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Midsagittal Facial Tissue Thicknesses of Children and Adolescents from the Montreal Growth Study

REFERENCE: Smith SL, Buschang PH. Midsagittal facial tissue thicknesses of children and adolescents from the Montreal growth study. J Forensic Sci 2001;46(6):1294–1302.

ABSTRACT: Knowledge of changes in soft tissue depths during growth and development is important in applied contexts of forensics and dentistry as well as in growth research. In forensics, applications include facial reproductions, video superimpositions, and child aging/progressions. Garlie and Saunders (1) recently published radiographic data from the Burlington Canadian growth study; here, we present data from a mixed longitudinal sample of French-Canadian children and adolescents. Females ($N = 159$) range in age from 6 to 18 years; males ($N = 129$), from 6 to 19 years. Cephalometric measurements include nine soft tissue thicknesses, two hard tissue distances (sella-nasion and nasion-menton), and three measures of nasal projection. Several tissue thicknesses are moderately correlated with one another. The majority of thicknesses show significant sex differences by the time of adolescence; nasion and upper labial thicknesses are significantly different by sex at all ages from 6 to 18 years, as are the two hard tissue distances. However, thickness at nasion, as well as at glabella, changes little over time. Thickness at pogonion is variable and differs most between males and females at age 16; the length of the anterior inferior portion of the nose is significantly different between the ages of 6 and 12. Measurements display small and slow changes during development. The greatest average change per year (c. 2 mm/yr) is for a hard tissue measure, nasion-menton. The nasal and mid-philtrum regions have greater age changes than do other soft tissue variables. Much of the variation remains unexplained by changes with age or differences between sexes.

KEYWORDS: forensic science, forensic anthropology, facial reconstruction, soft tissues, radiographs, growth and development

Soft tissue thickness data have been collected since the 1800s for use in facial reconstruction (see Ref 2). Although most of the data have been derived from cadavers, more recent studies have used radiographs, ultrasound, or CT scans to measure tissue depths (e.g., 3 [ultrasound]; 4 [radiographs and ultrasound]; 5 [CT]). The majority of tissue depth information comes from adult individuals. Exceptions include the recent Manhein et al. (6) ultrasound study of both children and adults, Garlie and Saunders' (1), Dumont's (7), and Williamson's (8) radiographic studies of subadults, and Hodson et al.'s (9) ultrasound study of children and young adolescents. Studies of the changes in soft tissue depths in children and adolescents during growth provide valuable information for age progression studies in forensics, for orthodontics, and for more general research in human growth and development. Despite the pioneering study of Subtelny (10) over 40 years ago, less is known about the soft tissue development of the facial region than is known about the growth and development of the hard tissues of the skull.

The purpose of this paper is to replicate and extend the findings of Garlie and Saunders (1) by utilizing another sample from another Canadian growth study. The population of Canada is ethnically diverse, our study of French-Canadian subadults complements growth research of the Burlington children, who are mainly of northwestern European origins. Our study has larger sample sizes for most ages, which allows for better estimation of values at the extreme percentiles, and we start at a younger age (six instead of eight years). Several measurement locations involve the same or similar landmarks, but we have used some different ones, including some located close together (Fig. 1).

Materials and Methods

The data are derived from serial lateral cephalographs, collected by the Human Growth Research Centre, Université de Montréal. The sample includes only French-Canadians, drawn from three school districts in Montreal chosen to represent the different socioeconomic sectors of the larger population. The sample and sampling procedures have been previously described (11,12).

Females range in age from 6 to 18 years and males from 6 to 19 years. Sample sizes vary by sex and age as well as by measurement points. The sample size is largest in the middle of the age range, starting at ten years with the introduction of the second cohort, and declining in size by 15 to 16 years of age. Any age-sex group totaling fewer than 15 individuals is not considered in the analyses presented here.

A concerted effort was made by the original researchers to evaluate participants each year very close in time to their birthdays. Of over 2200 data records representing yearly visits of 289 subjects, only 31 records had an absolute value of more than 0.1 decimal years from the birthday. One case with an extreme deviation was removed, leaving 288 subjects, 129 males and 159 females; all remaining records are within 0.3 decimal years of the birthdays. Since the vast majority of data records represent ages very close to the birthdays, whole ages rather than fractional decimal ages are utilized.

From the rectangular coordinates of landmarks previously digitized, distances between the landmarks were computed. The distances are corrected by a constant value of 11.08% for radiographic enlargement. Reliabilities for landmark locations are listed in Table 1.

As in Garlie and Saunders (1), we utilized the points glabella, nasion, and mid-philtrum (Fig. 1). Our superior labial (labrale superius) and inferior labial (labrale inferius) measurements closely

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Received 22 Jan. 2001; and in revised form 12 March 2001; accepted 14 March 2001.

