Use of Angular Measurements in Cephalometric Analyses

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Most cephalometric analyses make extensive use of angular measurements. This usage is based on the assumption that angular measurements for a particular individual tend to remain relatively constant with respect to time, ie, that they are affected minimally by growth. The tenability of this assumption is challenged in several instances on the basis of the results of a cross-sectional cephalometric study of certain angular variables.

Numerous points, lines, proportions, and angles are used in cephalometric analyses,[1] and in an increasing number of methods used in the analysis of craniofacial morphology and growth based on various combinations of these measurements. However, most of the proposed methods emphasize angular measurements, numerically and conceptually. Examples are the Tweed triangle[2] and the method of Downs[3] which is based on the scores for nine angular measurements and one linear measurement. An explanation of the reasons behind this emphasis on angular variables has been provided by Hunter:[4]

> The preponderance of angular values in such batteries of tests or analyses is a result of the fact that faces vary greatly in size and of course enlarge during growth, thereby making linear standards cumbersome for clinical use where simplicity is important. Furthermore, because growing faces change in proportion as well as size, the effect of proportional change can be minimized by careful selection of the angles used. Thus, several analyses utilize the angular relationship of the incisors to the facial plane or some variation of it. The population variance of this relationship far exceeds the change effected during growth so that, for practical purposes, a useful value can be established.

Received for publication May 27, 1971.

Although simplicity is important, and angular measurements generally are affected less by growth than are linear or proportional measurements, or both, it has been our experience that many angular variables show a strong dependence on growth and maturation, and that these factors generally should be incorporated into orthodontic diagnosis and treatment planning. Moreover, many growth curves for angular measurements exhibit a degree of sexual dimorphism which is of considerable clinical significance. In this paper we used cephalometric methods to investigate the distributions of several angular measurements in a large sample of "normal" individuals of several age groups and both sexes. The purpose was to study the dependence of these angular variables on age and sexual dimorphism.

Materials and Methods

The cephalograms of children and young adults with "normal" dental occlusion were obtained as part of a study of normal growth conducted at the Philadelphia Center for Research in Child Growth between 1948 and 1968. The project director (W. M. Krogman) "took in substance children who were in 'good medical health' and who had no more than the usual so-called mild 'childhood illnesses' . . . 'good dental health' . . . a low DMF index . . . and all four permanent molars in place." Those selected for the study were thought to be "reasonably representative of the white children of Philadelphia" during the period in question.

The cephalograms of this group of normal individuals were processed by one of the authors (G.F.W.), who also devised

TABLE 1
DESCRIPTIVE STATISTICS FOR THE DISTRIBUTION OF THE SNA ANGLE IN 474 NORMAL MALES AND 630 NORMAL FEMALES

Age	Males					Females				
	N	Mean	SD*	Min†	Max	N	Mean	SD	Min	Max
6-8	21	79.70	2.18	75.07	83.68	36	80.43	4.04	75.67	88.16
8-10	73	80.82	2.96	74.86	88.18	104	80.20	3.88	71.86	87.99
10-12	114	82.36	3.35	73.40	92.30	153	81.45	4.12	71.32	91.92
12-14	124	82.20	3.16	74.38	89.69	159	81.54	3.84	70.89	90.38
14-16	85	83.14	3.31	75.92	91.60	106	82.53	3.90	73.16	90.74
16-18	35	83.20	2.47	78.67	87.86	58	83.46	3.79	76.07	89.85
18-26	22	83.07	3.27	77.51	88.96	14	81.44	3.44	77.49	89.39

* SD, standard deviation.
† Min, minimum; max, maximum.

the computerized method used in this study[5] and supervised the transformation of the radiographic information into digitized form for ready access by statistical computing programs. The data were processed with a console-oriented statistical computing program called CONSTAT (developed by the Statistical Research Laboratory, University of Michigan).

