Secular Trends in Face Size

B. Holly Smith
Stanley M. Garn
W. Stuart Hunter

Comparison of lateral and postero-anterior radiographs of parents and their adult children shows a differential secular trend in facial depths, heights, and breadths. Children tend to have deeper, longer, and narrower faces than their same-sex parents.

KEY WORDS: • GROWTH • SECULAR TREND

Generational, or *secular* increases in stature were described more than a century ago, first by QUETELET (1835) in France and later by BOWDITCH (1877) in the United States. BOAS (1912) discovered the positive secular trend seen between first and second generation immigrants to the United States, and BOWLES's Harvard studies (1932) further demonstrated that secular trends were not limited to the poor.

It is now known that secular change is not restricted to stature, but encompasses the axial, appendicular, and facial skeletons, and the rate and timing of sexual maturation (BOWLES 1932, TANNER 1962, HUNTER AND GARN 1969, GREULICH 1976). As a result, manufacturers of clothing, shoes, gloves, beds, and coffins have had to adjust their size distributions to accommodate the secular trends (GARN 1980). Similarly, orthodontists may find it necessary to change existing concepts of face size and proportion.

This study, enlarging on an earlier report (HUNTER AND GARN 1969), describes changes in face size and shape in a sample of Michigan parents and their adult offspring. Measurements on both postero-anterior and lateral head radiographs are compared, allowing consideration of all three dimensions of the face. When continuing growth of the craniofacial skeleton throughout maturity is also taken

Author Address:

Dr. B. Holly Smith
Museum of Anthropology
The University of Michigan
Ann Arbor, MI 48109

Dr. Smith is Assistant Research Scientist at the Museum of Anthropology at the University of Michigan, Ann Arbor. She holds a Ph.D. in Anthropology from the University of Michigan.

Dr. Garn is Professor of Nutrition and Anthropology and a Fellow of the Center for Human Growth and Development at the University of Michigan, Ann Arbor. He holds a Ph.D. degree in Anthropology.

Dr. Hunter is Professor and Chairman of the Division of Orthodontics at the University of Western Ontario, in London, Ontario.

into account, estimates of the magnitude of the secular trend are considerably increased.

— Methods and Materials —

The sample consists of 40 middle-income families of northern European derivation living in Ann Arbor, Michigan (HUNTER AND GARN 1969).

The parental generation is largely composed of individuals born between 1910 and 1920, 50 to 60 years of age when they were radiographed.

"Children," in turn, were born between 1940 and 1950, and most were 20–30yrs old when radiographed. The mean ages are 56 and 26 for the two samples.

Both postero-anterior (P–A) and lateral radiographic views were made of parents and children, using a cephalostat with a tube-to-sagittal-plane distance of 60 inches.

Radiogrammetric points were digitized as Cartesian coordinates directly onto computer tape. Distances representing several areas of the face and skull were generated from selected landmarks (RIDLO ET AL. 1974). Dimensions of the skull and face in lateral and posterior views were chosen to give a representative sample of different anatomical regions of the head and face. Landmarks and dimensions for the three sets of measures, including commonly used measures taken on lateral cephalographs and less familiar measures from P–A views, are described in Table 1 and illustrated in Figure 1.

In each presentation of results, dimensions are ordered into three sets —

depths, all horizontal dimensions from lateral radiographs,

heights, all vertical dimensions, including five from the lateral and one from the P–A view, and

breadths, all horizontal dimensions from P–A radiographs (Fig. 1).

Results are coherent when ordered by direction or axis, but not coherent if organized by anatomical region.

Analysis

In the analysis, fathers are paired with sons and mothers with daughters. Paired computations repeat information for fathers with more than one son (up to three in three families), and for mothers with more than one daughter (three in two families). This method is preferable to ignoring the paired structure of the data, as if the subjects were unrelated, or discarding information from second sons and second daughters (ROSNER ET AL. 1977). About 30% of the pairs contain repeat information for parents.

The results of this comparison include differences considered both in standard deviation units and in percentages. Intra-individual patterns of generational change are investigated with correlation analysis.