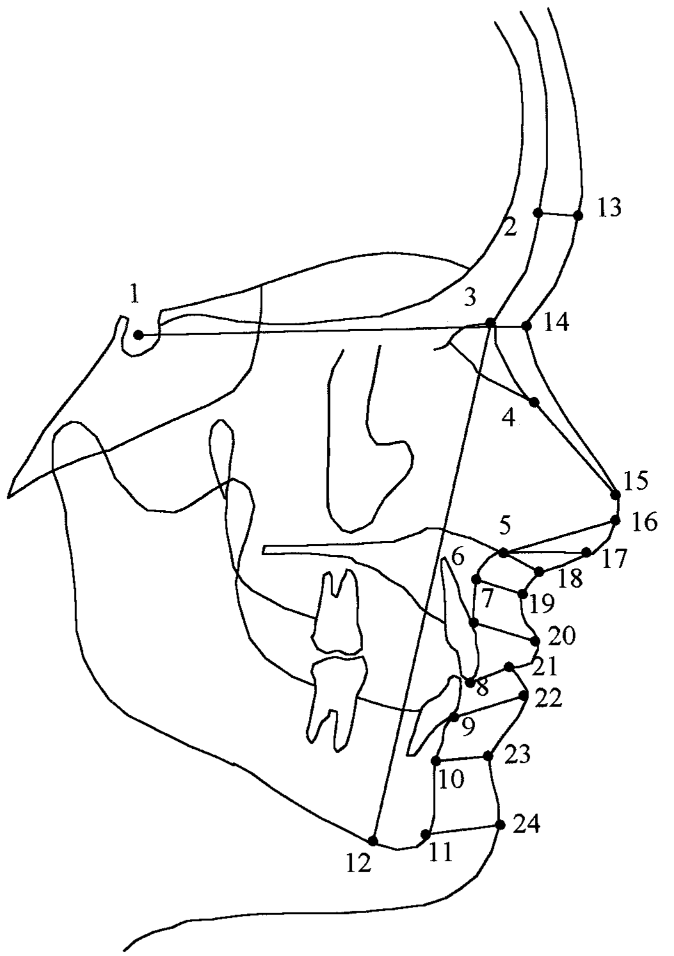

FIG. 1—*Thickness and distance measurements. See Table 1 for names and descriptions of points by number.*

correspond to their alveolar and infradentale measurements, respectively. In addition to superior and inferior labial points we have included stomion, the point in the middle of the interlabial space. Their chin lip fold is equivalent to our sulcus measurement, but our pogonion differs somewhat from theirs. Our soft tissue pogonion point is taken at the most anterior point on the chin determined by the tangent line descending from the lower lip (labrale inferius).

Garlie and Saunders (1) showed that nasal length was correlated with growth. Rather than duplicate their single measure in this instance, we selected three measures of nasal length and projection. The first, called nasal here, extends from inferior nasal to the superior nasal tangent (the anterior superior tip of the nose, as determined by a tangent line from the frontal bone). It provides an indication of nasal projection forward along the downward slope of the nose. Two more points of nasal projection are taken along the base of the nose from the anterior nasal spine. The first (NoseB1) extends to pronasale, the most anterior inferior point of the nose as determined by a tangent from the point of maximum chin projection. The second (NoseB2) extends from the spine to columella, the most anterior inferior point of the nose as determined by a tangent line from subnasale. This point should yield similar results to NoseB1, but the projection in the second case does not extend out to the tip of the nose. The third measure from the anterior nasal spine, SubN, extends from the spine to subnasale. It is directly above mid-philtrum along the soft tissue at the base of the nose and is expected to give very similar results to the philtrum measurement. In addition, we have included two hard tissue distances, sella to nasion and nasion to menton. These allow a comparison between hard tissue and soft tissue growth in the same individuals. Data analysis was conducted using SPSS.

Results

Distances and soft tissue thicknesses for the variables computed are given in Table 2. Sella-nasion consistently increases in both boys and girls through ages 19 and 17, respectively. The increases from six years of age are approximately 9 mm for boys and 7 mm for girls. Nasion-menton similarly increases through age 18 in boys and age 16 in girls, with greater increases of approximately 26 mm and 18 mm. Glabella shows only small fluctuations in thickness, from a low of 4.79 mm in 9-year-old boys to 5.74 mm at age 16, for an overall increase of only 1 mm. For girls, values range from 4.70 mm at age 7 to 5.57 mm at age 16, for a change of less than 1 mm. Nasion similarly changes little in girls, from 6.98 mm at age 10 to 7.62 mm at age 18, a difference again of under 1 mm. For boys the change is only slightly greater, from 7.54 mm at ages 9 through 11 to 8.86 mm at age 19. The anterior inferior nasal length (nasal) increases consistently in both sexes, up 4.5 mm in boys by age 15 and around 5 mm in girls by age 16 over the size at age 6. It is interesting that the changes in NoseB1 and NoseB2 for both sexes are of similar magnitude since both begin at the spine but NoseB1 is a longer measure. NoseB1 increases over 6 mm from ages 6 to 14 in males and 6 to 15 in females; NoseB2 similarly increases by about 6 mm in both sexes, from ages 6 to 15 in males and females. (There is a slight average decrease from ages 9 to 10 in males at the time of introduction of the second cohort.)

The soft tissue thicknesses in the lip and chin regions show age changes, with SubN and mid-philtrum being the most consistent. SubN increases more than 4.5 mm from age 6 to age 16 in males; the increase through age 15 in females is 3.2 mm. The mid-philtrum measure increases more than 6 mm through age 16 in boys and more than 4 mm through age 15 in girls. The remainder of the measurements show more fluctuation. Labial superior fluctuates but with a generally upward trend for both boys and girls, increasing in boys about 3 mm from age 6 to age 19 but increasing less than 2 mm in girls from ages 8 to 15. Stomion fluctuates within a 1.5 mm range for both sexes. The increase for labial inferior for boys is over 3.5 mm, but if the thickness at age 6 is omitted, the increase is about 2 mm. This is consistent with the change in girls between the ages of 6 and 13. The sulcus thickness increases between 1.5 and 2.5 mm, from 10.4 mm at age 8 to 12.7 mm at age 19 for males and from 9.49 mm at age 6 to 11.15 mm at age 18 for females. Pogonion increases over 2 mm in girls from ages 6 to 18 and about 3 mm in boys from 6 to 19.

