

TIMING AND MAGNITUDE OF THE MALE CIRCUMPUBERAL GROWTH ACCELERATION
OF HEIGHT, WEIGHT AND SEVERAL FACIAL DIMENSIONS

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INTRODUCTION

The adolescent or pubertal growth spurt may be defined as the approximate two-year period when a developing child has the most rapid rate of growth since his first year of life.

During this period there are many physiological differences in the development of individuals of the same chronological age and between boys and girls. For this reason growth in height, weight, hand/wrist development and tooth development and eruption have been preferred as indicators of the developmental age of individuals.

Although many investigators agree that of all the facial measurements the anteroposterior length of the mandible is the one that shows the most consistent relationship with growth in height throughout the adolescent period, there has been a lot of controversy and a clear relationship between the age at which the maximum increments of facial growth and corporal dimension occur, has not been established.

If a definite relation could be established, this would enable investigators to develop a method predicting the age at which the maximum growth rate would occur during adolescence, and would be of tremendous value and usefulness for the practicing orthodontist, enabling him to time the treatment plan more accurately.

The purpose of this investigation is to determine in a longitudinal study in boys, the age at which the maximum increment of body height, weight and facial growth occurs during adolescence and the relationship between height, weight and several facial measurements during this period.

LITERATURE REVIEW

In recent years there has been considerable interest in adolescent growth and the influence it exerts on facial structures. Probably the earliest longitudinal study on growth was conducted by Gueneau de Montbeillards²⁶ in 1776, who began an 18-year study on his son to determine yearly increments of growth. This recorded curve of annual height increments showed that the velocity of growth decreased from birth onwards, although the trend was altered twice. Between six and eight years of age there was a leveling of the increments of growth, and between thirteen and fifteen years of age there was a marked increase. This period of accelerated growth, known as the adolescent or pubertal growth spurt has since been recognized as an extremely active period of accelerated growth.

Tanner³¹, states that "the adolescent spurt is a constant phenomenon and occurs in all children, although it varies in intensity and duration from one child to another." The timing

and magnitude of the growth spurt during adolescence can be affected by malnutrition, major illnesses, climate and race, although climate and race do not influence the time of adolescence as greatly as nutrition does.

There are many physiological differences in the adolescent development of individuals of the same chronological age. For this reason a measure of physiological maturity is commonly used in preference to chronological age for the evaluation of development.

Sex is a significant factor; most authors agree that maximum pubertal growth occurs on the average approximately two years earlier in females than in males. The appearance of secondary sexual characteristics suggests that the peak velocity of the pubertal growth spurt has been passed. Height and weight are physical manifestations which are used to assess the growth and development of individuals. Probably the most commonly used measure of physiologic maturity is skeletal development³¹. An x-ray film of the hand and wrist has proven to be the most satisfactory method for the majority of investigators. Although

there are several different methods of determining skeletal age from wrist films, the most often used is the atlas or inspectional method in which the patient's radiograph is compared with a standard series to find the closest match (Greulich and Pyle¹³).

Another method consists of comparing all the bones in the radiograph with standardized written descriptions to obtain a skeletal age value. (Tanner, Whitehouse and Healy³²)

Dental development has also been used as an estimate of physiologic development. Numerous studies have been performed to test the relationship between tooth eruption and skeletal development and/or growth in stature^{1,2,5,14,19,22,24,27}. Others have investigated the relationship between root formation or crown calcification with skeletal development^{7,10,12,21,22,23}. Most of the studies showed varying degrees of nonrelationship^{1,7,14,19,21,22,24,27}, while others found a good relationship between dental development and skeletal growth^{2,5,8,12,23}. Krogman²⁰ says that tooth eruption seems to be more closely related to the stage of root formation than to either chronological age or skeletal age or development.

Calcification stages of the teeth, whether on a fifteen point, a seven point or a three stage scale, are extremely reliable measures of dental ages. These stages are more significantly related to skeletal development than are tooth eruption schedules²⁰.

The majority of these studies agree that dental development is not as accurate an estimate of skeletal development as the use of a roentgenogram of the hand and wrist. Burstone⁷ indicated that a crude guide to the rate of development is body type. He says that "generally, persons who are particularly tall for their age are early maturers, and those who tend to be particularly short for their age are late maturers."

Other investigators have attempted to test the relationship between growth of the face and skeletal development or growth in stature.

Nanda²⁶ in 1955 focused upon the relation between facial growth and skeletal growth (height). In his study of 5 girls and 10 boys with an age range of 10 to 17 years of age, he found that

the growth curves of the face were like those of general skeletal growth. But during adolescence the facial growth spurt occurred slightly later than that for body height. He found that 28% occurred at the same time as body height, 57% occurred six months or more later and 14.7% earlier. His results included a sex difference in the magnitude of growth of facial dimensions, being greater in boys than in girls.

Rose²⁸ in 1960 tried a different approach. He divided the face into three areas: 1) orbitoethmoid, 2) total maxillary, and 3) total mandibular. He did a cross-sectional study of 125 lateral headfilms of 50 boys and 50 girls, 30 premenarchial and 25 post-menarchial. Rose found that stature and body weight both showed distinct concomitance with facial growth during puberty. It is interesting to note that he found chronological and skeletal age ineffective guides to growth and development of facial areas in the pubertal period, while stature and weight were the "best indicators of facial development."

Bambha¹ in 1961 reported a longitudinal study of growth of

the face from lateral headfilms of a sample of 25 girls and 25 boys. He found that the duration in years of the pubertal growth spurt in boys was 2.57 for facial growth and 2.6 years for statural growth. The mean difference in the chronologic age of the maximum pubertal growth between boys and girls was 2.31 years for body height and 2.12 years for facial growth. He stated that the majority of individuals tended to have their maximum facial growth spurt after that of body height rather than before. Also that the face continued to show a small increment of growth after statural growth is completed, more so in boys than in girls. These findings support those of Nanda²⁵.

Hunter¹⁷ in 1966 in a report based on 25 boys and 34 girls studied serially, mainly during the circumpuberal growth period, found that the maximum facial growth increment occurred at the same time as the maximum increment in stature in 59% of the cases, 15% occurred before and 29% after. These findings were in disagreement with the findings of Nanda²⁵ and Bambha¹.

Bjork and Helm⁵ in 1967, in a study based on Danish

children, of which 32 were boys and 20 were girls, focused on height growth during the puberty and found that the age of the peak growth in height for males was at 14 years and for the girls was at 12.5 years. They also established that around puberty growth of the face and jaws closely follows the same maturational scale as general skeletal growth represented by height.

Bergersen⁴ in 1973 studied the adolescent growth spurt of seven facial dimensions and standing height longitudinally on 23 males to ascertain the relationship of these spurts. He used a two-year period as a basis for the duration of the adolescent growth spurt. He found that the onset of the spurt for height ranged from 11.8 to 14.6 years with a mean of 12.98 years. For mandibular length the range was 10.98 to 15.40 with a mean of 13.15 years of age. He also found a significant correlation between the onset of the male adolescent spurt of all facial dimensions and standing height. And that 75% of the peaks (63% of standing height) occurred during the first year while 25%

occurred during the second year of the spurt.

Grave¹¹ in 1973, in a study of Australian aborigines, found no significant differences either in boys or girls between the ages at which peak growth in body height and peak growth in any of the facial dimensions occurred. The average age of the peak facial growth in boys ranged from 13.0 to 13.9 years and in girls from 11.7 to 12.7 years.

Bowden⁶ in a study of Australian caucasian children, 52 boys and 60 girls, found that the peak of the adolescent spurt in females showed a mean chronological age of 11.67 years and in boys 13.91 years. The earliest maturing female completed her adolescent spurt of statural growth at 11.45 years and the earliest maturing male was 13.45 years. The latest maturing female completed her adolescent spurt at 14.5 years and the latest maturing male at 17.6 years.

Harris¹⁵ in 1962 on a serial study of the mandibular growth on 22 boys and 18 girls between the age of 4 and 12 years of age found that the female incremental growth curve is very similar to the

male curve if it is placed one year out of phase. Females tend to be one year ahead of males in their mandibular growth increments before the adolescent growth spurt.

Savara and Tracy²⁹ in 1967 in a study based on 52 boys with an age range of 3 to 16 years found that for the maximum length of the mandible, the adolescent increase started at 12 years and reached a peak at 13.6 ± 1.83 years and declined thereafter.

According to the literature reviewed most of the investigators agree that growth in body height shows a distinct concordance with facial growth. Hunter¹⁷, Fukuhara and Matsumoto⁹, Bergersen⁴ and Grave¹¹, all agree that the peak growth in height occurs at the same time as the peak of facial growth. But Nanda²⁶ and Bambha¹ found that the peak growth of the body height usually occurs before the peak of facial growth. Also it is interesting to note that Hunter¹⁷, Johnston et al¹⁸, Krogman²⁰ and Singh, Savara and Miller³⁰ all agree that of all facial measurements in both males and females, the antero-posterior length of the mandible exhibits the most consistent relationship with growth in height throughout adolescence.

Hunter¹⁷ reports a correlation of .76 between gain in mandibular growth and body height in the pubertal period. Also Grave¹¹ in 1973 reported a similar correlation between the age of peak growth in body height and mandibular length; for males $r = .78$ and for girls $r = .79$.

It is the purpose of this study to determine in boys the relationship between the age at which the maximum increment of body height, weight and certain facial dimensions occurs during the adolescence spurt, and the relationship between the maximum increment of weight, height and the facial dimensions during this period. It is also intended to investigate the distribution of the increments of mandibular growth for two years before and two years after the peak of the adolescent spurt in order to determine the impact of treatment timing before or after the growth spurt.

MATERIALS AND METHODS

For the present study 54 caucasian boys were selected from the longitudinal growth study conducted by the University of Oregon Child Study Clinic. The subjects lived in or near Portland, Oregon, were American of Northwestern European ancestry, and of average of above socioeconomic status. Height, weight, and four facial dimensions were studied for each subject for the circumpuberal period, from age 10 to 16 years of age. The criteria for acceptance into this study was to have complete bi-annual records from age 10 to 13 years and annually thereafter until age 16. In some cases where the growth spurt was suspected to occur after this age, records for ages 17 and 18 were used when available. One individual of every set of twins was selected and subjects with gross physical abnormalities or with orthodontic treatment history during this period were excluded from this study.

Of the 54 individuals studied in this investigation, three were not used due to the fact that the growth peak was occurring

after age 16 without having any records available after this period.

Lateral headfilms were traced on .003" acetate paper to reveal the landmarks articulare, nasion, pogonion and sella (see figure 1). Pogonion was determined on the tracing corresponding to age 13 and then by superimposition of the mandible it was transferred to the rest of the tracings. For condyle the lateral headfilm with the mouth at maximum opening was used. Condyle was determined as the farthest point from pogonion. Due to the asymetry in some of the cephalograms, the right and left images of the condyle were not exactly superimposed. When this happened both images were traced and the midpoint between the two landmarks was taken as the measurement point.

The variables articulare-pogonion (Ar-Po), nasion-pogonion (N-Po), and sella-pogonion (S-Po), were measured from the tracings at bi-annual intervals from age 10 to 13 and annually thereafter until age 16. For condyle-pogonion (C-Po), the measurements were taken at annual intervals. All measurements were taken with a vernier caliper and read to the nearest .1 mm.

The measurements for height and weight were taken directly from the records of each individual.

A sub-sample was randomly chosen to evaluate the measurement error of the operator. Ten individuals' serial records were re-traced and re-measured three weeks after initial data collection.

The Standard Error of the Measure was calculated using the formula:

$$S.E.MEAS. = \sqrt{\frac{\sum (x_1 - x_2)^2}{2N}}$$

Analysis of Data

The collected data were punched onto computer cards and a program was developed to generate the following computations:

- 1) Dates of the records were converted to years and decimal years, and weight in pounds to Kilograms.
- 2) Since some records were not taken exactly every 6 or 12 months, the continuous data were interpolated to conform bi-annually intervals.
- 3) The increments were plotted against age for all the variables in four ways: a) with the increments unsmoothed, b) with the increments smoothed once, and c) with the increments smoothed

twice. Using the following formulas:

$$\text{left point } y_{-1} = 1/6 (5f_{-1} + 2f_0 - f_1)$$

$$\text{middle point } y_0 = 1/3 (f_{-1} + f_0 + f_1)$$

$$\text{right point } y_1 = 1/6 (-f_{-1} + 2f_0 + 5f_1)$$

Only the non-smoothed incremental graph was used to determine the age at which the maximum increment occurred; the smoothed graphs were used only for guidance, d) with increments

expressed as a relative rate or percentage of growth using

$$\text{Nanda's formula: } \frac{\frac{Y_2 - Y_1}{Y_1 - Y_2}}{2} \times 100$$

where Y_1 and Y_2 are values at the beginning and the end of

the period, respectively. The percentage rates of growth

obtained were smoothed twice to show the basic trend, which

was obscured by excessive fluctuations.

