# A Cross-Sectional Study Of The Relationship Of Facial Areas With Several Body Dimensions

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## Introduction

Over a period of years investigators have used a variety of methods of assessing and describing the variabilities of size, form, and relationship of the various parts of the face.

Anatomists and anthropologists have developed a series of schemata including important points on the dried skull as well as certain lines and planes. Anthropologists have also established a series of points and planes on the head of living.

The subject received a completely new treatment with the development of the cephalometer by Broadbent who made longitudinal studies of the growth of the head with the Bolton cephalometer. This remains a classic to investigations of this type. A few years after Broadbent presented his work, Brodie (1941) published his very important study on the growth pattern of the human head from the third month to the eighth year of life. His work indicates that the growth pattern of the human head is established at a very early age and shows little change. Broadbent superimposed the entire tracing of the head on his "registration point"; Brodie based his work on the measurement of the various parts of the skull after first laying them out as areas.

The tracing of the lateral cephalometric roentgenogram as used by Brodie is shown in Figure 1. In the present study, the areas measured were based on those of Brodie with several modifications of points and boundaries and are shown in Figure 2. This study is an attempt to extend and develop certain phases of the subject by the introduction of the measurement of areas in addition to the points and lines previously used.

Investigations with the cephalometric roentgenographic method have usually relied upon angular and linear measurements involving certain landmarks. The measurement of areas, however, offers a less limited and more inclusive approach.

Since areal measurement is not a very common technique, it may be well to give a brief statement of its use. The measurement of structures of the human body are commonly made in terms of one dimension, such as length, diameter or circumference, or in terms of three dimensions *i.e.*, volumes or approximately by weights. However, measurements in two dimensions *i.e.*, surfaces or areas are equally valid and are particularly useful in roentgenographic studies.

Quantitative studies of areal growth and dimensions of the human body are not new. The cutaneous or skin area was measured by Abernathy as early as 1795, and later determinations have been made by a number of other observers.

Putiloff (1886) measured the area of the serous membranes of the body, and gastric mucous membranes were studied by Dargien (1890) and by Scott (1929). The square inches of the cerebral cortex have been calculated by Wagner (1860), Aresu (1914),

Based on thesis submitted in partial fulfillment for the degree of M.S.D., University of Minnesota Graduate School.

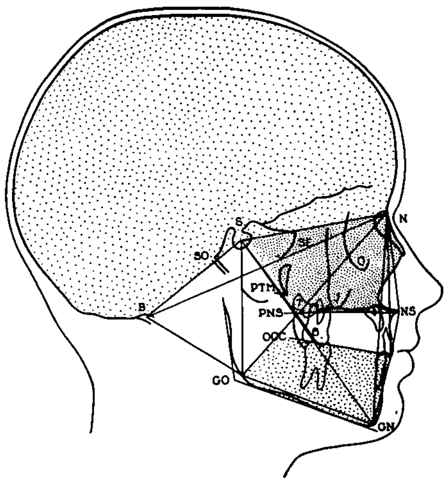


Fig. 1. A typical roentgenogram tracing of the head (after Brodie, 1941.) B, Bolton point; GO, gonion; N, nasion; NS, nasal spine; O, orbitale; OCC, occlusal plane; PNS, posterior nasal spine; PTM, pterygomaxillary fissure; S, sella turcica; SE, sphenoethmoidal junction; SO, spheno-occipital junction.

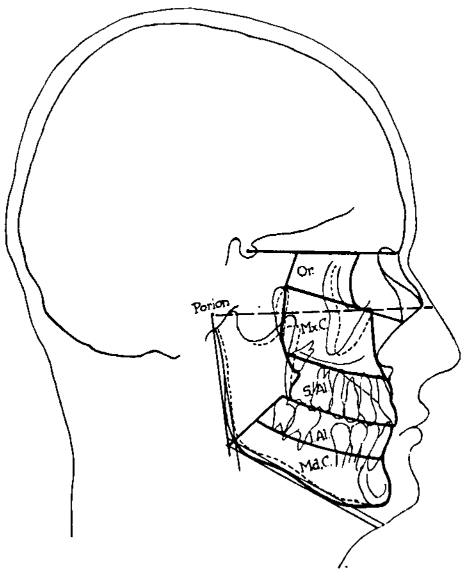


Fig. 2. Tracing of a right lateral roentgenogram of the head showing the facial areas as defined and used in this study. Heavy solid line shows boundaries of facial area. Or, orbitoethmoidal area; Mx.C, maxillary corpus area; S.Al., superior alveolar area; I.Al., inferior alveolar area; MaC., mandibular corpus area.

and Scammon and Hesdorffer (1936). The silhouette of the heart in the x-ray has been measured by Bamberg and Hermann (1919) and a number of other investigators. The area of the bones of the carpus as seen in the roentgenogram have been measured by Carter (1925, 1926) and others.