Table 3 shows the correlations among variables at ages 6, 10, and 16 years that are significant for both sexes at these ages. (Age six was selected because it is the youngest sample age. Age ten was selected as an intermediate age due to the large sample sizes at this age. Age 16 was used rather than a higher age for the third age because there are still good sample sizes for most variables at age 16.) Correlations among the presented variables are in the moderate range, ranging from 0.20 for nasal with NoseB2 in 10-year old males and for mid-philtrum with labial superior in 10-year-old females, up to 0.79 between SubN and mid-philtrum for 16-year-old females. One third of the combinations reach significance in both sexes only for the 10-year-olds.

As would be expected, the closely spatially associated glabella and nasion thicknesses are significantly correlated at all three ages.

TABLE 1—*Landmark locations and reliabilities.*

#	Name	Description	Reliabilities	
			Horizontal	Vertical
		Hard-Tissue Landmarks		
1	Sella	geometric center of sella turcica	0.99	0.98
2	Glabella	most prominent aspect of bone overlying frontal sinus	0.98	0.96
3	Nasion	anterior point of frontonasal suture	0.99	0.99
4	Inferior nasal	inferior point (tip) of nasal bone	0.99	0.96
5	Anterior nasal spine	tip of median, sharp, bony maxillary process on lower margin of anterior nasal aperture	0.98	0.98
6	Subspinale	most posterior point on curvature of maxilla between anterior nasal spine and supradentale; also known as A point	0.98	0.95
7	Supradentale	most anterior inferior point on maxilla at its labial contact with maxillary central incisor; also known as alveolare; sometimes equated with prosthion	0.98	0.98
8	Incisor tip	incisal tip of maxillary central incisor	0.99	0.99
9	Infradentale	most anterior superior point on mandible at its labial contact with mandibular central incisor	0.99	0.99
10	Supramentale	point most posterior to a line from infradentale to pogonion; also known as B point	0.99	0.98
11	Pogonion	most anterior point on contour of bony chin	0.99	0.98
12	Menton	most inferior point on symphyseal outline	0.98	0.98
		Soft-Tissue Landmarks	0.99	0.96
13	Glabella	most prominent point on soft-tissue profile overlying frontal sinus	0.99	0.99
14	Nasion	point on sella-nasion plane intersecting soft-tissue profile		
15	Superior nasal tangent	most anterior superior point of nose determined by a tangent from frontal bone	0.99	0.91
16	Pronasale	most anterior inferior point of nose determined by a tangent from soft-tissue chin	0.99	0.96
17	Columella	most anterior inferior point of nose determined by a tangent from subnasale	0.96	0.94
18	Subnasale	intersection point of nose and upper lip	0.99	0.97
19	Superior labial sulcus	most posterior point on soft-tissue profile to a line from subnasale to labrale superius	0.99	0.97
20	Labrale superius	most prominent point on upper lip	0.99	0.98
21	Stomion	midpoint of upper and lower lip intersection	0.99	0.99
22	Labrale inferius	most prominent point on lower lip	0.99	0.98
23	Inferior labial sulcus	most posterior point on soft-tissue profile to a line from soft-tissue chin to labrale inferius	0.99	0.98
24	Pogonion	most prominent point on soft-tissue chin	0.99	0.98

Similarly, SubN and mid-philtrum are associated measures at these three ages, as are sulcus and pogonion. The latter two thicknesses are in addition correlated by age ten with a constructed variable, labeled elongation. This variable tracks the vertical increase in the face throughout growth, as measured by the increase of the nasion-menton distance relative to the distance between sella and nasion (i.e., elongation = nasion-menton/sella-nasion). For boys, pogonion and elongation are already correlated at age six ($r = 0.39$; 0.01 significance level).

Not surprisingly, the different measurements extending from the anterior nasal spine are correlated with one another. The NoseB2 with SubN correlation attains significance for all three ages. NoseB1 is significantly correlated with both NoseB2 and SubN at six and ten years, but there are too few 16-year-old males with NoseB1 for these correlations to reach significance. For 18 females at age 16, the correlation of NoseB1 with NoseB2 is 0.74 (significant at the 0.01 level) and the correlation of NoseB1 with SubN is 0.49 (significant at the 0.05 level). SubN and labial superior thicknesses are significantly correlated by age ten for both sexes. Labial superior thickness is significantly correlated as well with the mid-philtrum and stomion thicknesses for both sexes at ages ten and 16. As would be expected, the superior and inferior lip thicknesses are significantly correlated at all three ages for both sexes.

As did Garlie and Saunders (1), we report F-ratios for ANOVAS testing for differences between the sexes in distances and thicknesses throughout growth (Table 4). It is important to remember, due to the large number of tests being run, that it is the patterning of the results that is most informative; the tests are meant to be exploratory. Many of the F-ratios are, however, large and highly significant, and several patterns are clear.

The distances sella-nasion and nasion-menton are significantly different for males and females at all ages from 6 to 18, as are the soft tissue thicknesses at nasion and labial superior. Stomion and labial inferior reach significance at age seven and remain significant thereafter. That the sulcus measure does not attain significance at age eight ($F = 1.68$; $p = 0.20$) when it is significantly different at all other ages from 7 through 18 would seem to be an anomaly, but note the inconsistency of the measure below at pogonion; the latter displays the greatest difference between the sexes at age 16.