- 4) Articulare-pogonion was used to observe and study the growth trend of the mandible. For this purpose the maximum 6 month circumpuberal gain and the annual increment for the year prior to the peak 6 month period and for the year prior to that were calculated, as well as the annual increment for the first and

and second years after the peak 6 month period. Histograms were constructed for each of these periods.

Statistical Analysis

The following statistical analyses were applied in this study:

- 1) Mean, Standard Deviation and Standard Error of the Mean were calculated for the age at which the maximum increment occurred and for the magnitude of the maximum 6 month increment of each variable.
- 2) The ages at which the maximum increment for each variable occurred were correlated as were the magnitude of the maximum 6 month increment for the various variables.
- 3) Histograms were constructed for the age at which the maximum increment occurred for each of the variables and for the magnitude of the maximum 6 month increments.
- 4) Correlation coefficient was calculated between the measurement of articulare-pogonion 2 years prior to the peak and the total increment of that variable thru the $4\frac{1}{2}$ years.

FINDINGS

The results of the data analysis are contained in Tables I thru XII, histograms appear in figures 2-17, and scattergrams appear in figures 18 and 19.

The standard error of the measure calculated for the four facial variables are contained in Table I. Sella-pogonion shows the lowest standard error of the measure, .194. Of the two mandibular measurements, articulare-pogonion and condyle-pogonion, the latter shows a relatively high standard error of the measure, .877, which is probably due to the difficulty of accurately tracing the head of the condyle in some of the roentgenograms. For this reason articulare-pogonion showing a standard error of the measure of .357 was chosen as representative of mandibular length. One of the problems in using articulare-pogonion is that it is not the true length of the mandible since articulare is the point where the ramus of the mandible intersects the temporal bone and if the radiograph is taken when the patient is not in centric relation

the measurement error would be increased.

Mean, range, standard deviation and standard error of the mean for the age at the midpoint of the six month period during which the maximum increments of each variable occurred are contained in Table II. All the mean peak ages for three of the facial variables and height are very similar, being approximately 13.5 years except for condyle-pogonion and weight which are 13.7 years. Also condyle-pogonion shows the higher standard deviation (1.3) in relation to the rest of the variables. The age range is also very much the same for all of the variables.

Figures 2 thru 7 contain histograms of the ages at the midpoint of the six month period at which the maximum increment for all the six variables occurred. For most of the variables 40% of the peaks occur between 13 and 14 years of age, with a wide range from 10.5 to 16 years.

Table III contains the breakdown of the timing of the maximum increments of the facial dimensions relative to that of height. The majority of the maximum increments of S-Po and Ar-Po occur at the

same time or after that for height. While N-Po has the majority of the peaks at the same time or before that of height. However, of the four facial dimensions, C-Po shows the greatest difference: over 50% of the cases have the maximum increment after that of height.

Descriptive statistics of the age at which the maximum increment of percentage rate of growth occurs using Nanda's²⁷ formula are contained in Table IV. The mean peak age for height was 13.41 years and for all of the facial variables after 13.49 years. Table V contains the breakdown of the relative timing of the maximum percentage growth rate of the facial dimensions relative to that of height. For all of the facial dimensions the maximum percentage growth rate occurs at the same time or after that for height. Figure 8 shows a scattergram of the distribution of the peak ages of percentage growth rate for the facial measurements in relation to the peak age of height.

Table VI contains the correlation coefficients of the age of the peak growth velocity between height and weight and the facial

measurements. Those between height and the facial variables are high, around $r = .80$, and are all significant at the 0.1% level. While weight has lower correlations with height and the facial variables. Table VII contains the correlation coefficients of the age of maximum percentage growth rate, between height and weight and the facial variables. All are similar to the correlations obtained when using unsmoothed increments (Table VI).

Descriptive statistics of the magnitude of the maximum increments during adolescence for all of the variables are contained in Table VIII. The mean maximum six month increment for the facial variables ranges from 2.41 to 2.72 mm, with C-Po having a slightly larger standard deviation. Figures 9 thru 14 contain histograms of the maximum six month increments for the different variables studied. These resemble a normal curve of distribution, where for the facial variables 60% or more of the individuals have an increment between 1.5 and 3 mm and a range from 1 to 5 mm.

Table IX contains the correlation coefficients of the maximum increments for the six month period. The correlations that were statistically significant were low, the highest being that of condyle-pogonion with height and weight ($r = .38$ and $r = .36$ respectively).

More detailed analysis of articulare-pogonion appears in Table X. The descriptive statistics for the maximum six month increment of articulare-pogonion and the annual increments for the year after and the second year after, and for the year prior and the second year prior to the peak 6 month period reveal that the difference between the mean annual increments for the two years prior, the two years after the peak are small, being only of the order of tenths of a millimeter. Table XI contains the length of the mandible (Ar-Po) 2 years prior to the peak 6 month period and the total increment over $4\frac{1}{2}$ years during adolescence. A correlation between these values was very low and non-significant ($r = .06$). A scattergram was constructed for these two variables (Figure 19) to examine whether a non-linear relationship existed.

The degree of scatter demonstrated no relationship.

Of the 51 cases, those showing a peak increment in Ar-Po between 13 and 14 years ($n = 25$) were excluded. The remaining cases were divided into two groups:

early spurts (10.5 to 13 years, $n = 12$)

Late spurts (14 to 17 years, $n = 14$)

The mean maximum increments were calculated for these two groups and are contained in Table XII. An unpaired "t" test revealed the difference between the two groups to be not statistically significant.

DISCUSSION

All of the 54 cases studied longitudinally showed a definite adolescence growth spurt for all the variables studied except for the three individuals in whom a definite peak could not be determined because it was possibly occurring after the age of 16 years and later records were not available. Even though circumpuberal growth spurts were present in the remaining 51 cases they varied in intensity from one individual to another, some presenting a very small peak but in most cases the peak growth was well marked. Some individuals however presented more than one peak during the adolescent period which made it difficult to determine which peak was representative of the adolescent growth spurt. Although the unsmoothed incremental graphs were used to determine the timing of the maximum growth increment, in the difficult cases with more than one peak the smoothed incremental graphs were used for guidance to determine the true peak of growth. The unsmoothed plots were used because while smoothing tends to eliminate

methodological errors it also obscures real changes in velocity and diminishes the true magnitudes of the growth rates.

Although the mean chronological ages at which the maximum growth increments in height and the facial dimensions occurred during adolescence are very similar, there was wide variation with a range from 10.75 to 16.75 years. The breakdown of the timing of maximum increments of the facial dimensions relative to that of height, shows that the majority of the peaks of S-Po and Ar-Po occur at the same time as that for height. This is in agreement with the findings of Hunter¹⁷, Fukuhara and Matsumoto⁹, Bergersen⁴, and Grave¹¹, who all agree that the peak growth in height occurs at the same time as the peak of facial growth. The histograms demonstrate that 40% of the peaks for all the variables occur between 13 and 14 years of age and 80% between 12 and 15 years for height and 12.5 to 14.5 for the facial variables (Figures 2-7).

The relationship between the age of maximum increments of height and Ar-Po was examined and a high correlation ($r = .79$) was found (Table VI). This is in agreement with the findings of

Grave¹¹ in his study in Australian aborigines. Similar high correlations were found between the age of maximum growth in height and the other facial dimensions. This relatively close relationship is not surprising since the physiologic events controlling adolescent development are probably the same for bone growth in general with minor variations within each individual. The relationship between weight and the other skeletal variables was not quite as strong which is not unexpected because weight was the only variable that underwent negative change at times.

Using Nanda's²⁷ percentage rate of growth during adolescence, the mean age at which the maximum percentage rate growth for all the facial variables and for height and weight occur almost at the same time with a difference of less than 6 months (Table IV). Table V shows the breakdown of the timing of the maximum percentage growth rate of the facial dimensions relative to that of height. For all the facial dimensions a higher percentage of the peaks occur after those for height,

except for Ar-Po where 52% of the peaks occur at the same time and 28% after the peak for height. This supports in part the findings of Nanda²⁷ and Bambha¹ where they state that in most individuals the facial growth peak occurs after the peak in height, rather than before.

Descriptive statistics of the magnitude of the maximum increments at the peak 6-month period for the mandibular length (Ar-Po) (Table VIII) shows a mean of 2.41 mm with a range from 1.64 mm to 4.19 mm. This finding is very similar to that found by Savara and Tracy²⁹, although they use C-Po as representative of the mandibular length. Height shows a mean increment of 31.24 mm with a range of 38.25 to 65.03 mm.

The correlation between the maximum increment in height and Ar-Po while statistically significant was very low ($r = .31$), indicating that individuals who have a lot of statural growth during adolescence do not necessarily have large mandibular increments, and vice versa. Low correlations were similarly found for the other facial variables and height. These findings are

very similar to those found by Thompson and Popovich in their study in females reporting also a very low correlation between the maximum increment in height and mandibular length ($r = .21$) significant at the .005 level. But Hunter¹⁶ found a relatively high correlation between the gain in length of the mandible and body height in the pubertal growth period in both males and females ($r = .79$).

Growth of the mandible, using Ar-Po as representative of mandibular length, was studied in more detail. The difference between the mean annual increments for the two years prior and the two years after the peak are small being only of tenths of millimeter (Table X). Clinically, this is extremely meaningful to the orthodontist. Orthodontic treatment, if it is dependent on facial growth would be greatly benefited if it could be properly timed to coincide with the years of most intense growth during adolescence.

Mandibular length two years prior to the peak adolescent spurt was correlated with the total circumpuberal increment

over the $4\frac{1}{2}$ years. This correlation was found to be non-significant which indicates that adolescent mandibular growth is not dependent on the size of the mandible prior to the spurt. This is confirmed by the clinical observation that small mandibles do not exhibit catch-up growth relative to the rest of facial growth. Whether this is true for developing skeletal Class III malocclusions is uncertain since very few of these were present in this sample.

In order to assess whether the so-called "early" maturers exhibited less mandibular growth than the "late" maturers, the maximum increment in Ar-Po was compared between these two groups and found not to be significantly different (Table XII).

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine in boys the relationship of the age and magnitude of the maximum increment during the circumpuberal growth period between body height, weight and certain facial dimensions and to investigate the distribution of the increments of mandibular growth for two years before and two years after the peak of the adolescent spurt in order to determine the impact of treatment timing before or after this growth spurt.

The data was obtained from longitudinal records of 54 boys enrolled in the Child Study Clinic of the University of Oregon Dental School. The records used were from age 10 to 16 years of age and included lateral cephalograms and recording of height and weight. The cephalograms were traced in acetate paper and measured to the nearest tenth of a millimeter. The raw data was converted by computer to bi-annual growth increments which were plotted for each variable and smoothed once and twice. The percentage increment

growth rates were calculated, smoothed twice and plotted for each variable.

Analysis of the data was by visual inspection of the incremental graphs and the following statistical analyses were carried out: means, standard deviation, standard error of the mean, correlation coefficients and "t" test.

From the findings of this investigation the following conclusions can be drawn:

1. A definite adolescent growth spurt for all the variables was found for all the 54 cases except for three individuals in whom a definite peak could not be determined because it was possibly occurring after the age of 16 years and later records were not available.
2. There was wide variation in the chronological ages at which the maximum increments of each variable occurred during the adolescent growth spurt.
3. In over sixty per cent of cases, the maximum increment in the facial dimensions occurred at the same time or after that of height.

4. The age of peak growth velocity of height, weight and the facial dimensions were highly correlated.
5. There was wide variation in the magnitude of the maximum increments of each variable during adolescence.
6. The relation between magnitudes of the maximum adolescent increments of height, weight and facial dimensions was found to be very low.
7. The differences between the mean annual increments for the two years before and after the peak growth of the mandible were small, being only of tenths of millimeter.
8. The circumpuberal growth of the mandible showed a non-significant correlation with its size at the beginning of the circumpuberal spurt.
9. "Early" and "late" maturers were not found to be significantly different as to the magnitude of the maximum increment in the mandibular length (Ar-Po).