Lastly, we consider how the difference in ages of the parents and adult children may alter estimates of the secular trend.

— Results —

Means and mean differences of craniofacial dimensions for sons compared to fathers, and daughters compared to mothers, are shown in Table 2.

The relative magnitude of the change is shown by Z change, the mean difference divided by the standard deviation of the raw dimensions (similar to the mean Z-score of children relative to the parental distribution). Thus, this column shows how much the entire distribution of the children has moved relative to the parents. The three sets of dimensions — depths, heights, and breadths — behave differently in intergenerational comparison.

Depths show a clear and consistent increase in both sons and daughters, as

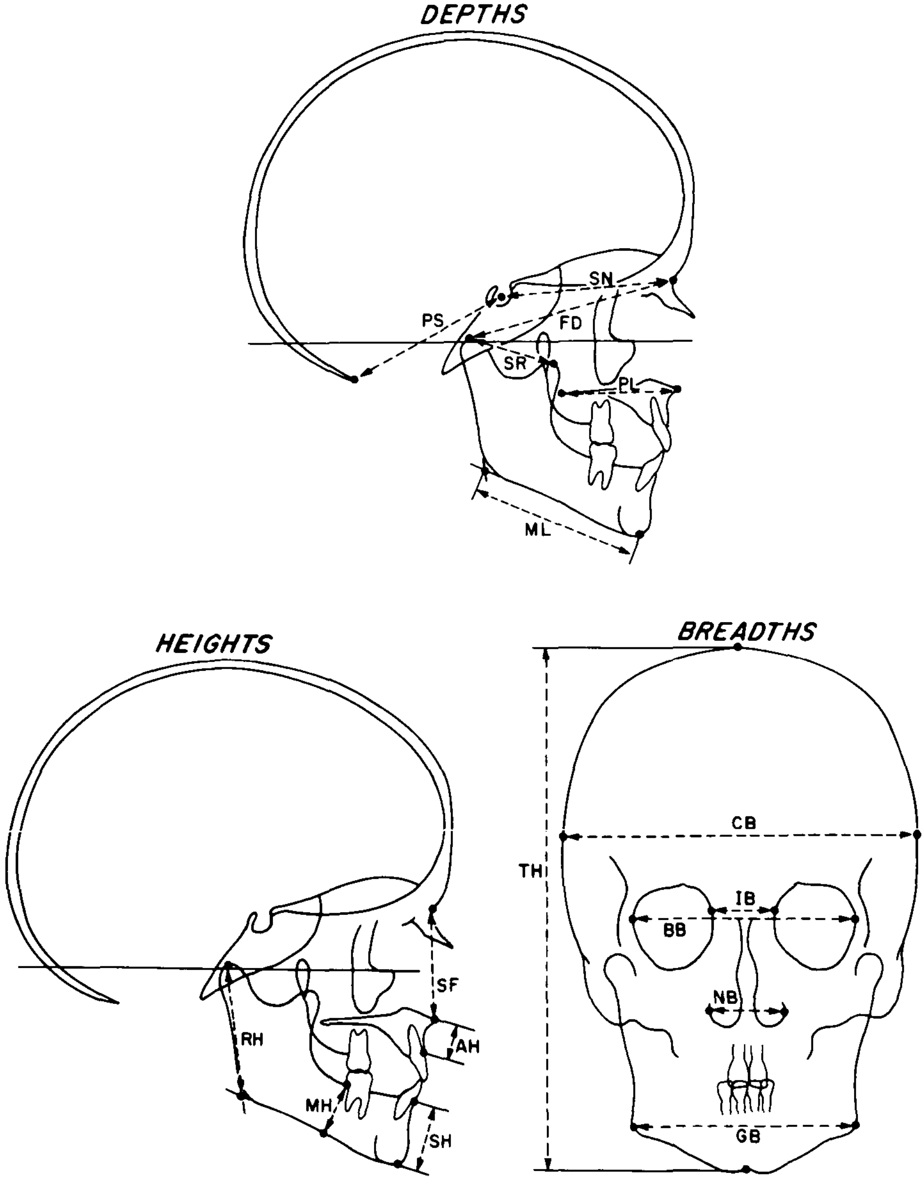

Fig. 1 **Dimensions used in this study. Depths and most height measurements are taken from lateral radiographs. Breadths and total height are taken from the postero-anterior view. Abbreviations correspond to those in Table 1.**

seen in Table 2. Faces of children in their 20's are already some 0.4 standard deviations larger than their mature parents (in terms of relative size, this is a change of about 2%). Ten of the fourteen parent-child comparisons are statistically significant ($p<.05$ by one-sided tests), and the overall trend suggests that those differences which are not individually significant are still part of the phenomenon of craniofacial enlargement.