The mid-philtrum measure is consistently different for males and females by age 12, especially so by age 14 to 15 years. SubN, for which we would expect similar results, is reliably different by age 14. (This measure is significantly different at the 0.01 level ($F = 37.78$) at age 18 for 14 females and 15 males but does not appear in Table 4 due to the number of females being below the cutoff criterion.) Low sample sizes affect NoseB1 by age 15 and NoseB2 by age 17, but at younger ages these measures are not consistently different between the sexes. In late adolescence, these measures probably are dimorphic; even with low numbers, NoseB1 reaches significance at 16 and 17 years and NoseB2 reaches significance at 17 and 18 years. The nasal variable shows an interesting pattern. It is significantly different in boys and girls from ages 6 through 12, but not at ages thereafter. Ages 16 through 18 are affected by small sample sizes for this measure, but a difference, if present, should be detectable at ages 13 and 14. Girls' noses may be growing enough during the early teen years for there not to be a difference in the length of this nasal portion from boys at this time.

TABLE 2—*Distances/thicknesses (mm) by age and sex (male/female).*

	Age 6	Age 7	Age 8	Age 9	Age 10
Sella-Nasion					
Mean	61.0/58.8	62.2/59.6	62.9/60.5	63.8/61.3	64.0/62.3
SD	3.06/2.11	3.01/2.08	2.93/2.11	2.94/2.27	2.93/2.16
N	54/94	66/94	65/83	63/71	116/119
Nasion-Menton					
Mean	91.7/89.0	94.1/91.1	95.7/92.5	97.6/94.4	100.3/97.3
SD	4.04/3.59	3.90/3.46	4.03/3.63	3.83/3.85	4.48/4.48
N	53/94	66/94	65/83	63/71	116/118
Glabella					
Mean	5.04/4.84	4.84/4.70	4.88/4.82	4.79/4.80	4.97/5.00
SD	0.94/0.80	0.82/0.71	0.88/0.83	0.86/0.65	0.86/0.69
N	54/92	66/92	65/82	62/69	114/118
Nasion					
Mean	7.73/7.27	7.61/7.15	7.59/7.10	7.54/7.09	7.54/6.98
SD	1.08/0.84	0.89/0.90	0.98/0.88	0.99/0.75	0.89/0.88
N	54/94	66/94	65/83	63/67	115/118
Nasal					
Mean	21.51/20.29	21.90/20.58	22.27/20.92	22.47/21.67	23.21/21.92
SD	1.72/1.60	1.72/1.62	1.98/1.78	2.18/1.58	2.02/1.86
N	53/92	65/93	64/83	60/64	105/115
NoseB1					
Mean	18.15/17.67	19.21/18.22	19.69/18.88	20.72/20.26	20.88/20.54
SD	1.24/1.52	1.27/1.35	1.30/1.48	1.49/1.56	1.50/1.69
N	23/49	48/75	62/78	56/64	79/91
NoseB2					
Mean	13.34/12.62	13.99/13.38	14.24/13.82	15.41/14.89	15.25/15.17
SD	1.65/1.65	1.67/1.55	1.75/1.61	1.71/1.75	2.02/1.84
N	54/92	66/93	65/82	63/70	114/118
SubN					
Mean	8.48/8.00	9.00/8.48	9.26/8.72	10.14/9.64	9.90/9.65
SD	1.22/1.22	1.30/1.14	1.30/1.36	1.27/1.39	1.36/1.50
N	54/93	66/93	65/82	63/70	114/118
Philtrum					
Mean	11.48/11.22	12.00/11.95	12.60/12.16	13.48/12.85	13.98/13.60
SD	1.41/1.51	1.43/1.63	1.63/1.47	1.36/1.36	1.55/1.68
N	45/83	54/79	52/78	60/68	108/116
Labial Superior					
Mean	13.52/12.66	13.71/12.67	13.67/12.34	14.41/13.18	14.22/13.17
SD	1.73/1.65	1.90/1.71	1.58/1.34	1.63/1.42	1.42/1.62
N	46/82	55/80	50/75	60/66	106/114
Stomion					
Mean	7.31/6.81	7.35/6.45	7.20/6.64	7.68/6.88	7.22/6.28
SD	2.07/1.81	1.59/1.77	1.28/1.54	2.15/1.76	1.64/1.91
N	21/45	46/71	54/75	54/65	81/91
Labial Inferior					
Mean	13.77/13.88	15.25/13.97	15.51/14.63	16.78/15.00	16.41/14.93
SD	1.76/1.84	2.06/1.61	1.40/1.32	1.74/1.34	1.70/1.71
N	17/46	46/73	55/75	53/64	80/92
Sulcus					
Mean	10.54/9.49	10.52/9.57	10.40/10.05	11.21/10.19	11.18/10.06
SD	3.32/1.66	2.11/1.25	1.76/1.30	2.03/1.34	2.10/1.25
N	17/43	46/72	55/74	53/63	80/92
Pogonion					
Mean	10.93/10.75	11.62/11.16	11.77/11.66	11.75/11.77	11.57/11.06
SD	2.84/2.26	2.52/1.56	2.76/2.08	2.41/2.07	2.32/2.06
N	50/89	65/90	57/79	60/69	110/117