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TABLE I

STANDARD ERROR OF THE MEASURE*

(Re-traced and remeasure 20%
of the sample)

N-Po	S-Po	C-Po	Ar-Po
.261	.194	.877	.357

$$*S. E. Meas. = \sqrt{\frac{\sum (X_1 - X_2)^2}{2N}}$$

TABLE II

MIDPOINT OF CHRONOLOGIC INTERVAL AT WHICH
MAXIMUM GROWTH RATE (UNSMOOTHED) OCCURS

	Height	Weight	N-Po	S-Po	C-Po	Ar-Po
Mean	13.54	13.72	13.46	13.58	13.75	13.58
Age Range	10.75- 16.75	11.75- 16.75	10.75- 16.75	11.25- 16.75	10.75- 16.75	10.75- 16.75
S.D.	1.12	1.15	1.18	1.20	1.30	1.14
S.E.M.	.15	.16	.16	.16	.18	.15

TABLE III

THE TIMING OF THE MAXIMUM INCREMENTS (UNSMOOTHED)
OF THE FACIAL DIMENSIONS RELATIVE TO THAT OF HEIGHT

	<u>Number</u>		<u>Percentage</u>
N-Po vs. Height	19	before	37.26%
	18	same	35.29%
	14	after	27.45%
S-Po vs. Height	13	before	25.49%
	21	same	41.18%
	17	after	37.33%
C-Po vs. Height	14	before	27.45%
	10	same	19.61%
	27	after	52.94%
Ar-Po vs. Height	14	before	27.45%
	20	same	39.22%
	17	after	33.33%

TABLE IV

MIDPOINT OF CHRONOLOGIC INTERVAL AT WHICH
THE MAXIMUM PERCENTAGE GROWTH RATE OCCURS

	Height	Weight	N-Po	S-Po	C-Po	Ar-Po
Mean	13.41	13.55	13.49	13.60	13.91	13.53
Range	10.75- 15.75	10.75- 15.75	10.25- 17.25	10.25- 17.25	10.25- 17.25	10.25- 17.25
S.D.	1.09	1.10	1.37	1.29	1.45	1.30
S.E.M.	.15	.15	.19	.18	.20	.18

TABLE V

THE TIMING OF THE MAXIMUM PERCENTAGE GROWTH RATE
OF THE FACIAL DIMENSIONS RELATIVE TO THAT OF HEIGHT

	<u>Number</u>		<u>Percentage</u>
N-Po vs. Height	11	before	22%
	13	same	26%
	26	after	52%
S-Po vs. Height	10	before	20%
	16	same	32%
	24	after	48%
C-Po vs. Height	14	before	28%
	11	same	22%
	20	after	58%
Ar-Po vs. Height	10	before	20%
	26	same	52%
	14	after	28%

TABLE VI

CORRELATION COEFFICIENTS OF THE AGES AT THE MAXIMUM VELOCITY

	Weight	N-Po	S-Po	C-Po	Ar-Po
Height	.67	.80	.84	.80	.79
Weight		.64	.65	.69	.66

All significant at 0.1% level

TABLE VII

CORRELATION COEFFICIENTS OF THE AGES AT
THE MAXIMUM PERCENTAGE GROWTH RATE

	Weight	N-Po	S-Po	C-Po	Ar-Po
Height	.65	.80	.86	.80	.86
Weight		.63	.63	.59	.63

All significant at 0.1% level

TABLE VIII

MAGNITUDE OF MAXIMUM INCREMENTS DURING ADOLESCENCE

(six month period)

	Height mm	Weight Kgs	N-Po mm	S-Po mm	C-Po mm	Ar-Po mm
Mean	51.24	5.40	2.46	2.65	2.72	2.41
Range	38.25- 65.03	2.66- 16.66	1.34- 4.91	1.70- 6.45	1.48- 5.30	1.64- 4.19
S.D.	7.21	2.12	0.79	0.77	0.81	0.61
S.E.M.	1.01	0.25	0.11	0.10	0.11	0.08

TABLE IX

CORRELATION COEFFICIENTS OF THE MAXIMUM SIX
MONTH INCREMENTS DURING ADOLESCENCE

	Weight	N-Po	S-Po	C-Po	Ar-Po
Height	.33**	.19 ^{ns}	.34**	.38**	.31**
Weight		.25*	.02 ^{ns}	.36**	-.03 ^{ns}

* Significant at 5% level

** Significant at 1% level

ns Not significant

n = 51

TABLE X

INCREMENTS OF ARTICULARE-POGONION FOR THE PEAK SIX
MONTH PERIOD AND FOR TWO YEARS BEFORE AND AFTER THE PEAK

	-2 years	-1 year	Max. Incre.	+1 year	+2 years
Mean	2.36	2.91	2.41	2.71	2.41
Range	0.71- 5.45	1.15- 4.60	1.64- 4.19	0.72- 3.96	0.97- 4.64
S.D.	1.00	0.81	0.61	0.80	0.82
S.E.M.	.140	.114	.085	.116	.130
n	51	51	51	49	40

TABLE XI

MAGNITUDE OF ARTICULARE-POGONION TWO YEARS PRIOR TO THE ADOLESCENT
RT AND THE TOTAL INCREASE FOR FOUR AND ONE HALF YEARS OVER THE ADOLESCENT PERIOD

	Ar-Po length at peak -2 years	Increase after 4½ years
Mean	100.18	12.85
Range	90.01-112.2	8.72-16.73
S.D.	4.11	1.75
S.E.M.	.576	.278

TABLE XII

COMPARISON OF THE MEAN INCREMENT OF ARTICULARE-POGONION IN
INDIVIDUALS WITH AN EARLY SPURT AND A LATE SPURT

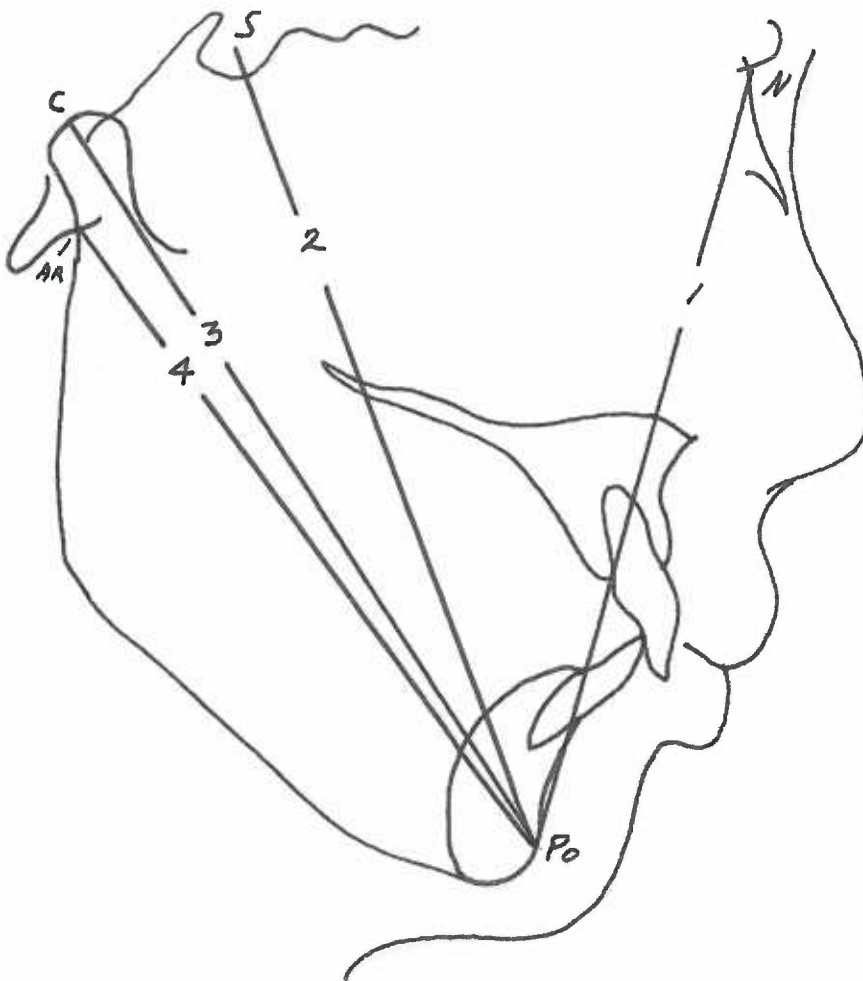
	Before the peak (12)	After the peak (14)
Mean	2.54	2.33
S.D.	0.82	0.42

"t" test = .63^{*} at 24 degrees of freedom

*Not significant

FIGURE I

Cephalometric Landmarks and Dimensions



LANDMARKS

N - Nasion
S - Sella
C - Condyle
Ar - Articulare
Po - Pogonion

DIMENSIONS

1. N-Po (Nasion-Pogonion)
2. S-Po (Sella-Pogonion)
3. C-Po (Condyle-Pogonion)
4. Ar-Po (Articulare-Pogonion)

FIGURE 2

Frequency distribution of the age at the midpoint
of the 6-month period of maximum growth rate in height

$n = 51$

$\bar{X} = 13.54$

$SD = 1.12$

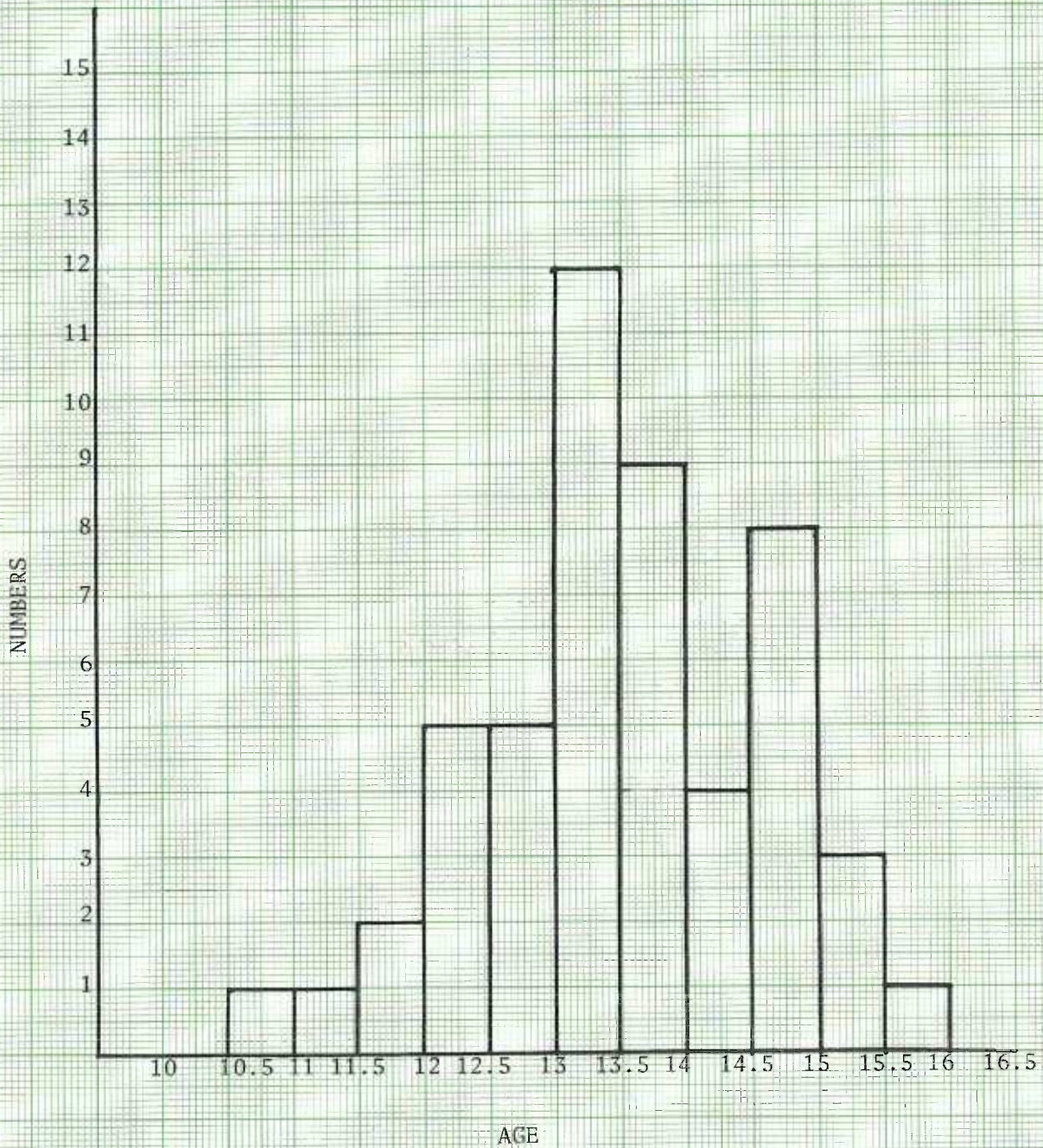


FIGURE 3

Frequency distribution of ages at the midpoint
of the 6-month period of maximum rate growth in weight