Vertical heights also tend to be larger in offspring, though some dimensions are equivocal. Superior facial and total heights are both about 0.3Z–0.4Z larger in children, but lower face heights show dimensionally and statistically insignificant differences and even some reversals. The fact that lower face heights fail to show clear increases in both male and female comparisons suggest that this is not entirely a result of sampling error.

For all 17 dimensions shown in Table 2, Z change in males and females is correlated at $r=0.75$, a remarkably good correspondence in pattern of change.

Breadth of face and cranium, on the other hand, exhibits a clear and striking reversal of direction in ten out of ten comparisons. Sons and daughters have

Table 1

Definitions of Craniofacial Dimensions
(Illustrated in Figure 1)

Dimension	Landmark/Definition
	Depths
PS Posterior skull	Sella – Opisthion
SN Sella–Nasion	Sella – Nasion
FD Facial depth	Condylion – Nasion
SR Superior ramus	Condylion – Coronoid Process
PL Palatal length	Anterior – Posterior Nasal Spines
ML Mandibular length	Gnathion – Gonial Intersection
	Heights
TH Total height	Highest point of skull vault to lowest mandibular point in midline
SF Superior facial height	Anterior Nasal Spine – Nasion
AH Alveolar height	Supradentale – Anterior Nasal Spine
SH Symphyseal height	Gnathion – Infradentale
RH Ramus height	Condylion – Gonial Intersection
MH Mandibular height	Perpendicular from inferior mandibular plane to distal M_1 cemento-enamel junction
	Breadths
CB Cranial breadth	Right – left Euryon
IB Interorbital breadth	Right – left Minimum Orbit
BB Biorbital breadth	Right – left Entoconchion
NB Nasal breadth	Right – left Alare
GB Gonial breadth	Right – left Gonial Angle

Definitions of landmarks are from: Riolo et al., 1974 (*depths and heights*)
Howells, 1973 (*breadths*)

Table 2

One-generation Change in Craniofacial Dimensions
(mm)

Parents paired with their adult children

Dimension	N Pairs	Sons Daughters	Fathers Mothers	Mean Diff.	Z Change
		Depths			
PS	♂44	77.7	76.4	1.2	0.31
PS	♀36	73.0	72.2	0.8	0.19
SN	♂49	80.0	78.3	1.7	0.50
SN	♀38	75.2	73.5	1.8	0.64
FD	♂49	99.3	95.7	3.5	0.74
FD	♀38	93.1	90.3	2.8	0.74
SR	♂49	41.1	40.2	0.9	0.28
SR	♀37	38.2	37.7	0.5	0.15
PL	♂49	59.5	58.6	0.9	0.26
PL	♀38	55.0	54.5	0.5	0.15
ML	♂49	87.6	85.5	2.2	0.38
ML	♀38	80.5	79.2	1.3	0.35
		Heights			
TH	♂45	238.8	235.0	3.7	0.33
TH	♀36	221.7	220.6	1.2	0.14
SF	♂49	60.1	58.6	1.5	0.40
SF	♀38	56.1	55.1	0.9	0.31
AH	♂48	18.9	19.8	−1.0	−0.31
AH	♀38	17.4	19.4	−2.0	−0.72
SH	♂49	33.9	33.8	0.1	0.03
SH	♀38	29.4	30.7	−1.3	−0.46
RH	♂49	71.2	72.0	−0.8	−0.11
RH	♀38	62.6	62.5	0.1	0.16
MH	♂41	28.9	28.2	0.7	0.24
MH	♀25	23.9	24.8	−0.9	−0.31
		Breadths			
CB	♂43	159.7	161.0	−1.3	−0.21
CB	♀35	152.4	156.0	−3.6	−0.73
IB	♂43	26.5	28.2	−1.7	−0.66
IB	♀36	25.1	26.0	−0.9	−0.33
BB	♂41	100.0	101.8	−1.8	−0.39
BB	♀36	97.3	97.8	−0.1	−0.12
NB	♂33	30.3	31.4	−1.0	−0.30
NB	♀27	30.1	30.4	−0.2	−0.07
GB	♂45	108.0	108.9	−0.9	−0.15
GB	♀36	99.9	102.3	−2.4	−0.58