The general object of this study is to measure and compare the growths and sizes of the various facial areas with those of certain body measurements, and to determine the interrelationships of the facial areas. It also seemed desirable to justify or modify, as the case might be, the various existing schemata by which the face (in norma lateralis) is divided into areas of growth.

In this cross-sectional study of 125 standardized profile (cephalometric) roentgenograms and corresponding carpal films, the plan is to draw, by recognized and statistical methods, a picture of the relationships between each of the facial areas and stature, body weight, carpal rank, chronologic age, and the other facial areas.

This investigation is based on the parapuberal period when many changes are taking place in the body. It is also the period in which most of the permanent dentition is completed. The records and findings of the premenarchial females are separated from the postmenarchial females and, as will be pointed out, this division has been of great value in analyzing the material. No such division was made for the males for there is no effective way of making similar separation of the prepuberal and postpuberal cases.

The changes in growth and development in this parapuberal period are often very different from those of other divisions of the life cycle, preceding and following it. This was clearly pointed out by Muhlmann (1900, 1910) Hall (1904), Minot (1908), Scammon (1920, 1930), Davenport (1930), and other observers, and has recently been demonstrated in detail by Shuttleworth (1938). Like the period of infancy and early childhood, the parapuberal period is one of rapid general growth. But otherwise, the two intervals are often very different. The central nervous system and the organs of special senses grow rapidly in the infant and young child. They are practically stationary in the parapuberal period. The organs of reproduction grow very little during the first six or seven years after birth; they increase over tenfold in the parapuberal years. The lymphoid structures and organs grow rapidly during the early part of the first decade; they are actually declining in size during adolescence. Merkel (1882) in an interesting paper on skull growth described a very different set of changes in the skull in the third epoch (about ten to about twenty years) from those of the first epoch (birth to about seven years) or in the second (about seven to about ten years). The paranasal sinuses (except for the ethmoidal cells) grow comparatively little in the six years following birth but increase rapidly in the parapuberal years (Maresh, 1940).

As mentioned above, one object of this study was to investigate the relation between the development of the facial areas and the status of carpal development.

The carpal bones have long been thought of as a criterion for determining skeletal ("anatomic", "physiologic") age. They have been used for determining the amount of calcification, and thus the degree of maturity of the bones of the body as far back as 1848 by Quain.

A given series of carpal plates can be arranged by three methods: (1) by inspection, (2) according to individual bone-area measurements or the sum of such bone-area measurements, and (3) by seriation.

With the ranking or seriation method, a series of roentgenograms, preferably a large series, is taken with the same magnification and under standardized conditions. These are then arranged before a light source and sorted into an order indicated by the degree of development each patient exhibits. Since it is possible to shift the plates at will, a very exact graduation can be obtained. This ranking is commonly done independently by two or more observers and is tested for consistency by rank correlations of the ratings turned in by each observer. Most of the modern series of carpal ranks, such as those of Flory (1936) and Todd (1937) were made by this method and its use is regarded as a standard research practice.

## Material and Method

This study was based upon individuals of the parapuberal period, defined as extending from nine to eighteen years. These age limits may seem rather extreme, but modern studies by Shuttleworth (1937, 1938), Richey (1937) and others show that, while the puberal changes in bodily growth commonly reach their maxima in the thirteenth year for American girls and in the fourteenth and fifteenth year for American boys, they frequently begin in the ninth and tenth year and are still evident in a reduced degree in the eighteenth year.

The individuals were taken at random, except for age, from patients of the pay clinic of the University of Minnesota Dental School. No special study was made of their origins, but previous studies on individuals of this age group in the University hospitals and clinics indicate that they are practically all American-born, mainly of the second and third generation, of diverse nationalities as regards family origins, but almost all of Northern European stock. In all, some 225 individuals were measured anthropometrically*, given dental examinations and x-rayed for lateral oriented head plates and right wrist roentgenograms. From this collection, 125 individuals were taken. These consisted of three groups, 50 males, 30 premenarchial females, and 25 postmenarchial females. The separation of these cases from the original mass of material was done by strict random sampling except in one or two instances where the cases were rejected because of indistinct x-ray plates and were replaced by cases taken by chance from the general supply.