Results

Table 1 gives the sample sizes (N), means, standard deviations, and minimum and maximum values of the sella-nasion-point A (SNA) angle (measured in degrees) for both sexes and several age groups. Although little sexual dimorphism was evident, except that the females exhibited more variability in each age group, there was a slight but definite tendency for this angle to increase with age. The correlation coefficient of the SNA angle and age is 0.22 for males and 0.21 for females, which is a tendency of the SNA angle to increase with age for both sexes. However, the correlation coefficient measures only the intensity of the linear association between the variables,[6] and growth curves are seldom linear. This is illustrated in Figure 1, where the SNA mean values for each age group and both sexes and the associated (approximate) 95% confidence intervals for the true mean values are plotted. This clearly illustrates the tendency for the SNA

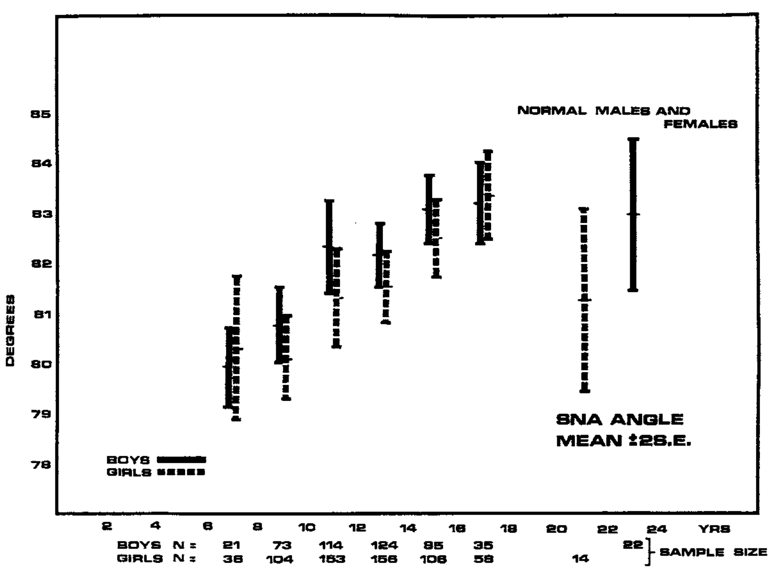

FIG 1.—Sex-specific growth curves and confidence intervals for SNA angle.

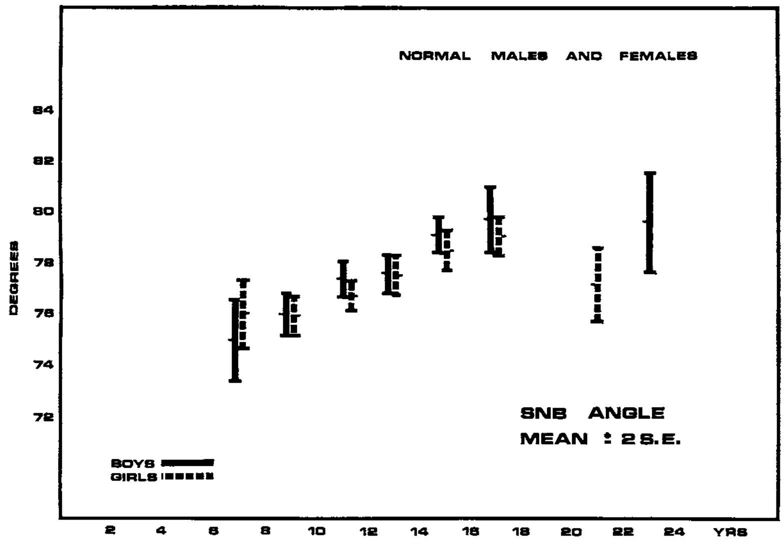

FIG 2.—Sex-specific growth curves and confidence intervals for SNB angle.

angle to increase during the interval from 6 to 18 years of age, with stabilization achieved during adulthood.

A similar pattern is shown in Figure 2, where the corresponding graph for the sella-nasion-point B (SNB) angle is presented. This similarity may be anticipated on "topographical" grounds,[7] ie, because common reference points are used in the definitions of these angles; but the fact that these indicators of upper (SNA) and lower (SNB) facial prognathism are age-dependent might profitably be incorporated into orthodontic diagnosis and treatment planning; this possibility seems to have been neglected in the literature.