	Age 11	Age 12	Age 13	Age 14	Age 15
Sella-Nasion					
Mean	64.7/63.1	65.2/63.5	66.0/64.4	67.1/65.0	68.4/65.5
SD	3.00/2.09	3.17/2.14	3.30/2.20	3.48/2.17	3.38/2.40
N	121/119	117/107	118/106	114/103	114/86
Nasion-Menton					
Mean	101.6/99.1	103.4/101.0	105.9/103.4	109.4/105.2	112.9/106.5
SD	4.58/4.80	4.76/5.08	5.41/5.16	5.76/5.23	5.64/5.38
N	121/119	117/107	118/106	114/102	114/85
Glabella					
Mean	5.08/5.18	5.13/5.30	5.20/5.37	5.35/5.55	5.47/5.53
SD	0.88/0.74	0.83/0.75	0.80/0.68	0.78/0.69	0.65/0.63
N	119/118	114/104	98/91	83/93	65/66

continues

TABLE 2—*Continued.*

	Age 11	Age 12	Age 13	Age 14	Age 15
Nasion					
Mean	7.54/7.09	7.64/7.16	7.71/7.24	7.80/7.32	8.11/7.41
SD	0.92/0.84	0.93/1.00	0.99/0.94	0.97/0.93	1.01/0.94
N	120/118	117/107	116/105	112/103	111/85
Nasal					
Mean	23.61/22.53	24.17/22.94	24.42/23.95	25.50/24.71	26.01/25.02
SD	1.80/1.94	2.10/1.92	1.95/2.12	2.09/2.10	2.17/2.00
N	100/113	89/84	66/56	37/55	15/33
NoseB1					
Mean	21.46/21.25	22.19/22.10	23.18/23.13	24.32/23.56	NA/24.09
SD	1.55/1.65	1.87/1.69	2.05/1.57	2.13/1.50	NA/1.70
N	85/82	76/72	49/38	26/47	NA/24
NoseB2					
Mean	16.04/15.76	16.39/16.87	17.41/17.64	18.70/18.02	19.35/18.82
SD	1.72/2.28	2.00/2.19	1.88/2.17	2.22/1.94	2.47/1.99
N	117/115	106/97	83/80	66/88	41/54
SubN					
Mean	10.34/9.93	10.71/10.49	11.20/10.71	12.33/10.89	12.81/11.20
SD	1.29/1.58	1.55/1.71	1.60/1.59	1.77/1.68	1.70/1.56
N	119/118	114/104	98/91	83/93	65/66
Philtrum					
Mean	14.35/13.95	14.80/14.23	15.52/14.88	16.60/15.26	17.40/15.40
SD	1.38/1.75	1.51/1.63	1.82/1.66	1.80/1.80	1.72/1.68
N	116/118	111/104	100/105	103/100	90/79
Labial Superior					
Mean	14.21/13.21	14.48/13.46	14.74/13.72	15.57/13.86	16.00/14.00
SD	1.61/1.59	1.57/1.80	1.75/1.61	1.84/1.63	1.84/1.52
N	116/116	112/101	99/105	102/99	92/77
Stomion					
Mean	7.44/6.65	7.61/6.99	7.94/7.17	8.48/7.21	8.25/7.44
SD	1.68/1.82	1.94/1.85	2.04/1.74	1.92/1.94	2.20/1.91
N	98/87	96/91	82/79	75/84	81/56
Labial Inferior					
Mean	16.36/15.25	16.35/15.29	16.76/15.85	17.27/15.68	17.34/15.71
SD	1.57/1.50	1.60/1.50	1.50/1.55	1.66/1.70	1.65/1.61
N	98/87	99/90	81/79	78/84	80/57
Sulcus					
Mean	11.27/10.53	11.40/10.54	11.66/10.86	11.94/11.00	12.09/11.00
SD	1.90/1.40	2.04/1.06	2.15/1.29	2.20/1.14	1.89/1.04
N	98/87	98/90	80/79	77/83	79/57
Pogonion					
Mean	12.04/11.27	12.22/11.74	12.65/11.92	12.71/12.34	12.84/12.14
SD	2.38/2.11	2.38/2.10	2.40/1.94	2.17/1.76	2.06/1.93
N	117/118	114/106	105/105	110/101	106/84

	Age 16	Age 17	Age 18	Age 19
Sella-Nasion				
Mean	68.8/65.8	69.5/65.9	70.0/65.3	70.2/NA
SD	3.16/2.19	3.25/1.81	2.92/1.96	3.01/NA
N	61/45	53/32	44/22	30/NA
Nasion-Menton				
Mean	115.5/107.2	116.8/106.7	117.9/107.0	117.8/NA
SD	5.65/6.39	6.08/6.24	5.71/6.55	6.35/NA
N	61/45	53/32	44/22	30/NA
Glabella				
Mean	5.74/5.57	5.73/5.53	5.71/NA	NA/NA
SD	0.60/0.79	0.48/0.78	0.58/NA	NA/NA
N	32/32	23/27	15/NA	NA/NA
Nasion				
Mean	8.32/7.25	8.69/7.42	8.76/7.62	8.86/NA
SD	1.00/0.86	1.25/0.87	1.11/0.98	1.17/NA
N	59/45	53/32	44/22	30/NA
Nasal				
Mean	NA/25.21	NA/NA	NA/NA	NA/NA
SD	NA/1.44	NA/NA	NA/NA	NA/NA
N	NA/18	NA/NA	NA/NA	NA/NA
NoseB1				
Mean	NA/23.91	NA/NA	NA/NA	NA/NA
SD	NA/1.55	NA/NA	NA/NA	NA/NA
N	NA/18	NA/NA	NA/NA	NA/NA

