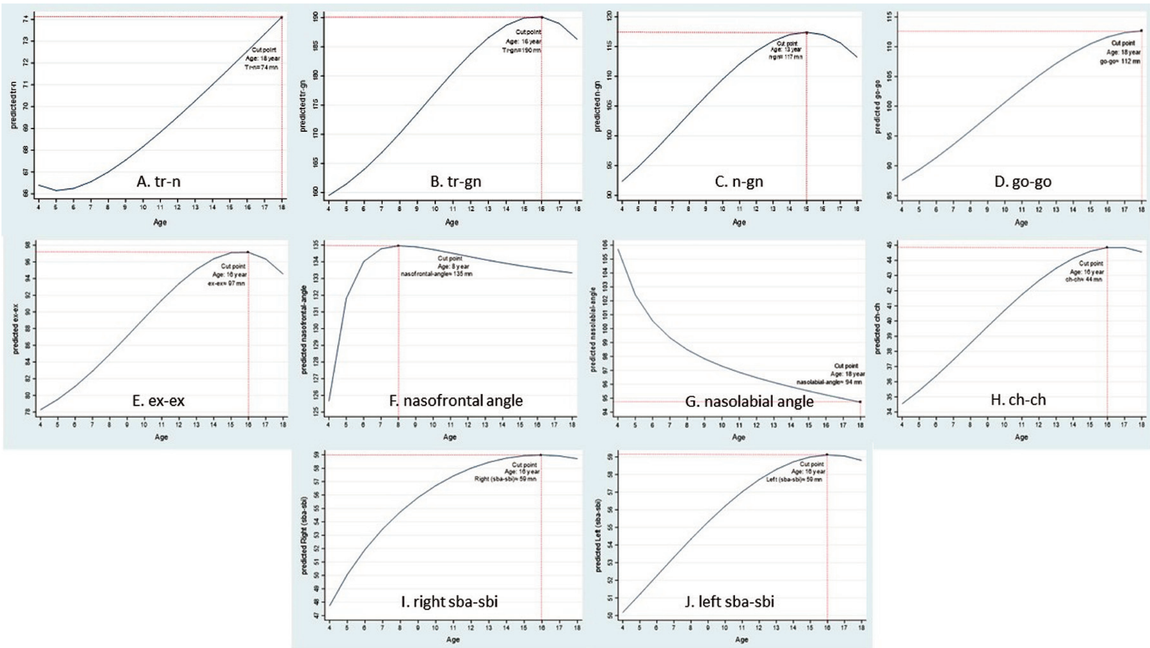

Figure 2. A-J: The growth curves in each region corresponding with age. The maximum growth of tr-n was 74 mm at the age of 18 years, tr-gn was 190 mm at the age of 16 years, n-gn was 117 mm at the age of 13 years, go-go was 112 mm at the age of 18 years, ex-ex was 97 mm at the age of 16 years, nasofrontal angle was 135 mm at the age of 8 years, nasolabial angle was 94 mm at the age of 18 years, ch-ch was 44 mm at the age of 16 years, and right and left sba-sbi was 59 mm at the age of 16 years.

Table 6. Normal range of measurement of ear regions of North Thai population aged 4 to 18 years old

Age (year)	Sex (n=363)	Ear regions			
		sa-sba (left) (mm)		sa-sba (right) (mm)	
		Mean±SD	p-value	Mean±SD	p-value
4 to 6	Male	52.48±3.08	0.957	52.15±3.86	0.929
	Female	52.52±3.63		52.06±3.52	
7 to 9	Male	54.28±4.74	0.378	54.56±4.74	0.321
	Female	53.41±3.37		53.56±3.58	
10 to 12	Male	57.79±3.53	0.069	58.17±3.52	0.025
	Female	56.10±4.96		56.30±5.10	
13 to 15	Male	61.40±4.96	<0.001	61.64±4.72	<0.001
	Female	57.63±3.77		57.56±4.67	
16 to 18	Male	61.09±4.30	0.014	61.04±4.20	0.009
	Female	57.75±4.62		57.91±3.95	

SD=standard deviation

increases with age and the cutoff point is 18 years old. However, it could not be concluded that the stable age is 18 years old as our sample finished at aged 18.

Face region: two age groups of Thai males, 10 to 12 and 16 to 18 years old, have significantly wider mandible width (go-go) than the same age group of female. In addition the mean face height (n-gn) of 10 to 12 year old Thai males which is 112.38 mm, is significantly longer than the face height of 10 to 12 year old Thai females, 108.64 mm. The upper lip height (sn-sto) of the whole 4 to 18 years age group shows a narrow distribution of between 20 and 25 mm. Obviously, across the 5 age groups, the growth of physiognomical face height (tr-gn), morphological face height (n-gn), lower face height (sn-gn) and mandible width (go-go) is more rapid than other structures. In the present study, the trend was for morphological face height (n-gn) to increase with age and be stable at after 13 years old, a finding which is similar to one of Nanda's studies(10) which included the measurement of seven linear measurements, including n-gn. Each of the measurements was plotted on a graph versus chronological age. The n-gn growth curve was most similar to other skeletal growth curves. In addition, the cumulative growth curve for male face height (hard tissue nasion to menton) described by Broadbent and Golden(11) showed that the curve tended to increase with age and be stable at the age of 15 years old. These two studies add weight to the findings of the present study.