$n = 51$

$\bar{X} = 13.72$

$SD = 1.15$

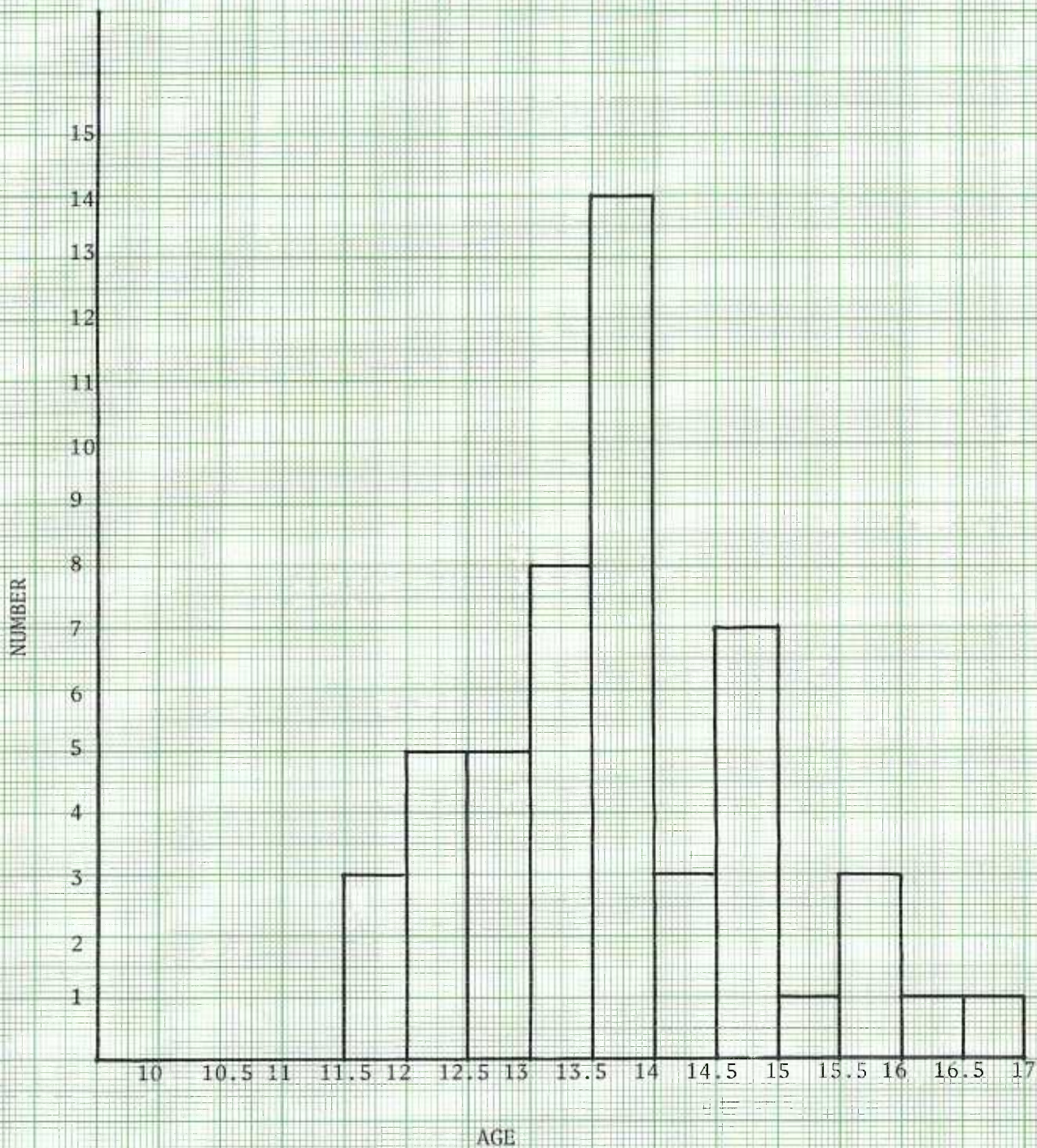


FIGURE 4

Frequency distribution of ages at the midpoint of the
6-month period of maximum rate growth in N-Po

$n = 51$

$\bar{X} = 13.46$

$SD = 1.18$

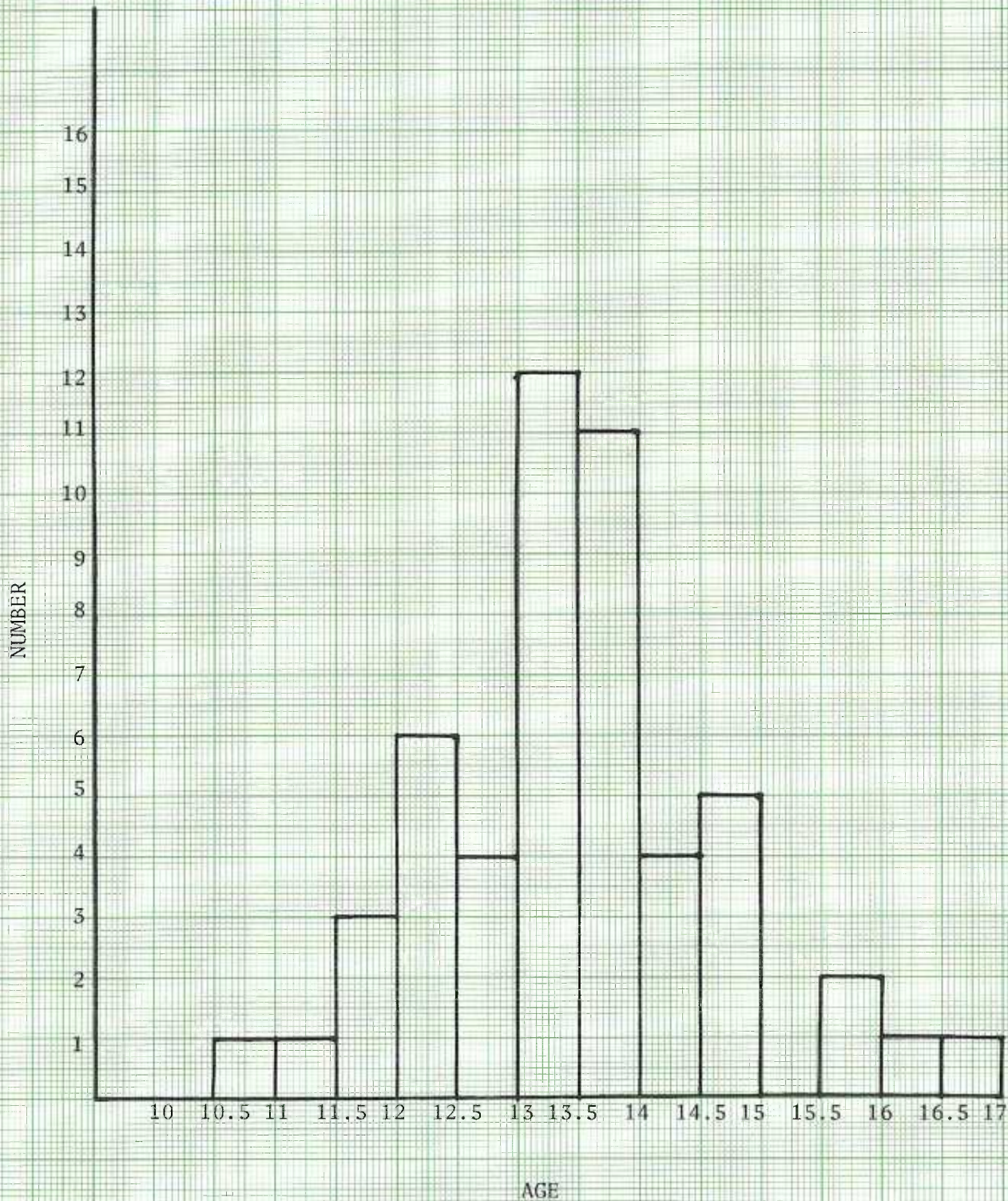


FIGURE 5

Frequency distribution of ages at the midpoint of the
6-month period of maximum rate growth in S-Po

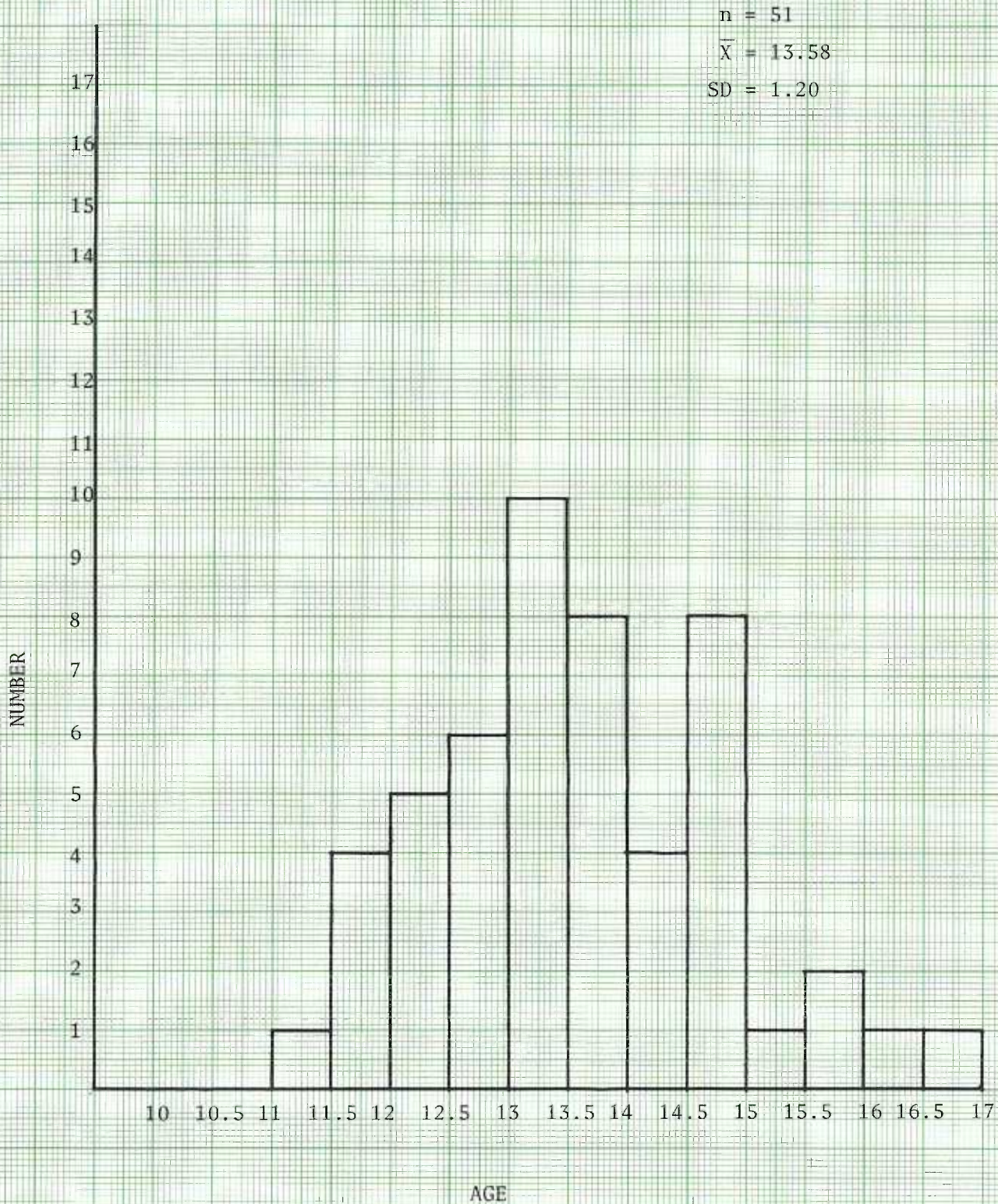


FIGURE 6

Frequency distribution of ages at which the
6-month period of maximum rate growth in C-Po