A tracing of each head x-ray was made on 0.003 plastic matte tracing film (Eastman) for measuring purposes. The boundaries were marked off according to a plan to be described later. Each tracing then consisted of five separate areas, each quite irregular in shape, which were measured directly in square inches with an instrument called a planimeter.

It is desirable to compare, insofar as possible, the great bodily measures of the present group of children with those of a larger sample of the local population as a whole, with a view of determining if the present small group is a moderately representative one. This is possible by the use of the O'Brien, Girschick and Hunt tables.

When this comparison is made, it is found that the stature is about the same (within one inch) for each of the three groups and the corresponding O'Brien, Girschick and Hunt standards. The premenarchial and postmenarchial females are a little heavier (four to five pounds) than these standards and the weight of the males is almost the same. The coefficients of variability in stature and body weight of the three groups are of the same order of magnitude as those found by O'Brien, Girschick and Hunt. It is probably safe to assume that insofar as stature and weight are concerned, the present sample is fairly representative of the population from which it was drawn.

*Height (inches) without shoes, weight (lbs.) normal indoor clothing, age (mos.), bideltoid and biachromial distances. The latter mentioned distances were later discarded because the height measure proved so reliable.

## The Facial Areas

The problem of establishing boundaries for the several facial areas is not only one of growth demarcation but one of practicability. The area limitations must consist of points and outlines that have easily visible shadows on the roentgenogram.

The facial boundaries of the present study enclosed those areas where growth demarcation seemed reasonable and consisted of points and outlines easily identifiable on the x-rays.

The facial areas were:

1. Orbitoethmoid (Or.)
2. Total maxillary — a combinaation of maxillary corpus (Mx.C.) and superior alveolar (S.Al)
3. Mandibular areas — a combination of inferior alveolar (I.Al) and mandibular corpus (Ma.C.)

Specifically, the basic boundaries were drawn to encompass the following areas. Some of the finer details and the reasoning behind them have been omitted for the sake of clarity.

1. Orbitoethmoid (Or.) designed to include the orbit and more specifically to exclude it from the growing facial area beneath it:
   - (a) nasion to center sella turcica
   - (b) sphenoethmoidal junction to superior anterior angle of pterygomaxillary fissure.

(c) most forward boundary of orbit as seen on roentgenogram
(d) to inferior border orbit.

2. Total maxillary area:
   (a) anterior border pterygomaxillary fissure around the maxillary tuberosity to encompass any crowns
   (b) irregular line drawn along anterior margin facial skeleton including tip of central incisor
   (c) smooth curve (drawn with aid of appropriate French curve) from incisal tip of central incisor through first molar cusps.
3. Mandibular areas:
   (a) straight line from gonial angle to intersection of occlusal curve
   (b) tracing of remainder of mandible.

After tracing, each area was measured with a planimeter. This device automatically computes the area (in square inches) of an irregularly-shaped, flat surface with great accuracy. Tests made by retracing several of the cephalometric x-rays and again measuring them showed no appreciable difference between tracings.

The comparisons were made by rank correlation with each area's dimensions being compared with that of each of the other areas.

The carpal assessment was accomplished by the serial ranking of each individual's wrist x-rays to determine the relative calcification of the respective x-ray in the group.

## Findings

1. Chronological age proved an ineffectual guide to the growth and development of facial areas in the parapuberal period.

2. Measures of carpal rank also proved an ineffective guide to facial development.

3. Stature and body weight proved the best indicators of facial development found in this study. Both show distinct concomitance with facial growth during this period.

4. A particularly close concomitance exists between the total maxillary area and mandibular areas in the three groupings. (Premenarchial female, postmenarchial female, male.)

5. Orbitoethmoidal area shows little if any relation to other facial areas or to stature, body weight or age increase.

6. There is distinct difference in size of facial areas in favor of males when compared with premenarchial females.

7. Postmenarchial status seems to cause a slowing of the rate of increase of size of the total maxillary and mandibular areas; critical ratios indicate that this is not entirely due to increased chronological age.

8. Relative rates show that all facial areas are undergoing a reduction in percentage increase in the postmenarchial period.

9. The orbitoethmoidal area grows quite differently from the total maxillary and mandibular areas and its style of growth may be said to approach the neural type. Its inclusion as a typical facial area is most questionable.