TABLE 2—*Continued.*

	Age 16	Age 17	Age 18	Age 19
NoseB2				
Mean	19.11/18.10	NA/17.86	NA/NA	NA/NA
SD	2.79/2.20	NA/2.26	NA/NA	NA/NA
N	24/29	NA/23	NA/NA	NA/NA
SubN				
Mean	13.16/10.74	12.93/10.90	13.73/NA	NA/NA
SD	1.96/1.68	1.97/1.65	0.95/NA	NA/NA
N	34/33	23/27	15/NA	NA/NA
Philtrum				
Mean	17.65/15.18	17.52/14.81	17.85/14.34	17.70/NA
SD	1.74/1.61	1.90/1.41	1.24/1.81	1.18/NA
N	54/41	38/31	29/19	18/NA
Labial Superior				
Mean	16.55/13.56	16.20/13.57	16.57/13.30	16.68/NA
SD	2.04/1.96	1.96/1.60	1.86/1.73	1.82/NA
N	54/41	36/31	29/19	16/NA
Stomion				
Mean	8.62/7.16	8.56/7.28	8.71/7.12	8.41/NA
SD	1.85/1.52	1.89/1.81	2.15/1.85	1.67/NA
N	51/36	35/20	32/17	20/NA
Labial Inferior				
Mean	17.09/15.59	16.54/15.67	16.88/15.26	17.20/NA
SD	1.61/1.51	1.42/1.64	1.48/1.67	2.06/NA
N	52/38	36/21	32/18	18/NA
Sulcus				
Mean	12.38/10.92	12.29/11.02	12.35/11.15	12.70/NA
SD	2.00/0.92	1.57/0.97	1.90/1.20	1.80/NA
N	52/37	36/20	32/17	18/NA
Pogonion				
Mean	13.82/12.29	13.17/11.97	12.97/12.83	13.91/NA
SD	2.42/1.93	2.20/1.96	1.86/1.62	1.46/NA
N	58/44	46/31	37/21	23/NA

NA = Not Available or $N < 15$.

TABLE 3—*Significant correlations among variables (male/female).*

	Age 6	Age 10	Age 16
Glabella and Nasion	0.52†/0.40†	0.45†/0.39†	0.41*/0.53†
Nasal and NoseB2		0.20*/0.25†	
NoseB1 and NoseB2	0.47*/0.65†	0.60†/0.62†	
NoseB1 and SubN	0.51*/0.50†	0.61†/0.54†	
NoseB1 and Philtrum		0.39†/0.27*	
NoseB2 and SubN	0.66†/0.68†	0.71†/0.60†	0.46*/0.60†
NoseB2 and Philtrum		0.45†/0.42†	
NoseB2 and Labial S		0.23*/0.24*	
SubN and Philtrum	0.48†/0.50†	0.57†/0.60†	0.58†/0.79†
SubN and Labial S		0.30†/0.37†	0.46†/0.48†
Philtrum and Labial S		0.30†/0.20*	0.42†/0.36*
Labial S and Stomion		0.44†/0.43†	0.59†/0.64†
Labial S and Labial I	0.53*/0.43†	0.24*/0.37†	0.46†/0.37*
Stomion and Labial I		0.31†/0.26*	
Labial I and Sulcus		0.58†/0.45†	
Sulcus and Pogonion	0.62†/0.56†	0.53†/0.43†	0.45†/054†
Sulcus and Elongation		0.38†/0.37†	0.40†/0.41*
Pogonion and Elongation		0.24*/0.27†	0.35†/0.42†

* = Significant at 0.05; † = Significant at 0.01. All reported here are significant for both males and females at a given age. S = Superior; I = Inferior.

Figure 2 shows the average change per year in the variables, separately for males and females. These average slopes are based on standard least squares regressions and are meant to provide only estimated changes. All slopes are positive and are significantly different from zero at the 0.01 level; r^2 values are provided in Fig. 2 and range from 0.01 for nasion in girls up to 0.69 for nasion-menton in boys. Nasion-menton, with a change of about 2 mm per year, has the highest slopes, while glabella and nasion display very little change during growth, with slopes between zero and 0.1 mm per year.

The nose-related variables and the mid-philtrum soft tissue thickness have slopes exceeding 0.3 mm/year. These variables also have r^2 values closer to those for the hard tissue distances sella-nasion and nasion-menton than do the other soft tissue variables, ranging between 0.25 for nasal in males to 0.60 for NoseB1 in females. Labial superior's r^2 for males is 0.21, but the value for females is much lower (0.06). Elongation has a lower slope than its component variables, with r^2 values in the 0.20 to 0.30 range.

Discussion and Conclusions

For the six measures most comparable to Garlie and Saunders' (1) measures (i.e., glabella, nasion, mid-philtrum, labial superior and inferior, and sulcus), values are similar for the ages shared in common in our two studies (8 to 14 and 16 to 18 years), allowing for expected variation within and among samples and remembering that our measurements are already corrected for radiographic enlargement. There is some tendency for our measurements in the glabella and nasion regions to be thinner, while the mid-philtrum, labial inferior, and sulcus measurements appear somewhat thicker.