Figures 3 to 5 show the angular variables comprising the Tweed triangle that were

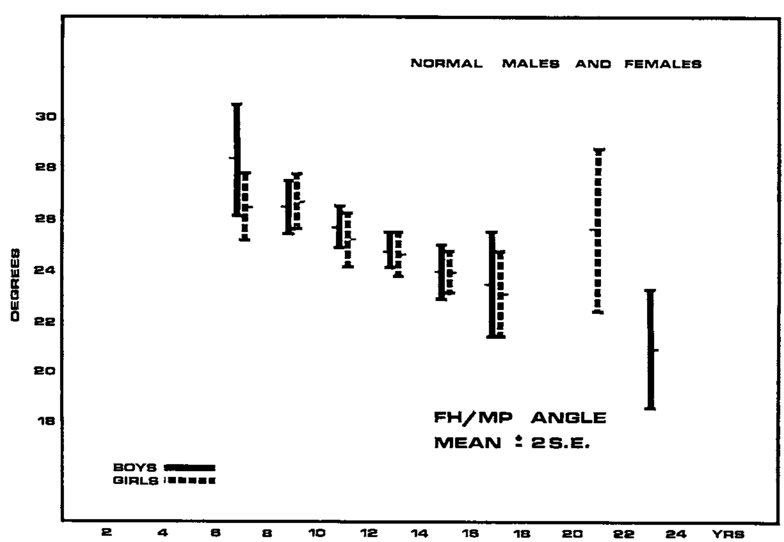

FIG 3.—Sex-specific growth curves and confidence intervals for FH/MP angle.

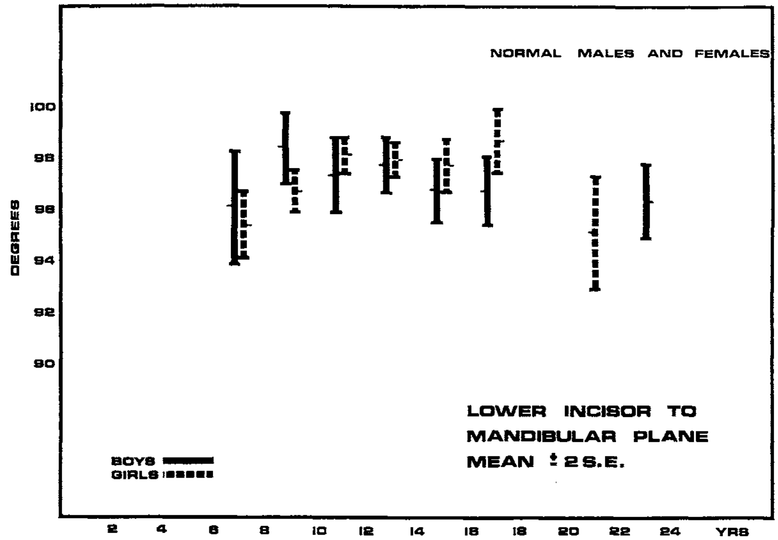

FIG 4.—Sex-specific growth curves and confidence intervals for LI/MP angle.

examined for changes during growth. The Frankfort horizontal-mandibular plane (FH/MP) angle decreased with age; the lower incisor-mandibular plane (LI/MP) angle remained relatively constant; the lower incisor-Frankfort horizontal (LI/FH) angle increased with age. The departures of the sample mean values of these angles from the normative (or "ideal") values proposed by Tweed were discussed previously.[8,9] The purpose of the present discussion is to indicate that the triangle tends to shift with time. Although the LI/MP angle remained relatively constant, the FH/MP angle decreased with age, and was balanced (the sum of the three angles must be 180°)