10. Fourteen empirical formulas were developed by expressing the growth of facial areas in relation to other measurements in each of the fourteen instances where the respective correlates showed distinctly significant coefficients of correlations. This is shown in Table 1 and Figure 3.

## Discussion

It may be pointed out at the beginning of this discussion that all the findings under consideration are concerned only with the parapuberal

Table 1

Empirical Formulae for Prediction of Average Values of Facial Areas from Stature, Body Weight and Other Facial Areas

(Constants of Formulae and Mean Weighted Errors, or Residuals, for Averages.)

General Formula: $A = aB \pm b$

| For Prediction of "A" From "B" | | Constants of Formula | | Mean Weighted Errors of Averages | |
|---|---|---|---|---|---|
| A | B | a | b | sq. in. 100 | per cent |
| *MALES* | | | | | |
| Total maxillary area | Stature | 6.07 | — 0.33 | 4.6 | 1.3 |
| Total maxillary area | Body weight | 0.97 | +236 | 8.3 | 2.2 |
| Mandibular areas | Stature | 7.45 | — 81.3 | 5.2 | 1.4 |
| Mandibular areas | Body weight | 1.02 | +267.5 | 3.3 | 1.0 |
| Mandibular areas | Total maxillary area | 0.708 | + 77.8 | 1.6 | 0.5 |
| *PREMENARCHIAL FEMALES* | | | | | |
| Total maxillary area | Stature | 6.04 | — 16 | 0.9 | 0.3 |
| Total maxillary area | Body weight | 1.064 | +241.2 | 2.3 | 0.6 |
| Mandibular areas | Stature | 4.54 | + 55.6 | 3.1 | 0.9 |
| Mandibular areas | Total maxillary area | 0.677 | + 94.6 | 4.3 | 1.7 |
| *POSTMENARCHIAL FEMALES* | | | | | |
| Total maxillary area | Stature | 5.76 | — 13.8 | 5.4 | 1.2 |
| Total maxillary area | Body weight | 0.799 | +268 | 3.4 | 0.8 |
| Mandibular areas | Stature | 6.34 | — 61.9 | 3.8 | 1.0 |
| Mandibular areas | Body weight | 1.43 | +172.5 | 1.4 | 0.3 |
| Mandibular areas | Total maxillary area | 0.458 | +169.1 | 8.9 | 2.6 |

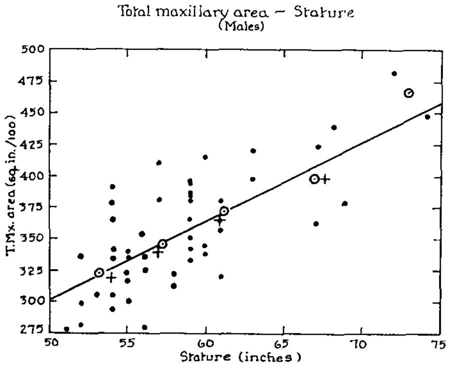


Fig 3. A typical field graph of the relation of total maxillary area to stature for males. The dots represent individual cases and the circled dots represent means. Crosses show medians. The solid line, a representation of the central trend, was drawn to the empirical formula. Total maxillary area (sq.in. /100) = 6:07 Stature (in.) — 0.33.

period. It is interesting to note that chronological age and carpal ranking did not prove to be as reliable a guide to facial development as stature and body weight. From this we might find an indication that general body growth — usually demonstrated by stature and weight — does bear some relation to facial growth.

It was expected that the orbital area, which from previous investigations had been found to follow the neural type of growth, would show little relationship to facial or general body growth.

The postmenarchial status caused a decrease of the relative rate of facial area growth when compared with the premenarchial group. It would have been advantageous to have been able to divide the data for males similarly.

The development of empirical formulae as listed are of value in that they exhibit some order to a series of plottings on a field graph.

As a whole, the first or "a" constants of the formulas which are multiplying factors and represent absolute rates of increase are remarkably consistent. They are of the same order of magnitude for given correlates in all three sets of data (male, premenarchial and postmenarchial females).

The mean weighted relative or percentage residuals range from 0.3 to 2.6 per cent, being above 2 percent in only two instances. They show no particular consistency but they indicate a high degree of correspondence between observed and calculated means. Most empirical formulae based upon data on human structures show mean weighted relative residuals ranging between 5 and 10 per cent.

The author wishes to acknowledge the assistance given by Drs. S. R. Steadman and R. E. Scammon in this study.

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