Orbit region: there was no statistically significant difference between male and female as regards

Table 7. Normal range of measurement of orbit and nose regions of North Thai subpopulation aged 1 to 3 years old

Landmark	Sex (n=363)	Mean±SD (mm)	Min (mm)	Max (mm)	Mean±SD (mm) (both sexes)	p-value
Orbits regions						
ex-ex	Male	83.65±5.14	72.70	91.50	82.63±5.95	0.177
	Female	80.03±7.47	70.30	91.40		
en-en	Male	29.58±6.22	19.90	42.90	28.82±6.20	0.334
	Female	26.86±6.20	21.10	32.30		
en-ex (left)	Male	27.48±3.06	21.20	31.80	27.19±3.11	0.466
	Female	26.44±3.35	23.00	30.90		
en-ex (right)	Male	26.59±3.53	21.70	33.10	27.29±3.12	0.943
	Female	26.73±4.61	23.30	32.60		
ps-pi (left)	Male	10.42±2.45	6.60	14.50	9.82±2.39	0.041
	Female	8.27±1.43	5.90	10.20		
ps-pi (right)	Male	10.52±5.05	6.60	12.80	9.97±4.42	0.333
	Female	8.57±1.59	5.60	10.10		
Nose regions						
al-al	Male	28.38±2.83	25.00	34.70	27.96±2.80	0.229
	Female	26.86±2.61	22.90	30.20		
n-prn	Male	25.54±3.53	18.30	32.80	25.10±5.18	0.509
	Female	23.97±8.24	20.30	36.90		
sn-prn	Male	8.36±1.82	5.20	11.60	8.02±2.37	0.257
	Female	7.14±3.44	5.20	11.30		
nasofrontal angle	Male	127.31±27.29	112.00	157.00	128.94±24.38	0.602
	Female	133.14±15.45	120.00	150.00		
nasolabial angle	Male	106.11±18.53	91.00	133.00	103.48±17.74	0.242
	Female	96.71±14.56	80.00	108.00		

SD=standard deviation

intercanthal width (en-en) in all 5 ranges of age. In the present study, biocular width (ex-ex) tended to increase with age and be stable at 16 years old which is similar to findings published by Farkas et al[12]. Farkas et al measured biocular width in 1,594 North American Caucasians aged 1 to 18 years. According to that report, the level of growth achieved by 5 years old was 88.1% in the binocular width of both genders and showed an increasing trend with age which is similar to our study. Studies by Farkas also revealed that biocular width in North American Caucasians reached adult size by 13 years in females and 15 years in males which are in the same range of age of the present study which showed that biocular width tended to be stable at the age of 16 years.

There were statistically significant different in ex-ex in the 4 to 6 years age group, and in the 13 to 15 years group showing that male subjects in the preschool age group have greater binocular width than female subjects, and as they grow binocular width increases with age and adolescent age male subjects have greater binocular width than female subjects. There were statistically significant different in left eye fissure length [en-ex (left)] and right eye fissure length [en-ex (right)] in the 4 to 6 years age group showing that male subjects of preschool age have greater eye fissure length than female subjects.

Nose region: there were statistically significant different in nose height (n-sn) in the 10 to 12 years age group showing that the male subjects of school age have nose height longer than female subjects and as they grow, nose height (n-sn) increases with age. There were statistically significant different in the morphological nose width (al-al) in the 13 to 15 years age group, and in the group 16 to 18 years old showing that male subjects in the adolescent and teenage years have a wider nose width than female subjects, and as they grow nose width increases with age. There were statistically significant different in the nasal bridge inclination (n-prn) in subjects aged 16 to

18 years old showing that male subjects in the later teenage years have greater nasal bridge inclination than female subjects, and as they grow the nasal bridge inclination increases with age. In the present study, there was an increasing trend in the nasofrontal angle with age until 8 years old. After this time the trend was to decrease with age which is similar to the findings of a study by Wen et al(13) which measured nasofrontal angle from 266 Chinese subjects aged 12 to 18 years. According to that report, nasofrontal angle tended to decrease with age which is similar to the findings of the present study. These changes reflect that the nasal dorsum becomes more horizontally inclined during growth, rendering the nose to have a more forward position. According to the study by Farkas et al(12), the nasofrontal angle stops growing at the age of 12 in women and at age 14 or 15 in men. This finding is not similar to the present study which may be due to the either difference of the population. Farkas et al(12) reported that the nasofrontal angle is less likely to change after maturity which is similar to the findings of the present study. In addition, there was no statistically significant different between male and female as regards the nasofrontal and nasolabial angles in all 5 age ranges.