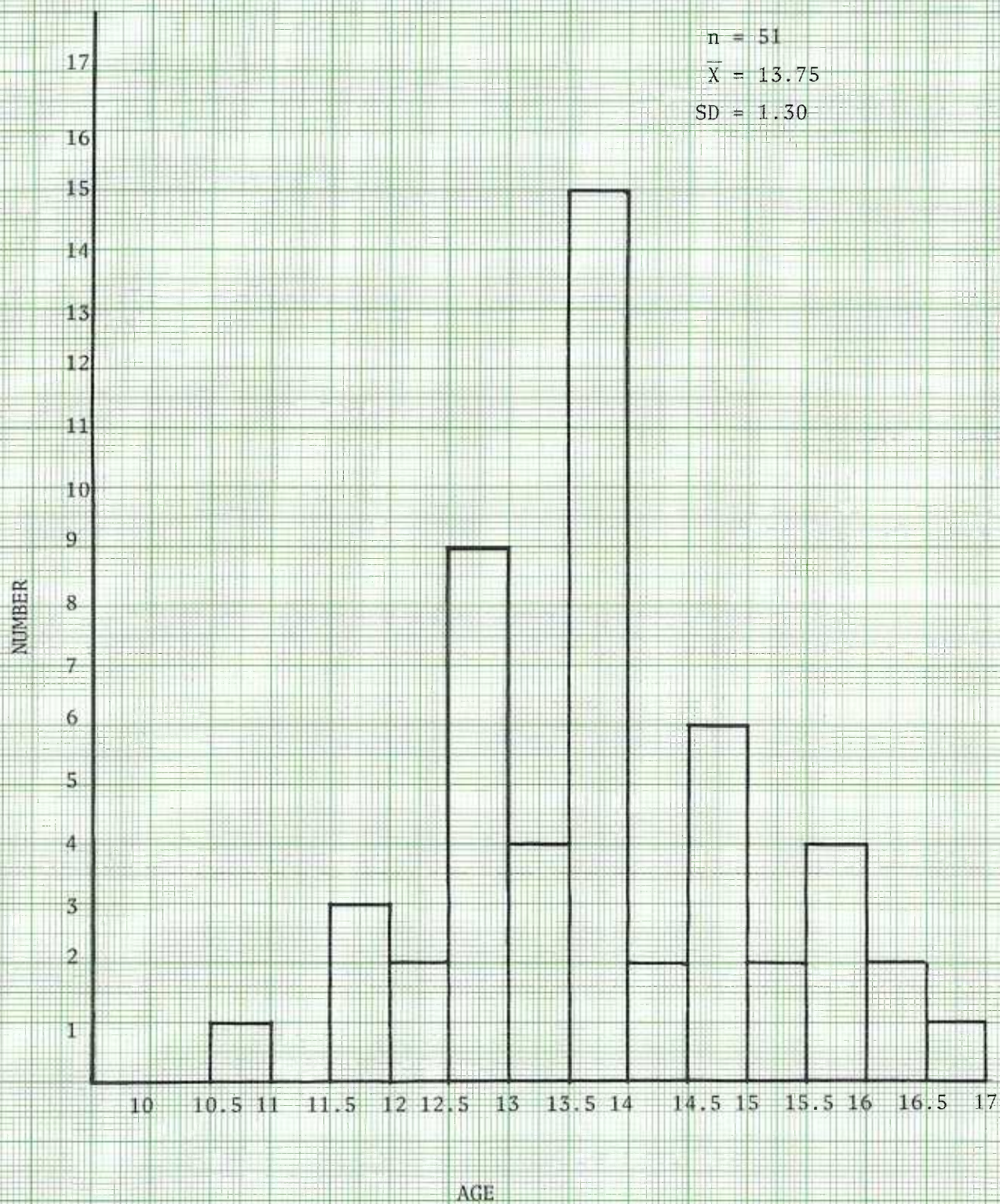


FIGURE 7

Frequency distribution of ages at the midpoint of the
6-month period of maximum rate growth in Ar-Po

$$n = 51$$

$$\bar{X} = 13.58$$

$$SD = 1.14$$

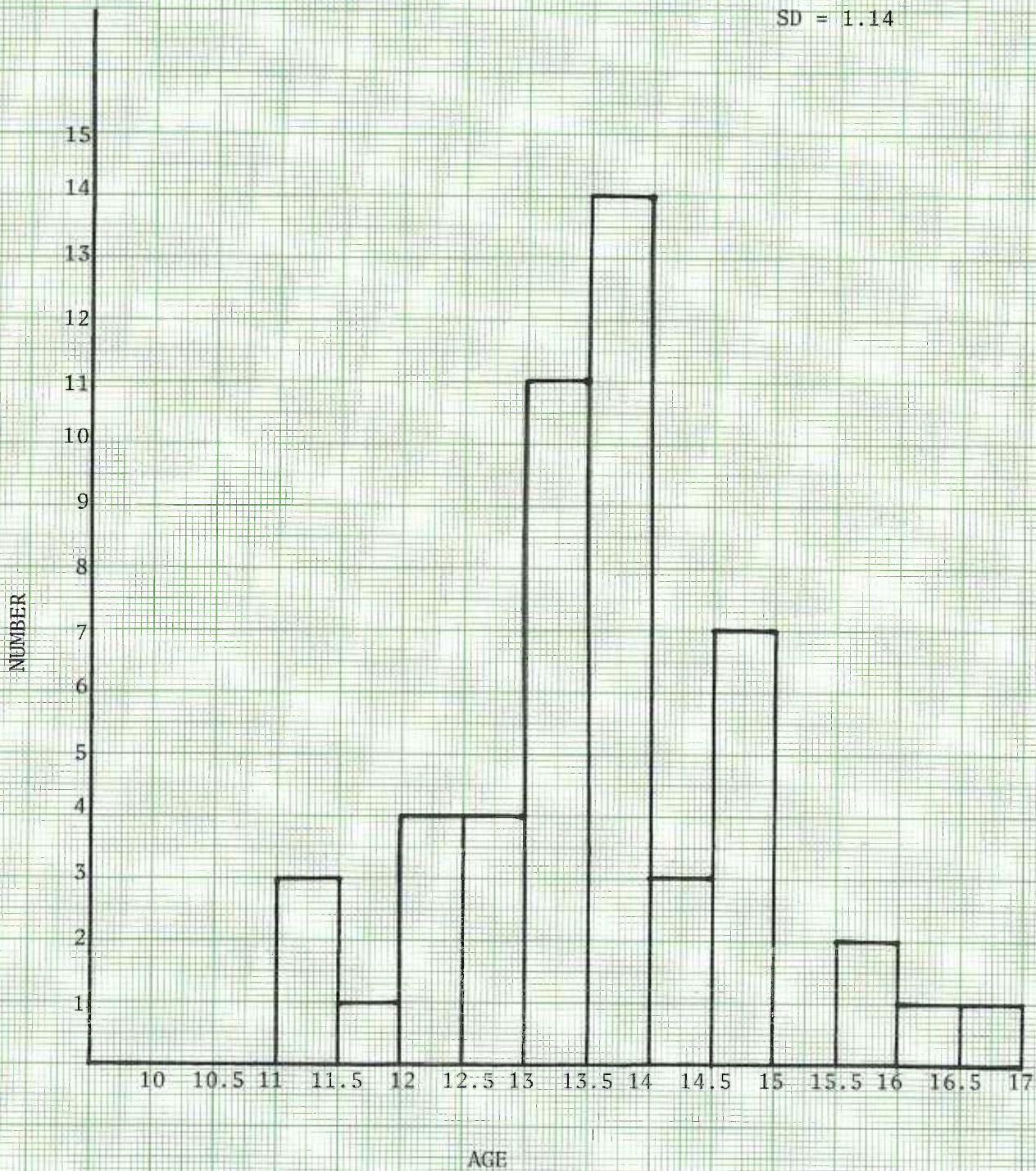
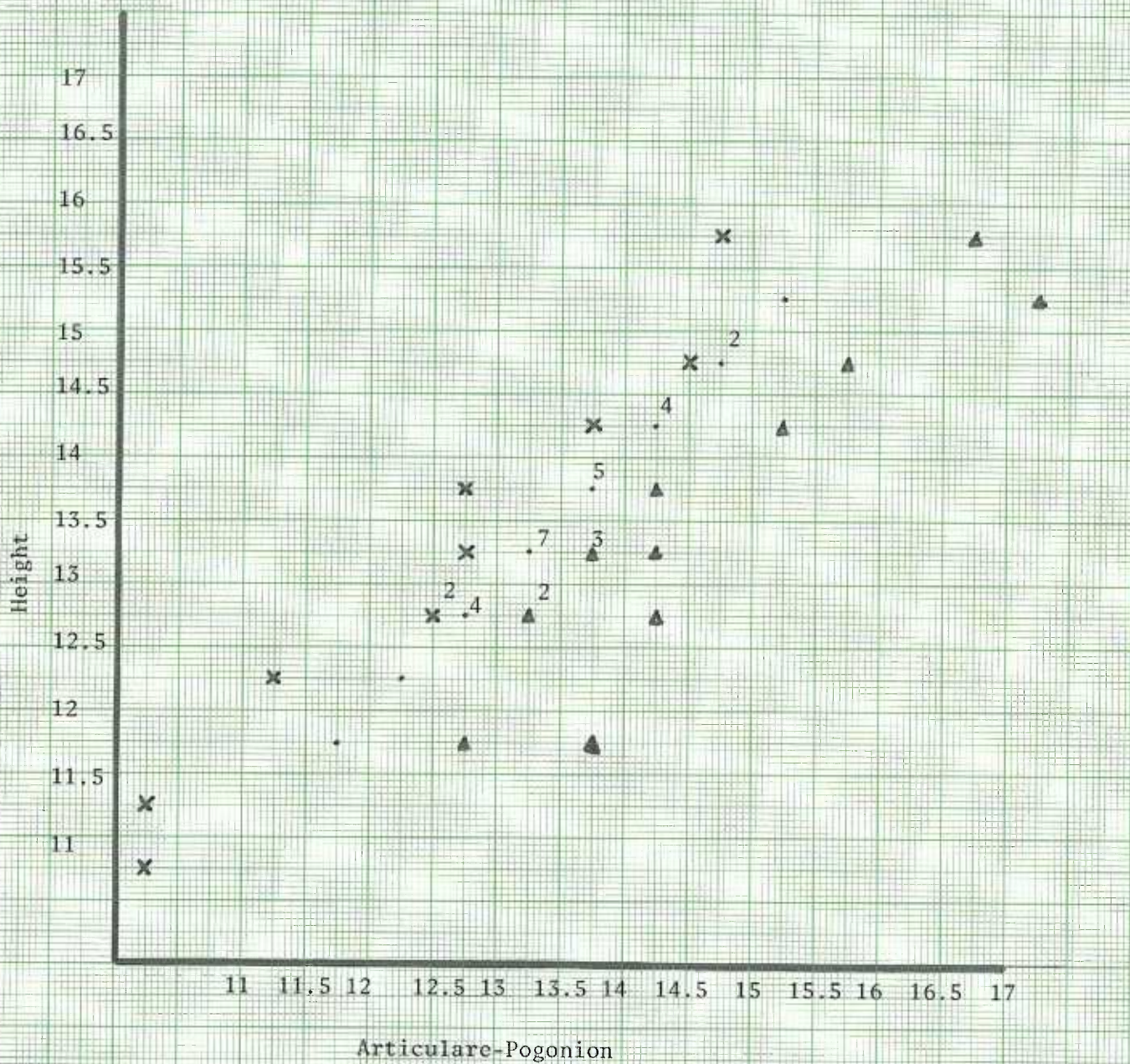


FIGURE 8

Relation of mandibular peak age with
height age using relative percentage



Height peak occurring
After mandibular peak x
Before mandibular peak ▲
Same as mandibular peak •