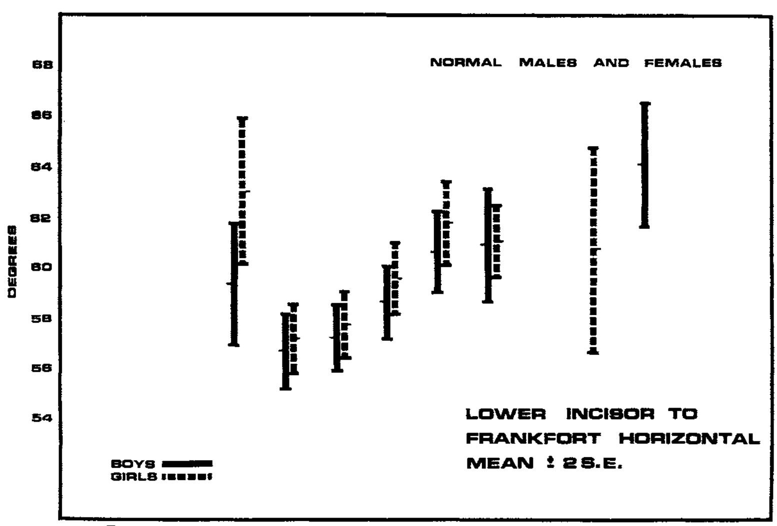

FIG 5.—Sex-specific growth curves and confidence intervals for LI/FH angle.

by a corresponding increase in the LI/FH angle.

Our final example exhibited age dependence, a significant degree of sexual dimorphism, and a clinically significant departure from the currently used normative value. The point A-nasion-point B (ANB) angle has been recognized for some time as a useful guide to the diagnosis and treatment of malocclusion. It is an integral part of the Steiner[10,11] analysis; it measures the relationship between the maxilla and mandible, and its value may suggest an effective treatment regimen. Therefore, it is of considerable interest to determine normative values for this variable in various population groups. Steiner[11] chose a set of craniofacial norms, "which express our concept of a normal average American child of average age"; the norm for the ANB angle is set at 2°. He asked the reader to "please bear in mind that these are rough estimates, to be used as a starting point from which to vary and must be modified by other factors . . . age, sex, growth potential and individual variations within these and other groupings," but provided little insight into how these modifications should be accomplished; nor did he indicate whether or not normal individuals conformed to his ideal.

Table 2 gives the descriptive statistics for the distribution of the ANB angle in the 1,104 individuals in our sample. A glance at this table is enough to show that, in the population studied, the "typical" value of the ANB angle is quite different from 2°. The overall mean is more nearly 4.5°. The 474 males had a mean of 4.65°, and the 630 females had a mean of 4.34°. This does not mean that an angle of 2° is not in some sense "better," but indicates that normal individuals do not, on the average, attain this ideal. The mean value seems to be a good summary statistic in this context because a check of the distributions of this angle in the various groups considered showed no significant departures from normal (Gaussian) distributions. Figure 6 is a histogram of a typical distribution.

The next questions involved the dependence of the ANB angle on age, and sexual dimorphoism. Analysis of the data[12] showed a definite tendency for the ANB angle to decrease with age in males, but not in females. Thus, there seems to be a considerable amount of sexual dimorphism associated with the ANB angle in the population studied. The males had slightly larger ANB angles until about 15 years of age, when a reversal occurred; the males then tended to have smaller ANB angles than the females. Although the ANB angle for females remained relatively constant from 6 to 26 years of age, there was a definite tendency for males to exhibit a decreasing ANB angle with increasing age.

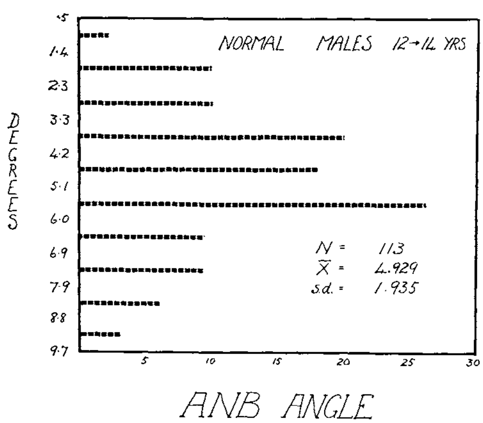

FIG 6.—Histogram of ANB angle for males 12 to 14 years of age.