Like Garlie and Saunders (1), we find that the mid-philtrum thickness and measures involving the nose are of interest, having slow but consistent changes with age. Nasal projection both inferiorly and anteriorly and the mid-philtrum thickness show larger age

TABLE 4—F-*Ratios for ANOVAS.*

	Age 6	Age 7	Age 8	Age 9	Age 10
Sella-Nasion	26.52†	39.59†	33.99†	30.84†	24.57†
Nasion-Menton	18.10†	26.48†	26.75†	23.58†	26.84†
Nasion	8.29†	10.13†	10.44†	8.87†	22.76†
Nasal	18.32†	24.24†	18.88†	5.51*	24.22†
NoseB1		16.71†	11.54†		
NoseB2	6.45*	5.55*			
SubN	5.48*	7.27†	6.00*	4.72*	
Philtrum				6.87†	
Labial S	7.77†	10.94†	25.74†	20.55†	26.30†
Stomion		7.84†	4.77*	4.97*	11.88†
Labial I		14.34†	13.48†	38.83†	32.07†
Sulcus		9.29†		10.45†	18.55†
Pogonion					
	Age 11	Age 12	Age 13	Age 14	Age 15
Sella-Nasion	24.29†	19.37†	18.73†	29.83†	46.41†
Nasion-Menton	16.82†	13.17†	13.10†	30.34†	64.78†
Nasion	16.26†	13.75†	13.03†	13.47†	25.13†
Nasal	17.69†	16.04†			
NoseB1					
NoseB2				4.16*	
SubN	4.87*		4.47*	30.91†	31.95†
Philtrum		7.23†	6.95†	28.37†	58.02†
Labial S	22.65†	19.35†	18.92†	48.49†	58.00†
Stomion	9.57†	4.99*	6.57*	17.15†	5.00*
Labial I	24.23†	22.25†	14.07†	35.99†	33.43†
Sulcus	8.86†	12.67†	8.12†	11.61†	15.60†
Pogonion	6.84†		5.87*		5.74*
Sella-Nasion	29.23†	32.90†	46.15†		
	Age 16	Age 17	Age 18		
Nasion-Menton	48.96†	53.25†	47.85†		
Nasion	33.45†	25.61†	16.59†		
Nasal					
NoseB1					
NoseB2					
SubN	29.39†	15.61†			
Philtrum	50.16†	43.65†	63.69†		
Labial S	51.31†	35.51†	37.43†		
Stomion	15.01†	5.97*	6.65*		
Labial I	19.92†	4.42*	12.50†		
Sulcus	17.11†	10.80†	5.60*		
Pogonion	11.97†	5.95*			

* = Significant at 0.05; † = Significant at 0.01. S = Superior; I = Inferior. Blank spaces for nonsignificant *F*-ratios or for $N < 15$.

differences than do the other soft tissue thicknesses. As shown in Fig. 2, changes per year in the midfacial region are greater than those of the lower portion of the face, and the forehead tissue depths change little with age. Also congruent with Garlie and Saunders' (1) findings, much of the variation in soft tissue thicknesses remains unexplained by changes with age or differences between the sexes.

Several decades ago, Subtelny (10) carefully examined a small longitudinal series of radiographs from 15 male and 15 female Bolton growth study subjects. He also found merely slight fluctuations in tissue depth at nasion from 3 to 18 years of age, measuring the nasion tissue depth along an extension of a cranial base line; tissue thickness at pogonion increased about 2.5 mm in boys and 1 mm in girls while thickness at Point A (similar to our mid-philtrum but measured parallel to the palatal plane) increased about 5 mm for both sexes over the same age range.

With our larger sample sizes and the extension of the age range down to six years, we are able to detect consistently statistically significant differences between boys and girls as young as six years old for two soft tissue thicknesses, nasion and labial superior, as well as for the hard tissue distances sella-nasion and nasion-menton. The latter hard tissue differences are meaningful, but while the former soft tissue differences are statistically significant, they are not of practical relevance, being within 0.5 mm for nasion and within 1 mm for labial superior at age six years. Furthermore, the change in thickness at nasion for both sexes throughout growth is minor, as is the change at glabella. In contrast, the length of the anterior inferior portion of the nose increases about 4 to 5 mm and the basal projection of the nose increases 6 to 7 mm, with most of the latter change perhaps occurring closer to the anterior nasal spine rather than farther out. In addition, the importance of nasal length is shown by the significant difference between boys and girls as young as six years for the nasal variable, although timing differences in the adolescent spurt between the sexes may extinguish this difference in early to mid-adolescence. Thickness at mid-philtrum increases approximately 4 mm in girls and 6 mm in boys, and the difference in thickness between the sexes is apparent by 12 years of age.

The chin region is another area that warrants more exploration. Pogonion in particular is a variable measure, and this is interesting given the importance of variation in the form of the chin in facial recognition and the recent development of the mental eminence in human evolution. From photographic data, Bishara et al. (13) reported SDs for chin prominence larger than the mean change in size between ages 4 and 13 years for ten boys and ten girls.

The elongation of the face is correlated to some degree with soft tissue thicknesses at sulcus and pogonion. Since both facial length and tissue thickness increase during growth, no more may be involved in the correlation than this, but it is interesting that the other soft tissue thicknesses are not consistently significantly correlated with facial elongation. Thus, it is possible that individuals with longer faces tend to have thicker tissue thicknesses in the chin region, and this relationship may prove useful in reconstruction if further verified.

The nose and chin regions are known to be variable both among individuals and populations and therefore to be critical in facial recognition. Care should therefore be taken in reconstructing these areas and further research is warranted into the development of these features with age and into the relationship between bony and soft tissue growth. Also needed is further research into areas not positioned in the midline that are known to differ among individuals and populations, a prominent example being the cheek region. Manhein et al. (6) found that thickness of the cheek region both directly above and below the second molars, on the mandibular corpus below the second molar, and at gonion showed considerable variation for both children and adults.