FIGURE 9

Frequency distribution of increments in
height at the peak 6-month period

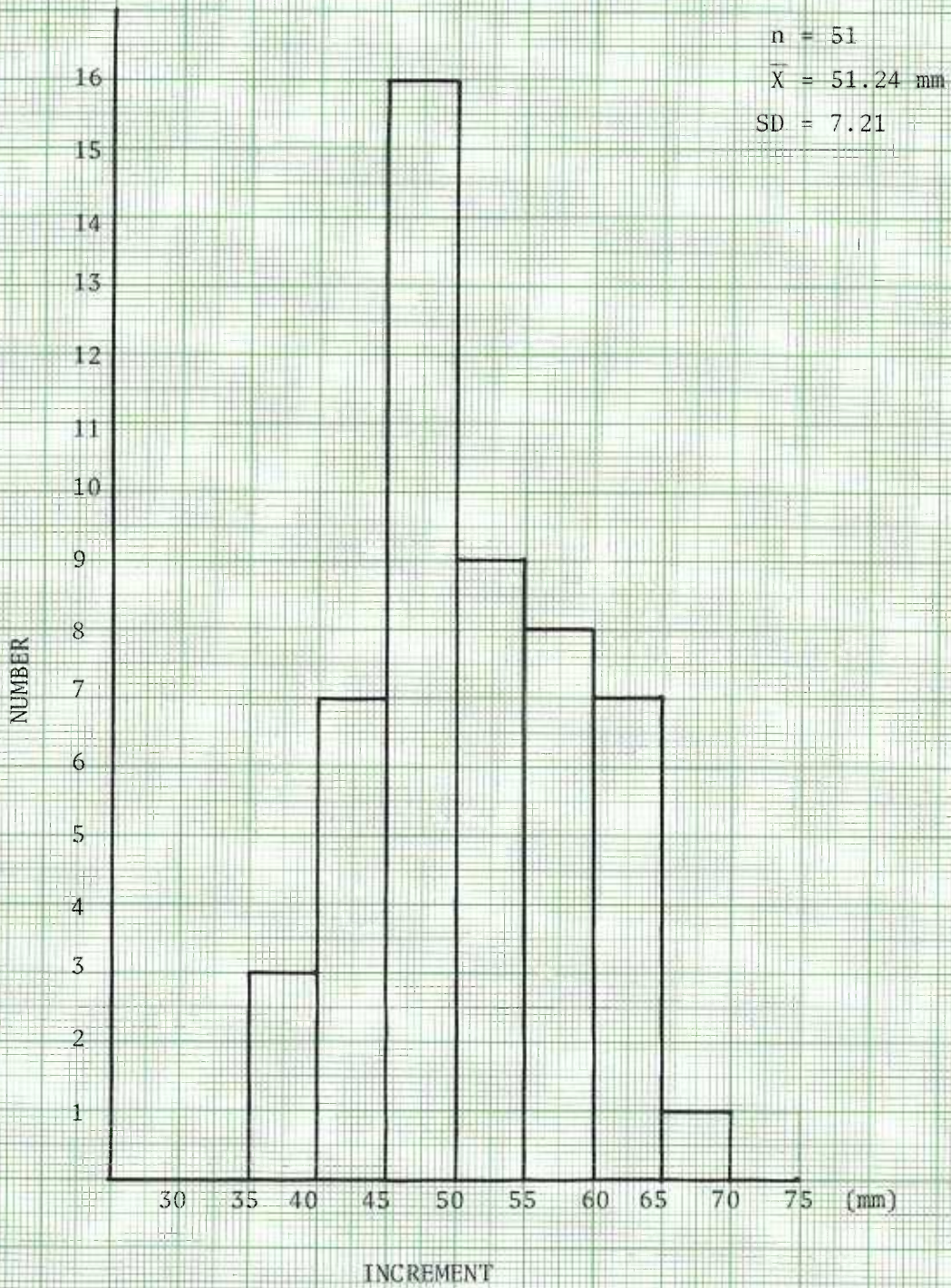


FIGURE 10

Frequency distribution of increments in
weight at the peak 6-month period

$n = 51$

$\bar{X} = 5.40 \text{ Kgr}$

$SD = 2.12$

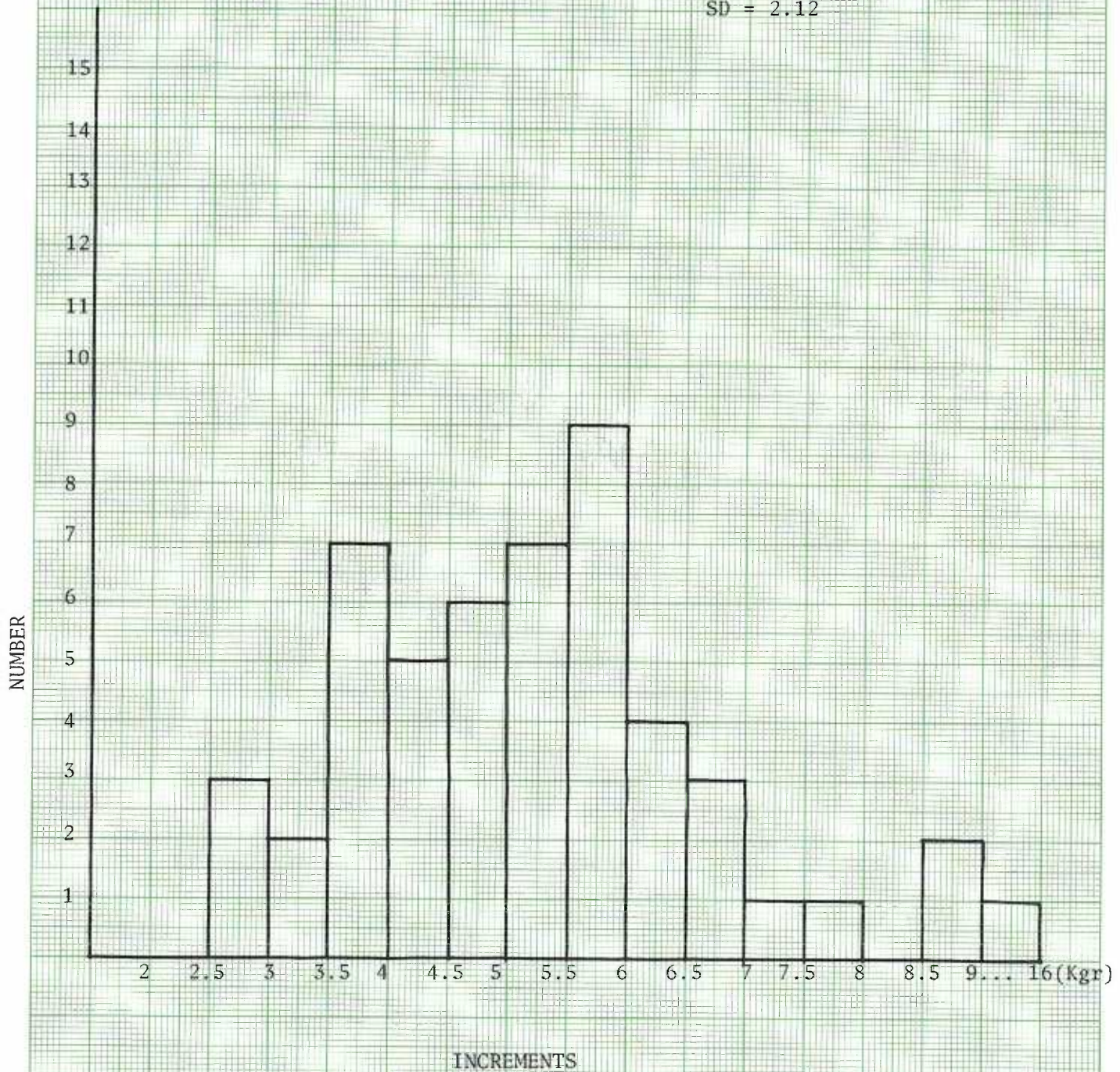


FIGURE 11

Frequency distribution of increments in
N-Po at the peak 6-month period

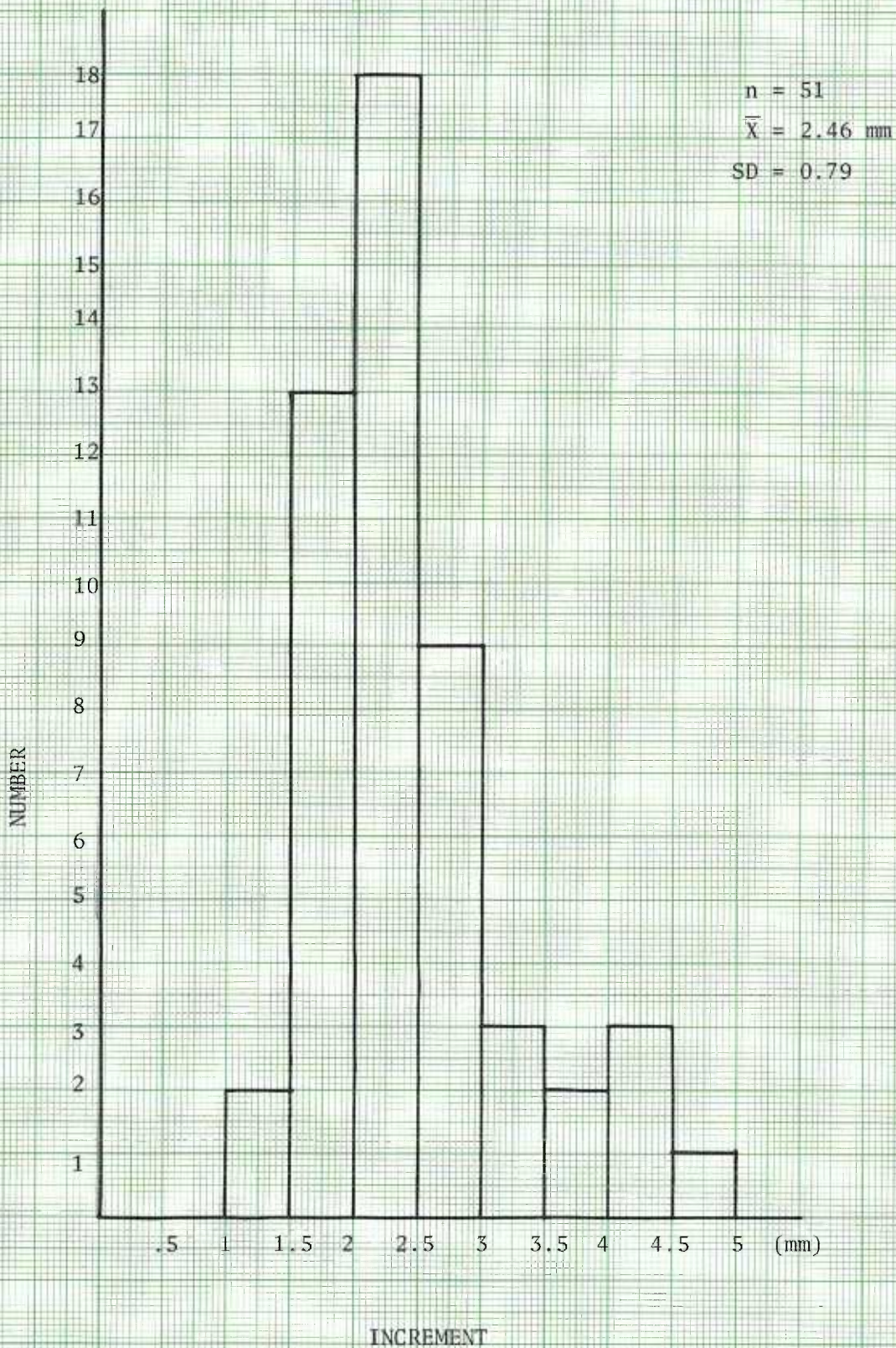


FIGURE 12

Frequency distribution of increments in
S-Po at the peak 6-month period