Labio-oral region: mouth width (ch-ch) tended to increase with age and be stable at 16 years old which is similar to the findings reported by Ferrario et al(14). Ferrario et al measured growth and development of lips including mouth width in 2,023 White Northern Italians aged 6 to 32 years. According to that report, the mouth width of both genders showed a trend of increasing with age which is similar to the present study and the growth pattern of the mouth width increases one fifth of its value from 6 years to adult. Studies by Ferrario et al(14) also revealed that the mouth width of White Northern Italians reached adult size by 13 to 14 years in females and 15 to 18 years in males. These findings are within the same age ranges of the present study as mouth width tended to be stable at the age of 16 years. There were statistically significant different in mouth width (ch-ch) in the 13 to 15 years old age group showing that male subjects of preschool age (0 to 3 years) have similar mouth width (ch-ch) to female subjects and as they grew up, mouth width (ch-ch) increased with age and in adolescence male subjects have greater mouth width (ch-ch) than female subjects. There were statistically significant different in lower vermillion height (sto-li) in the 4 to 6 years age group showing that male subjects of preschool age have greater lower vermillion height (sto-li) than female subjects and as they grew up lower vermillion height (sto-li) increases. In adolescent age male subjects have similar lower vermillion height (sto-li) to female subjects.

Ear regions: In the present study, the length of the auricle (sa-sba) showed the trend of increasing with age and being stable at 16 years old which is similar to those reported by Purkait(15). Purkait measured the length of the auricle from 2,147 children belonging to a central Indian population from birth to the age of 18 years. According to that report, most of the dimensions were 52% to 76% of their adult size at birth and the length of the auricle of both genders showed a trend of increasing with age which is similar to the present study. Moreover, studies by Purkait indicated that the maturity age of the length of the auricle varied from 12 to 16 years which is in the same age range as the present study. In addition, there was statistically significant different between male and female as regards length of the left auricle [sa-sba (left)] in 2 age ranges, specifically age 13 to 15 years and age 16 to 18 years old ($p=0.014$). There was statistically significant difference between male and female in the length of the right auricle [sa-sba (right)] in 3 age ranges, 10 to 12, 13 to 15 years old, and 16 to 18 years, showing that male subjects of preschool age and school age have similar auricle length (sa-sba) to female subjects and as they grow, auricle length (sa-sba) increases with age and adolescent male subjects have greater auricle length (sa-sba) than female subjects.

Certain limitations should be considered in the interpretation of results. The subpopulation aged 1 to 3 years old were selected by convenient sampling from Ban Kingkaew Chiang Mai Orphanage Foundation due to limited number of subjects. Convenient sampling could be vulnerable for selection bias. Despite this limitation, the present study could be useful for construction of a data base of facial anthropometry specific to the Thai race for pre-operative planning of plastic and reconstructive surgery. In addition, an optimal period for surgery could be predicted from growth curves of the different parameters. Each parameter tends to be stable at a specific cut-off age, therefore craniofacial reconstruction should be carried out after those cut-off ages. Patient weight and body mass index (BMI) may affect on the bigonial distance, however, these data are not available. For further studies, the authors suggest the need to include adult age group and also subjects from all parts of Thailand to accumulate results which could be used to create standard data for use in Thailand.

Conclusion

In the Northern Thai population aged 4 to 18 years, upper vermillion height and auricle height in males are wider than those of females. In this population aged 1 to 3 years, the left palpebral fissure in males is wider than those of females. Aging of the face occurs in allometrically and at different periods of life and each parameter tends to be stable at a specific cut-off age. These findings mean that, craniofacial reconstruction should be done after the cut-off ages identified in the results of the present study.

What is already known on this topic?

A patient who is about to have plastic and reconstructive surgery requires the use of anthropometric measurements together with CT scans and MRI for pre-operative planning[4]. Previously, Bazmi and Zahir published results which can be used to provide an effective treatment plan through soft tissue analysis in Bengali children aged 6 to 14 years[5]. In Thailand, there is still no reliable database of craniofacial anthropometric measurements.

What this study adds?

The trend in morphological face height was stable after 13 years old. The trend in physiognomical face height, binocular width, mouth width, and auricular height was stable after 16 years old. The trend in forehead height, mandible width, and nasolabial angle was stable after 18 years old. Therefore, craniofacial reconstruction should be done after the cut-off ages identified in the results of this study.

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Conflicts of interest

The authors declare no conflict of interest.

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