Ultimately, for better reconstructions we will need to go beyond the two dimensional view of standard radiographs and beyond other measurement techniques that measure depths at a limited series of landmarks. We need to examine the overall shapes of facial surfaces and to gain a better understanding, and quantification, of the three dimensional relationships between bony surfaces and the soft tissues covering them (2,4). Nelson and Michael have advocated the use of CT and MRI to allow simultaneous visualization of cranial bones and overlying tissues, making the critical point that "it is not solely the accuracy of the soft tissue depth data, but the sparsity of landmarks, which contributes to a lack of understanding of how soft tissue changes between the landmarks" (14,167). CT and MRI, however, are not routinely employed in obtaining nor-

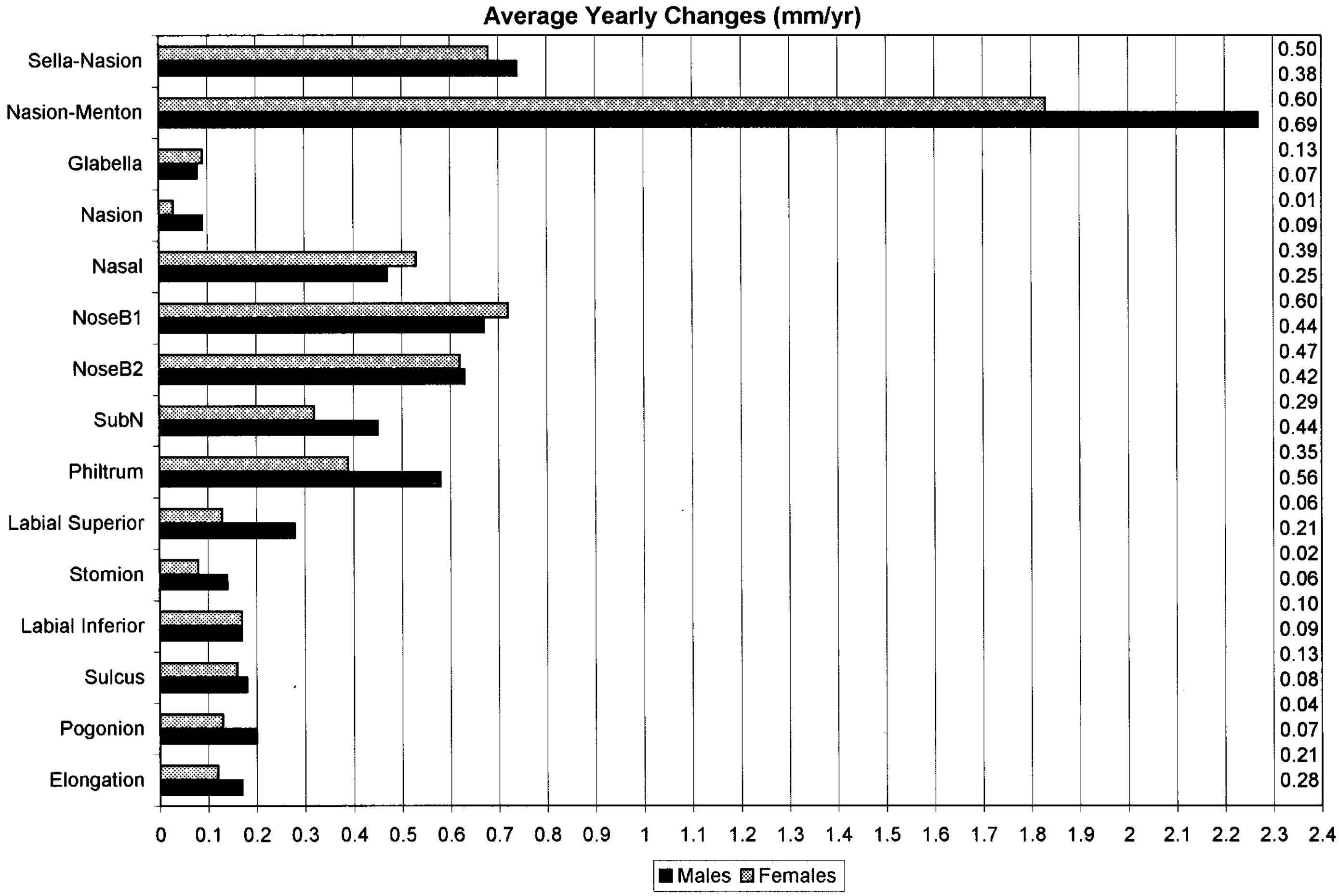

FIG. 2—*Sex differences in average yearly changes.* R^2 *values given to right of bars.*

mative data, certainly not for longitudinal data analysis. Three dimensional digital radiography may prove more practical in a clinical setting (15) and allow for some repeated measures of patients in dental practice. In another approach, previously collected frontal and lateral two dimensional cephalographs from the Bolton study are being combined to create three dimensional images (16). We are initiating research employing three dimensional ultrasound reconstructions, a technology with promise once technical difficulties have been overcome.

Given the inherent limitations of research yielding normative data, it is prudent to utilize several sources of data. Series of longitudinal lateral cephalographs, although limited to the two dimensional view, provide priceless information that should not be ignored. The tissue depth data obtainable from the Montreal Growth Study will be particularly important in documenting velocity changes in soft tissue growth, a subject we are currently exploring.

Acknowledgments

The original study from which these data are derived was supported by MRC grant #MA-8917. Special thanks are extended to the participants of the Human Growth Research Center.

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