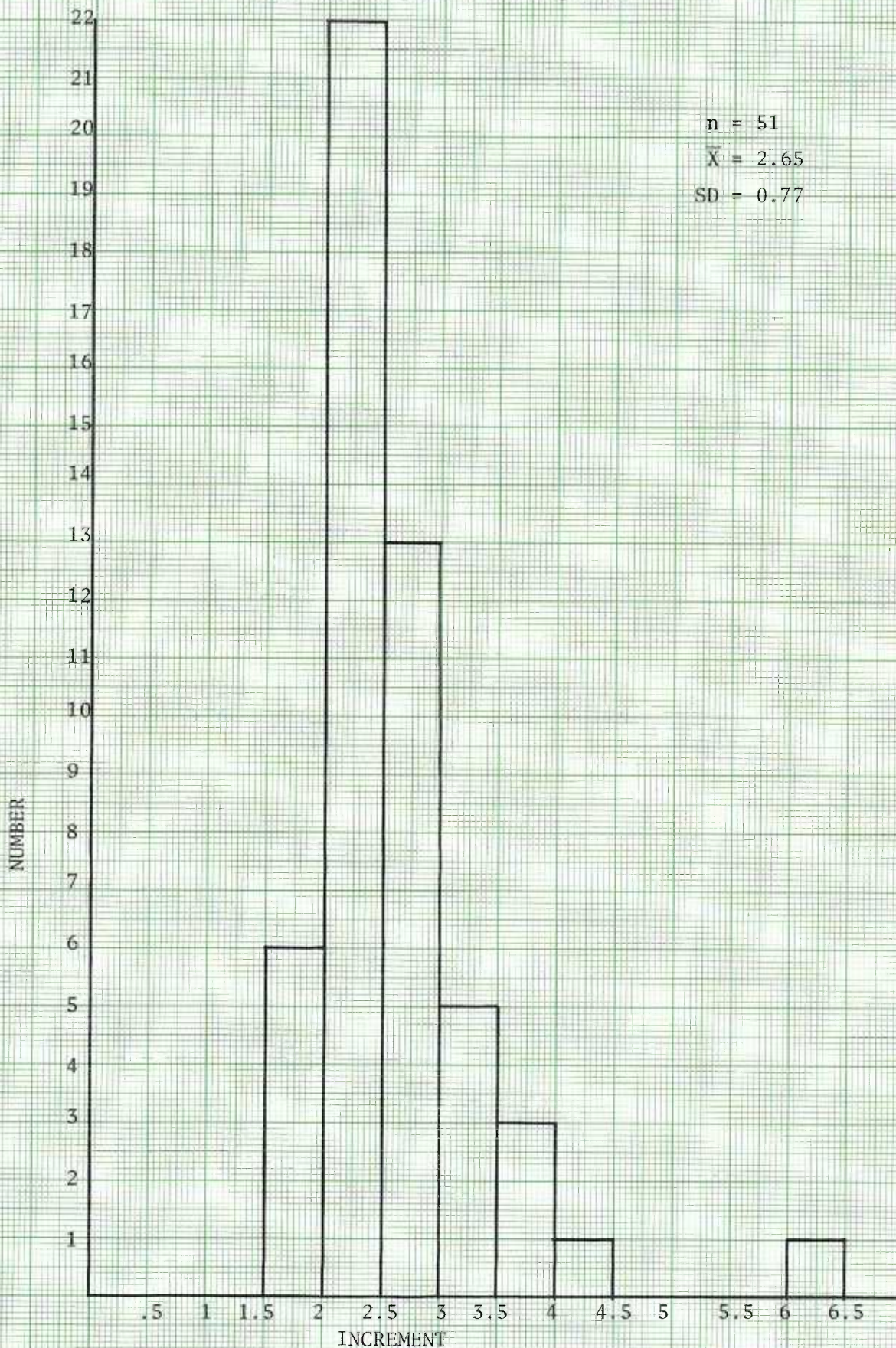


FIGURE 13

Frequency of distribution of increments in
C-Po at the peak 6-month period

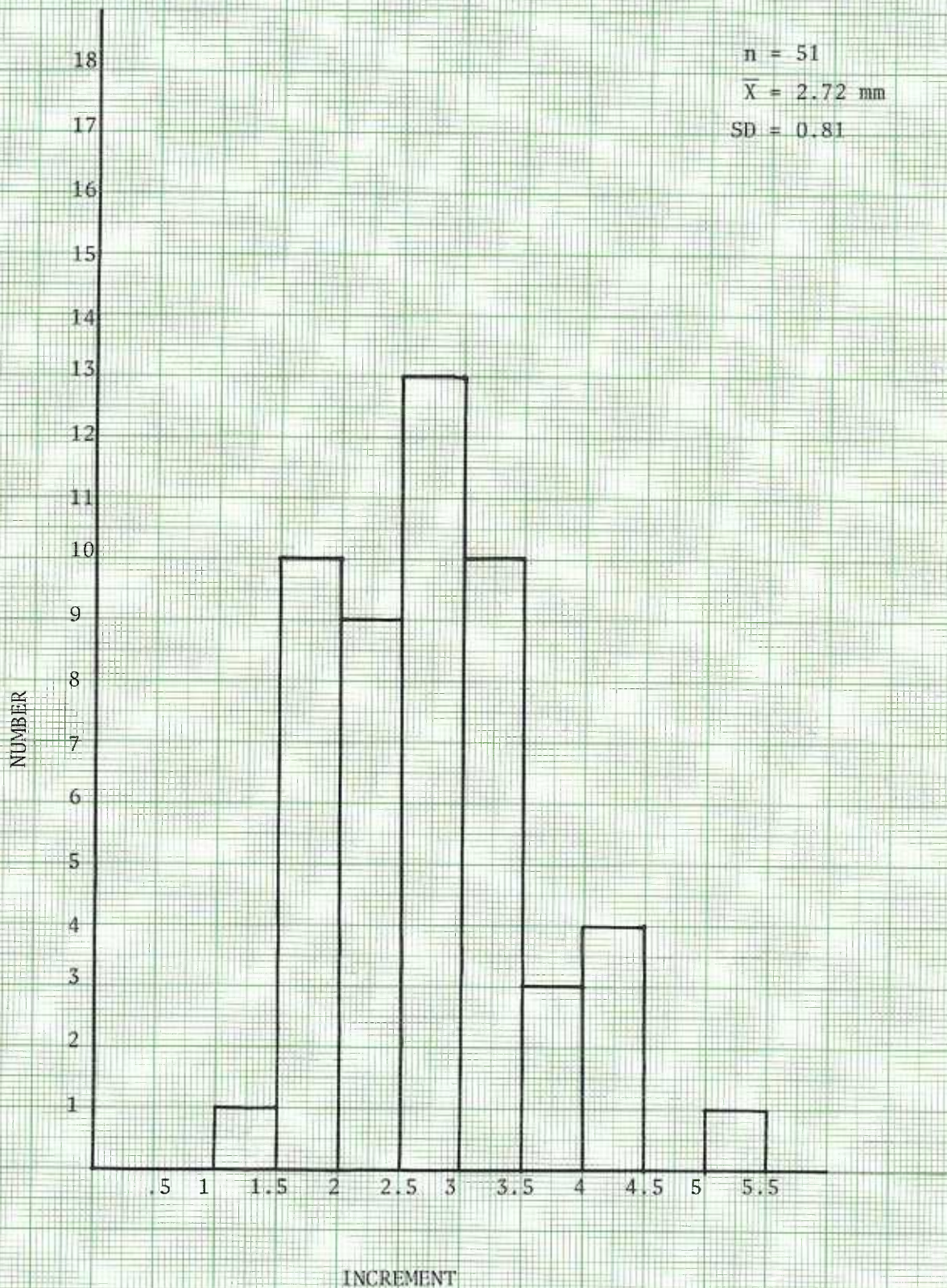


FIGURE 14

Frequency distribution of increments of
Ar-Po for the peak 6-month period

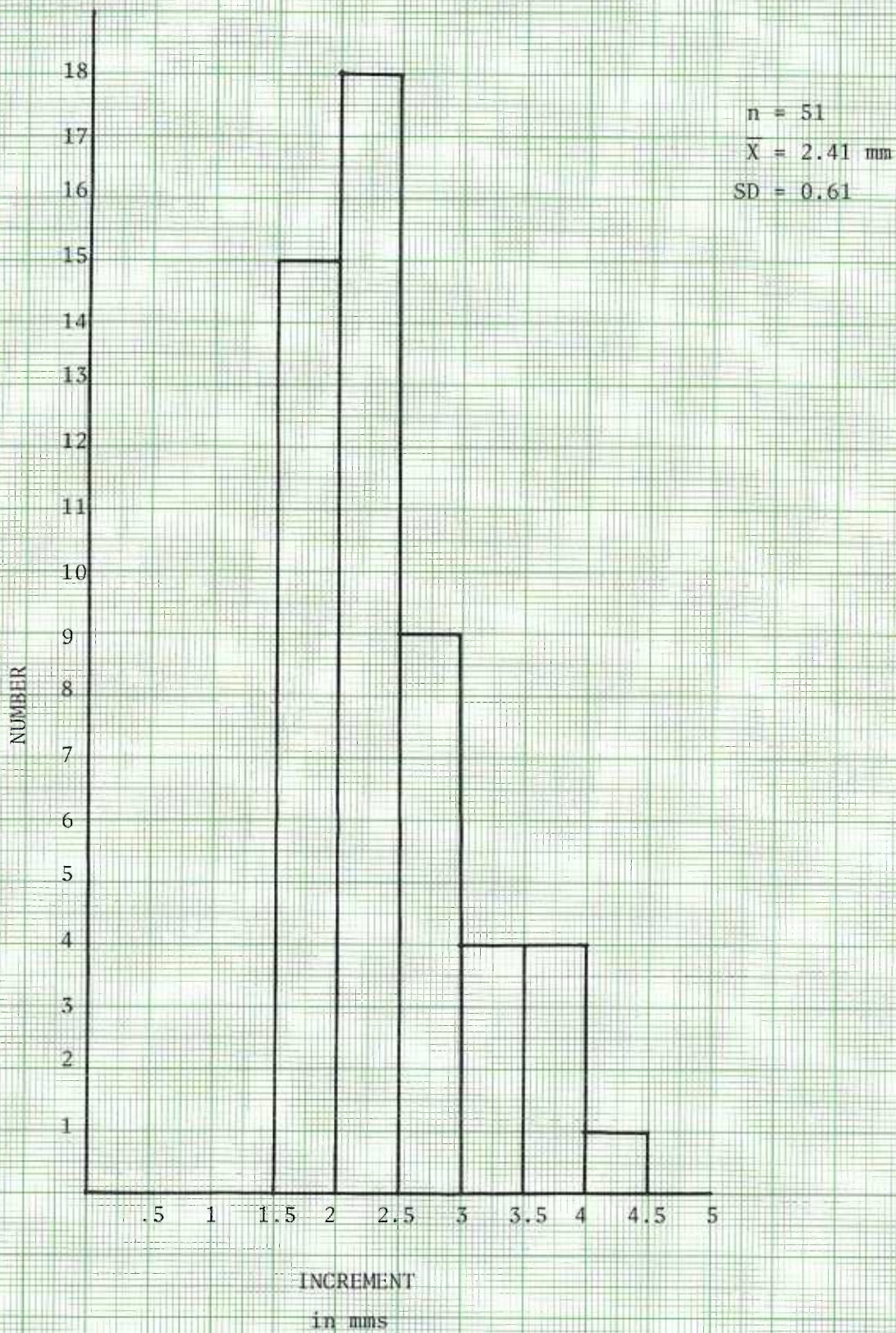


FIGURE 15

Frequency distribution of increments in Ar-Po
for the second year prior to the peak 6-month period

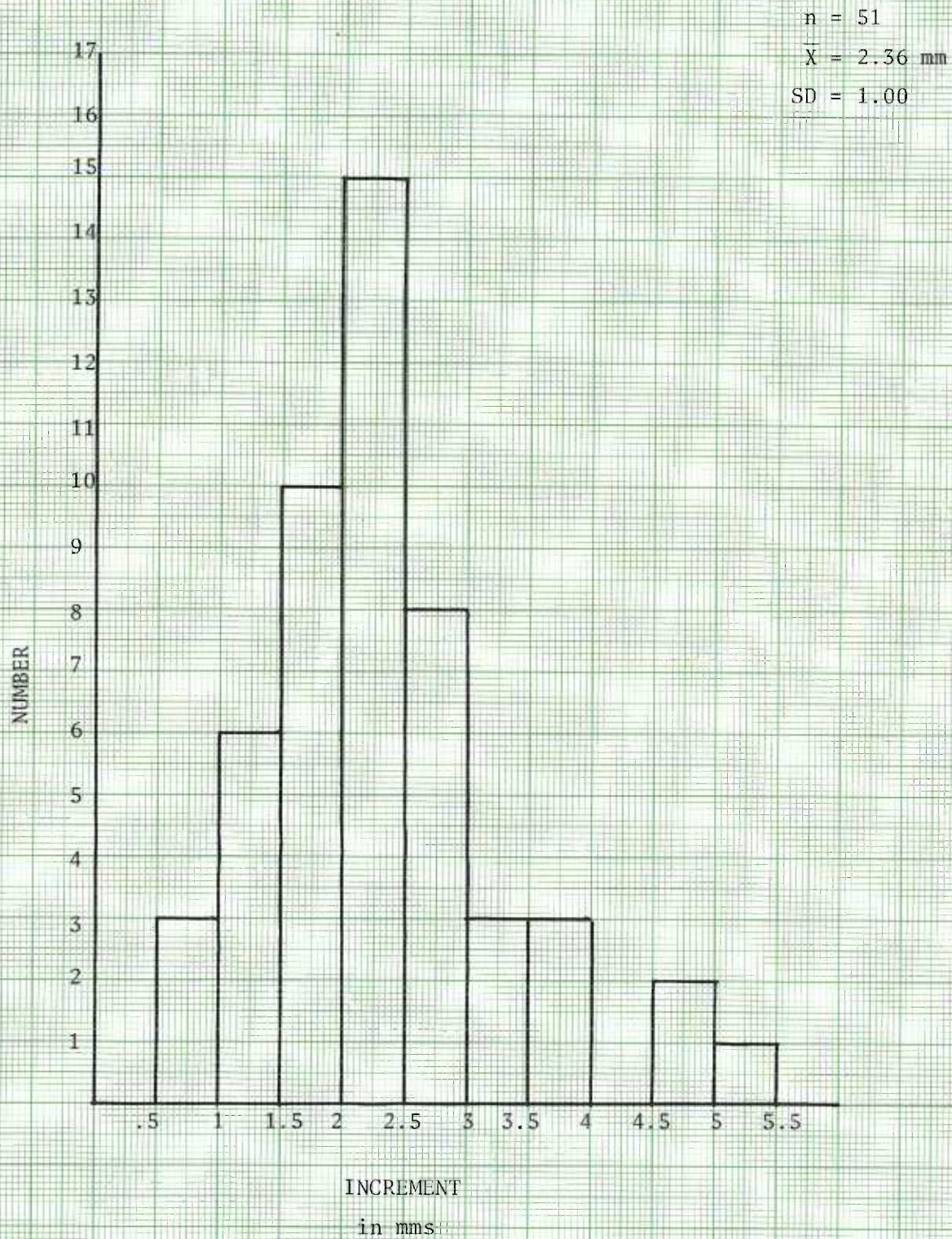


FIGURE 16

Frequency distribution of increments in Ar-Po
for the year prior to peak 6-month period