TABLE 2

DESCRIPTIVE STATISTICS FOR THE DISTRIBUTION OF THE ANB ANGLE IN 474 NORMAL MALES AND 630 NORMAL FEMALES

	Males					Females				
Age	N	Mean	SD*	Min†	Max	N	Mean	SD	Min	Max
6-8	21	4.70	2.12	1.27	8.67	36	4.47	2.27	0.38	8.48
8-10	73	4.78	2.07	0.23	9.74	104	4.18	2.18	0.10	10.49
10-12	114	5.08	2.07	0.31	10.40	153	4.78	2.26	0.33	10.64
12-14	124	4.84	1.96	0.50	9.77	159	4.08	2.32	0.06	9.66
14-16	85	4.30	2.07	0.07	9.60	106	4.20	2.04	0.66	10.88
16-18	35	3.87	1.44	0.34	5.90	58	4.42	1.74	0.25	8.66
18-26	22	3.44	1.92	0.14	6.67	14	4.24	2.25	0.64	8.53

* SD, standard deviation.

† Min, minimum; max, maximum.

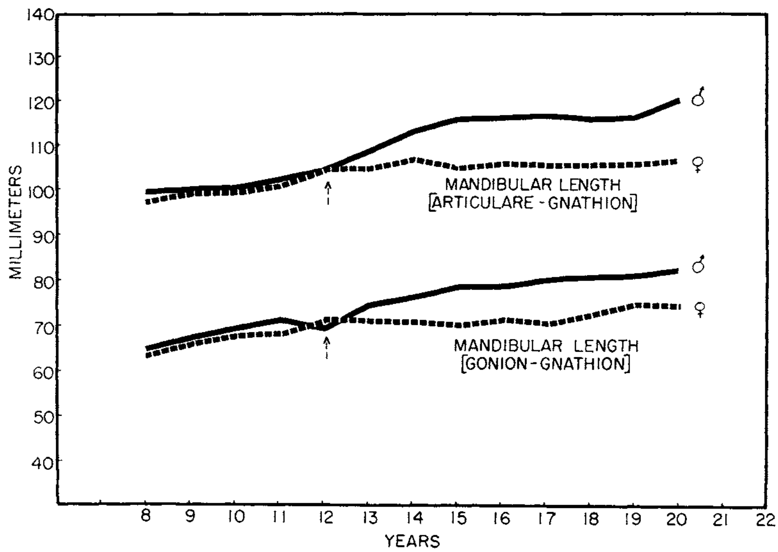

FIG 7.—Sex-specific growth curves for two measures of mandibular length.

This finding naturally raises the question of the structural dynamics of this difference in growth pattern. After we studied the growth curves of other variables generated from our model of the skull, we were able to explain the observed differences in terms of mandibular growth. In males, the mandible continued to grow steadily after puberty, but this tendency was not exhibited in females. Until about 12 years of age, mandibular morphology and growth in the two sexes were remarkably parallel, but lower facial growth continued in males well into the late teens. Figure 7 shows the sex-specific growth curves for two different definitions of mandibular length. This prolonged growth of the mandible (relative to the maxillary structures) causes the closure of the ANB angle to occur after puberty and has direct relevance to decisions about orthodontic diagnosis and treatment planning.

Discussion

We investigated the behavior of six angular variables that are used widely in orthodontic cephalometric analyses, with special attention to their dependence on maturation and sexual dimorphism. No attempt was made to provide the "best method" of orthodontic diagnosis and treatment planning because, as noted by Scott,[13] "it does not matter very much which method or combination of methods are used. What is important is a full understanding of what is being measured, the relative stability of the points used, and the 'normal' range of the measurements at various ages." We attempted to illustrate, despite the apparently widespread belief to the contrary, that growth and sexual morphism may be important factors in the interpretation of the scores on angular variables included in any method of analysis. This is not to say that angular measurements should not be used (they often provide information about shape that cannot be quantified in any other way) but, rather, that their use is not necessarily a simple matter, and that considerable care should be exercised in interpretation.

Conclusions

Angular measurements often are used in cephalometric analyses on the basis of the assumption that they are, for most practical purposes, independent of age and sexual dimorphism. The results of a cross-sectional cephalometric study of more than 1,100 "normal" children indicated that these assumptions are untenable. The accuracy of cephalometric analyses for diagnosis, case assessment, and treatment planning may be increased significantly if the orthodontist takes into account sexual dimorphism and the existing regression of these measurements with age.

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