Significantly different at $p < .05$ in one-sided tests

Z Change is the change in standard deviation units —
the mean difference divided by a sex-specific pooled estimate of the standard deviation of each dimension

smaller, narrower faces than their parents by about 0.3Z–0.4Z.

This reversal of direction cannot be explained by a technical difference in lateral and P–A films since total height, which shows the opposite direction of change, was also taken from P–A films. Since heights and breadths have changed in opposite directions, the shape of the facial oval has changed. Both sons and daughters have a slightly more "masculine" (longer, narrower) face than their same-sex parents. This tendency is stronger in sons than in daughters.

The opposite secular changes in depths and heights versus breadths suggests a considerable degree of independence in the three axes of the face.

Axis Differences

Correlation analysis was used to investigate the relationship of dimensions in different axes, and the pattern of size change within individuals. Intra-individual correlations of dimensions show a low correspondence of measures from different axes of the face.

Summarizing 136 intra-individual correlations for fathers in this sample, dimensions with the same orientation, such as all the measures of height, are found to be related at approximately r=.3; but correlation values of only r=.2 were found for dimensions with different orientations, such as heights vs. breadths.

We also investigated whether the change in one axis is predictable from that in another. Within a plane, secular changes correspond at r=.3, but secular change across planes is virtually independent at r=.0 to r=.1 in 136 male and 136 female correlations.

A significant degree of independence exists between the three axes of the face, so we cannot predict that because a child is larger in depth he will also be larger in height. Nor is there a negative relationship between change in heights and breadths — there is no evidence of a developmental connection that produces a narrower face in the presence of increased facial height.

Adult Growth

Although the parents and children in this study were adults at the time of examination, a period of some thirty years in age separates the two groups. Since there is good evidence of continuing bone expansion in adulthood, as shown for tubular bones by GARN ET AL. (1967), and for the face and skull by ISRAEL (1973) and most recently by BEHRENTS (1984), we recomputed the secular trend after correcting for such increases.

Both craniofacial studies are similar in ethnicity and birth cohort to the parental sample described here, so we employed the more conservative of the estimates as given by BEHRENTS (1984) for the Bolton-Brush study.

Whereas continuing bone expansion could not account for the fact that younger children are already larger than their parents in depths and heights, it is possible that the smaller facial breadths of the children might disappear if mature size increase is taken into account.

Table 3 shows the estimates of continuing growth from Behrents's study for dimensions that match or closely approximate those used here. The secular trend (as a percent) observed in this sample is given for each sex, followed by the estimated percent change after compensating for the increase in size of the parents over 30 years. As shown, secular trends of 2% for depths and heights are observed in this sample. Taking continuing growth of parents into account increases our estimates of the secular trend to about 3%–

4% for both depths and heights. In some cases, such as ramus height and mandibular height, apparent reversals in size disappear when corrected for expected continual growth.

In contrast to the depths and heights, for which we have information on continuing adult growth, no such information currently exists with respect to cranial and facial breadths. Accordingly, we show only the observed secular decrease, which averages −2.6% in males and −1.2% in females.