$n = 51$
 $\bar{X} = 2.91$
 $SD = 0.81$

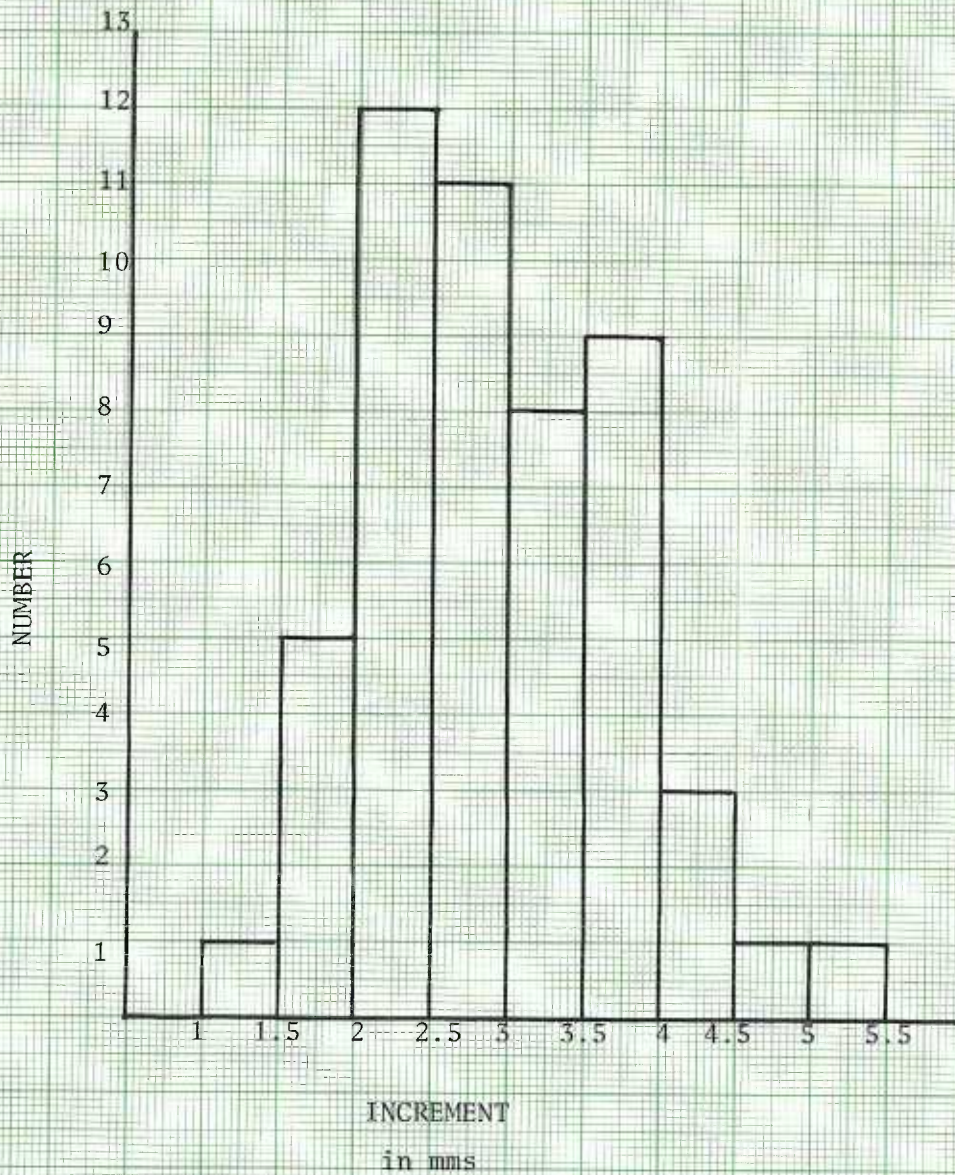


FIGURE 17

Frequency distribution of increments in Ar-Po
for the year after the peak 6-month period

$n = 49$

$\bar{X} = 2.71$

$SD = 0.80$

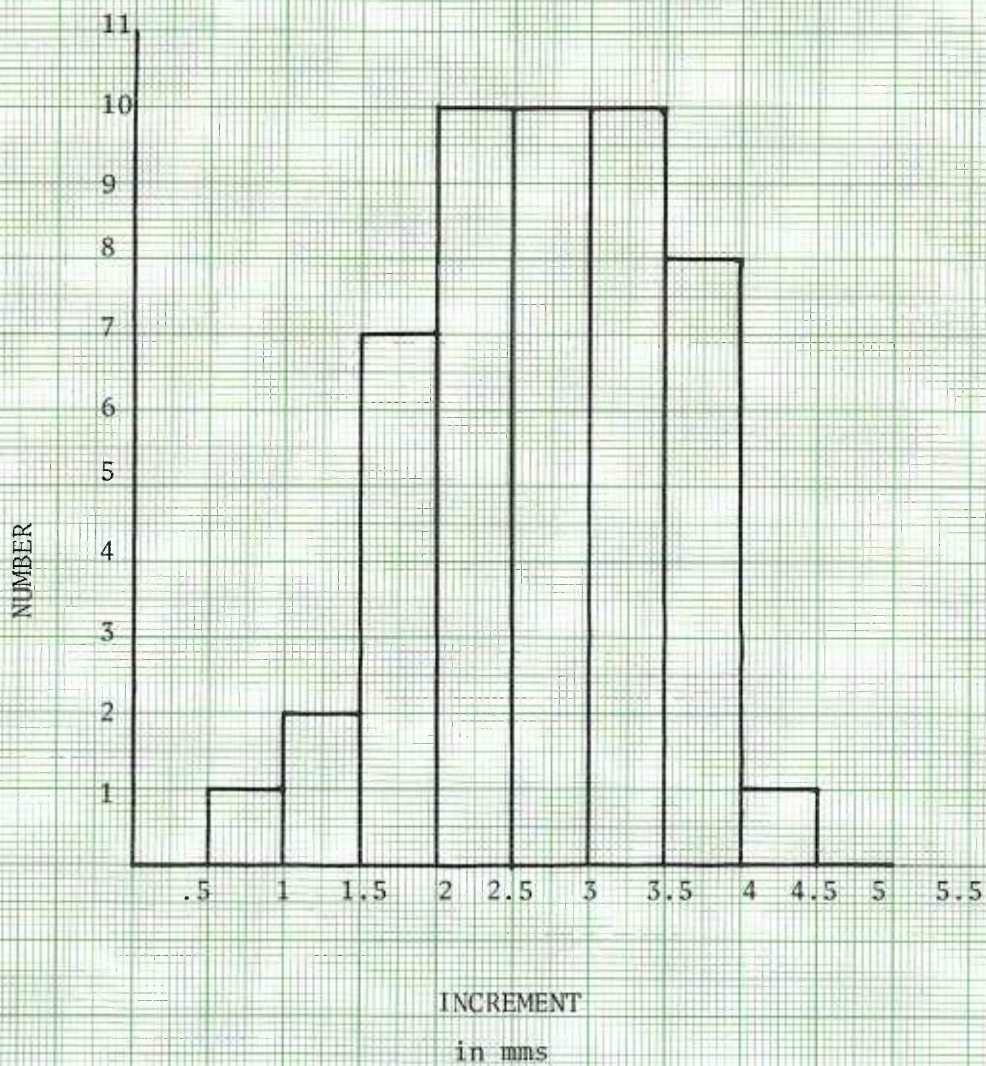


FIGURE 18

Frequency distribution of increments in Ar-Po
for the second year after the peak 6-month period

$n = 40$

$\bar{X} = 2.41$

$SD = 0.82$

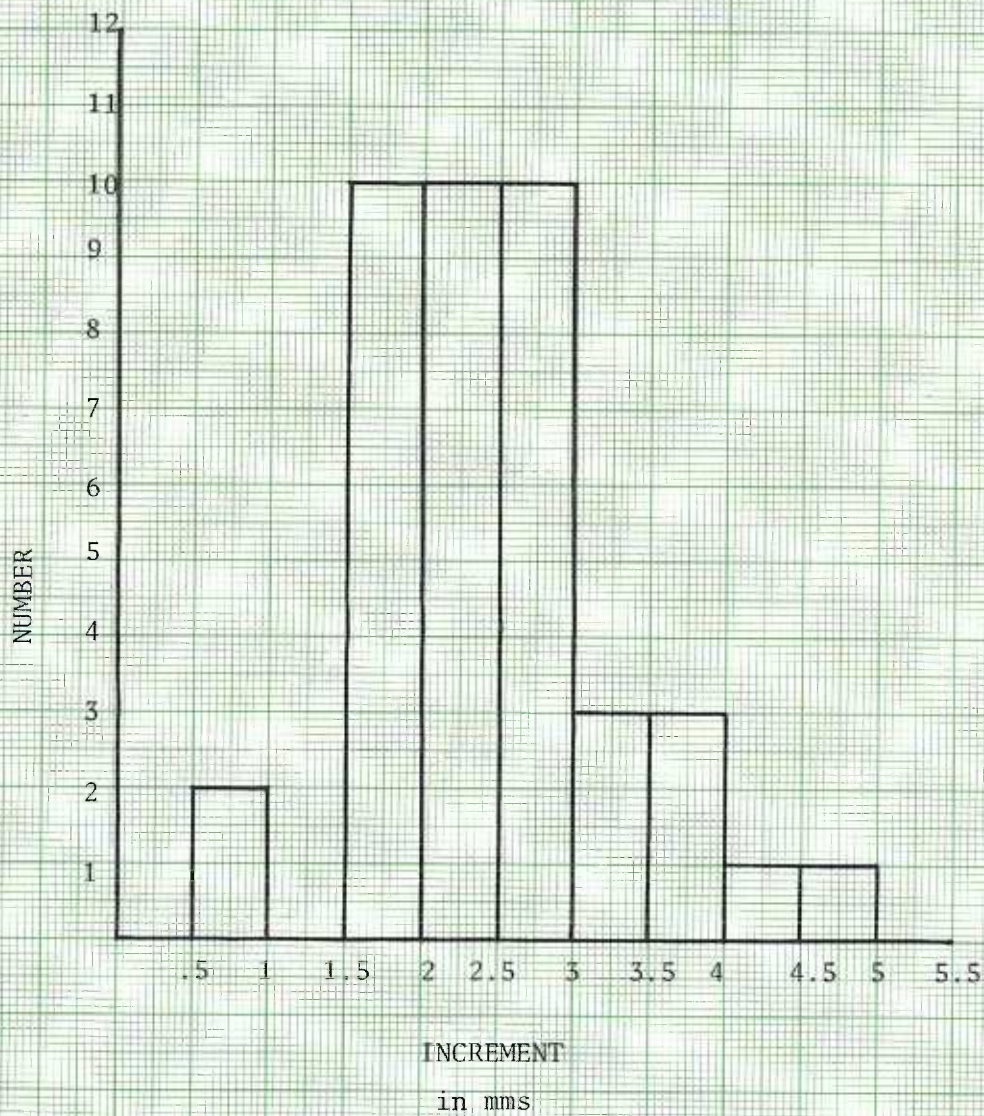


FIGURE 19

Scattergram of the length of Ar-Po 2 years before the peak and the increase in Ar-Po for $4\frac{1}{2}$ years over the adolescent period