Whether there is continuing adult expansion in facial breadths is conjectural, but an amount comparable to that shown for depths and heights would result in a *zero* difference between par-

Table 3

Secular trend in Craniofacial Dimensions
Corrected for Continual Growth during Adulthood
(percent)

		Secular Trend (%)			
	Continual	Males		Females	
Dimension	Growth (%)	Observed	Corrected	Observed	Corrected
		Depths			
PS	0.5	1.6	2.1	1.0	1.5
SN	1.5	2.1	3.6	2.4	3.9
FD	1.4	3.7	5.1	3.0	4.4
SR	≃2.2	2.2	4.4	1.3	3.5
PL	≃2.0	1.6	3.6	0.9	2.9
ML	≃1.1	2.5	3.6	1.7	2.8
		Heights			
TH	-	1.6	-	0.5	-
SF	1.6	0.4	2.0	1.7	3.3
AH	≃3.1	−5.0	−1.9	−10.3	−7.2
SH	≃2.7	0.0	2.7	−4.2	−1.5
RH	≃5.2	−1.1	4.1	0.1	5.3
MH	≃4.2	0.2	4.4	−3.6	1.6
		Breadths			
CB	-	−0.8	-	−2.3	-
IB	-	−6.1	-	−3.3	-
BB	-	−1.8	-	−0.5	-
NB	-	−3.3	-	−0.8	-
GB	-	−0.8	-	−2.3	-

Continual growth percentages are from Behrents (1985)

≃ Percentages are marked as approximate if the landmarks used differ slightly (i.e., Gonion instead of Gonial Intersection).

ents and children. However, it would take far more expansion in breadths to equal either the observed or the corrected secular changes seen for depths and heights. The more parsimonious conclusion is that there is no secular increase in facial breadths.

— Discussion and Conclusions —

This comparison of parents with their adult children reveals several new aspects of the secular trend in craniofacial dimensions.

First, coherent patterns of secular change occur along all three axes of the face and skull, and they apparently are not associated with specific bones or structures.

Second, secular change in one axis of the face is a poor predictor of change in another axis. This is consistent with correlations of dimensions within individuals, in which depths of two adjacent bones are more highly correlated than a depth and a height projected from a single point on a single bone.

Third, the secular trend in facial depths and upper facial heights that occurred over a period of 30 years is considerable — at least 2%, and possibly of the order of 3% to 4% if estimates of continuing growth during maturity are correct.

Despite the advantage of an additional 30 years of size increase, parents are still smaller in facial depths and heights than their adult offspring.

Fourth, it appears that this secular increase in depths and heights is not paralleled in facial breadths. In the age range of 20–30yrs, the children have longer, deeper, and narrower faces than their mature parents. Unless continued expansion in facial breadths takes place throughout adulthood at a higher rate than in the other dimensions, the children will never match their parents in facial shape.

Impressively, sons and daughters both exhibit the same pattern of change relative to their parents, although the amount of increase in facial height may be greater in sons than in daughters.

Continuing growth on the order of 1%–3% would be enough to eliminate the apparent seculat decrease in facial breadths of the children, but such increases in breadth would have to reach 4% to 5% to catch up with depths or heights during mature growth. Such continued increases would involve major apposition, resorption, and remodeling of the orbit, nasal aperture, nasal bones, cranial vault, and mandible during adulthood.

In the absence of such marked later increases in breadths, it would appear that faces must be becoming deeper, longer, and narrower from one generation to the next.

The main question for orthodontists is whether a secular trend of 3%–4% in each generation can continue. Standards dating to the 1930's or 1940's are likely to be inappropriate for children born in the 1970's. There has been some suggestion that the secular trend in stature is ending, that modern populations have achieved all the benefits possible from increased calories and improved medical care (Bakin and McLaughlin 1964).

Secular increases in stature may be a good gauge for change in facial size. For example, our particular sample also shows a significant secular increase in stature of sons (who average one inch taller than fathers) and daughters (one-half inch taller than mothers). Even if the secular trend has already produced its maximum effect in middle-income Western populations, significant increases in facial size may still be in store for impoverished Americans and inhabitants of underdeveloped nations.

Of particular interest is the finding that facial shape as well as size is different in the offspring. It would be most useful to determine whether this finding is replicated in other samples, and whether the trend toward longer, deeper, and narrower faces is a general one. If so, current orthodontic norms may not only be too small, but may describe facial shapes that are outdated. A/O

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