The change of voice during puberty in 11 to 16 years old choir singers measured with electroglottographic fundamental frequency analysis and compared to other phenomenona of puberty

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THE CHANGE OF VOICE DURING PUBERTY IN 11 TO 16 YEARS OLD CHOIR SINGERS MEASURED WITH ELECTROGLOTTOGRAPHIC FUNDAMENTAL FREQUENCY ANALYSIS AND COMPARED TO OTHER PHENOMENONA OF PUBERTY

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INTRODUCTION

A well known survey of the mutation of boys' voices is given by Weiss (1950). He differentiates between the following phases in puberty development: 1/pubescence, with a disorganization of the voice, 2/transformation, and 3/adolescence, where the function continues on a new organized level. The changes are seen in the pharynx, larynx and the breathing capacity, organically as well as functionally. The functional and organic changes must be kept separate. The pitch range drops to a new level, this also affects the pitch level of the speaking voice. A survey of the relevant litterature is given by Kitzing (1979).

The somatic signs of puberty are among others a spurt of growth, increasing weight, changing of pubes- and axilary hair and growth of testes (Taranger, 1976). Several examinations have been carried out, where also an evaluation of the voice has been included. Taranger differentiated between: child voice, breaking voice and fully broken voice (= adult voice).

The qualifications in a choir situation during mutation e.g. in the Copenhagen Boys' Choir is a big problem. No singing teacher wants to disturb the boys' voice in puberty.

Weiss summarizes the premutational changes of the voice cited in the litterature as: a certain loss of voice power, and more frequent cases of indisposition of voice. These changes can start already at 10 years of age, which is the same time as the choirboy has his best capacity. Also for this reason it is essential in the relation to the singing teacher to give objective measurements for how far the boys is in puberty. The present work compares the criteria which are of significance for the evaluation of the mutational development with objective measurements of the voice fundamental frequency during speech.

MATERIAL AND METHOD

25 boys were used as subjects. They were chosen at random from the 6th to the 10th level in the Singing School of Copenhagen, which is the basis of the Copenhagen Boys' Choir. Their general health state was good. They were all participants of the choir.

An examination was carried out with the following parametres:

1. mean voice fundamental frequency during speech according to Kitzing (1979).
2. and voice range. The range was between the 15th and 85th percentile.
3. biological tone range evaluated by a singing teacher with piano accompagnement, in several cases veryfied by spectral analysis.
4. musical tone range in this examination defined as the range, which was usable in a choir situation and described in general terms.
5. serum testosterone of vein blood.*

* We are grateful to the Danish Serum Institute for assistance.

6. height.
7. weight.
8. pubes hair (the axilary hair has been measured, but because of great variance, the results were not included).
9. testes size, measured a.m. Prader, as described by Tanner and Taranger.

INSTRUMENTATION

Electroglottograf, FJ electronics 830. Tape-recorder, Revox type A 77, 19 cm/sec. microphone AKG CE 10 (20—18000 Hz), Distortion area: better than $+/\div 0.08$ %. Glottographic frequency analyzer model 3. (Kitzing, 1978) Text: IPA book. The North Wind and the Sun. Spectral analyzer Nicolet type 440 A Mini Ubiquitous.

RESULTS

Indirect laryngoscopy and strobocopy in the 25 subjects were without organic changes in 23, not possible in one with a auditively clear voice (age $15^{8}/_{12}$ years). One boy, $12^{8}/_{12}$ years of age had known small nodules and was singing in the choir, his top pitch being 698 Hz. The result are seen in Fig. 1. The tone ranges are seen in Fig. 2. In Fig. 3 the fundamental frequency (Fo) is seen to be high and the serum testosterone low until the age of 13. Between 13—15 years the serum testosterone increases, but not more than the value 10, while the fundamental frequency still is high (lowest value 195 Hz). From 15 years of age the fundamental frequency has fallen (highest value 148 Hz) and serum testosterone never lies under 10.

The tendencies of measuring of the musical tone range are: All voices have in boys height and strength from 523—1047 Hz. High values for serum testosterone show relation to either falling height or clear register breaking. All young adults at 17—18 years age had an adult sound. The fundamental speaking frequency lies about 8—12 semitones over the lowest tone in the biological tone range.

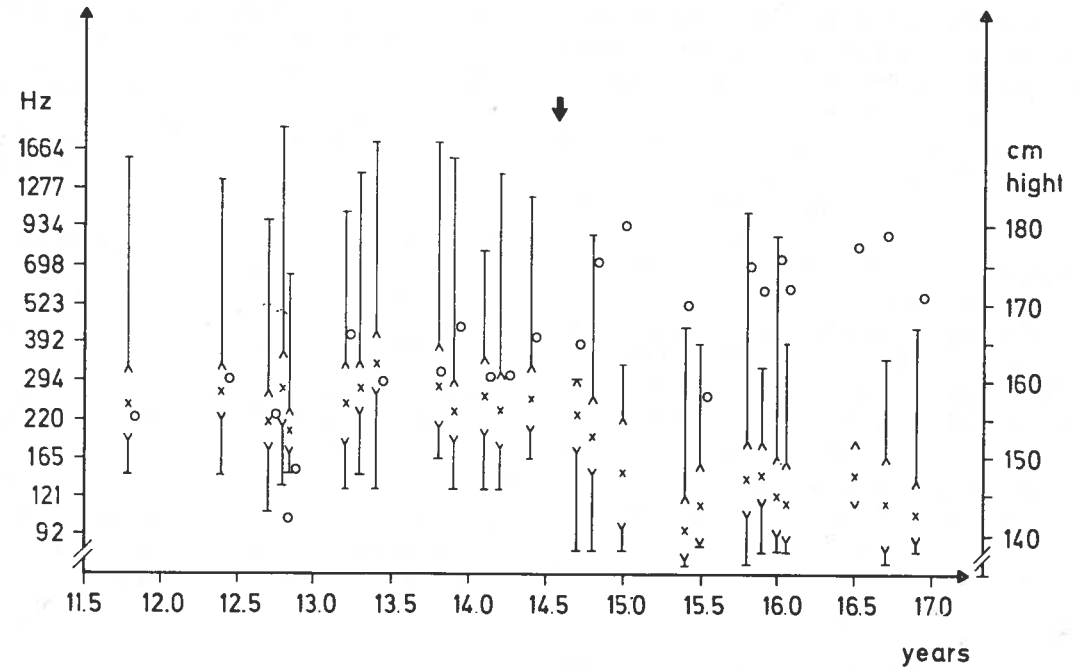
DISCUSSION

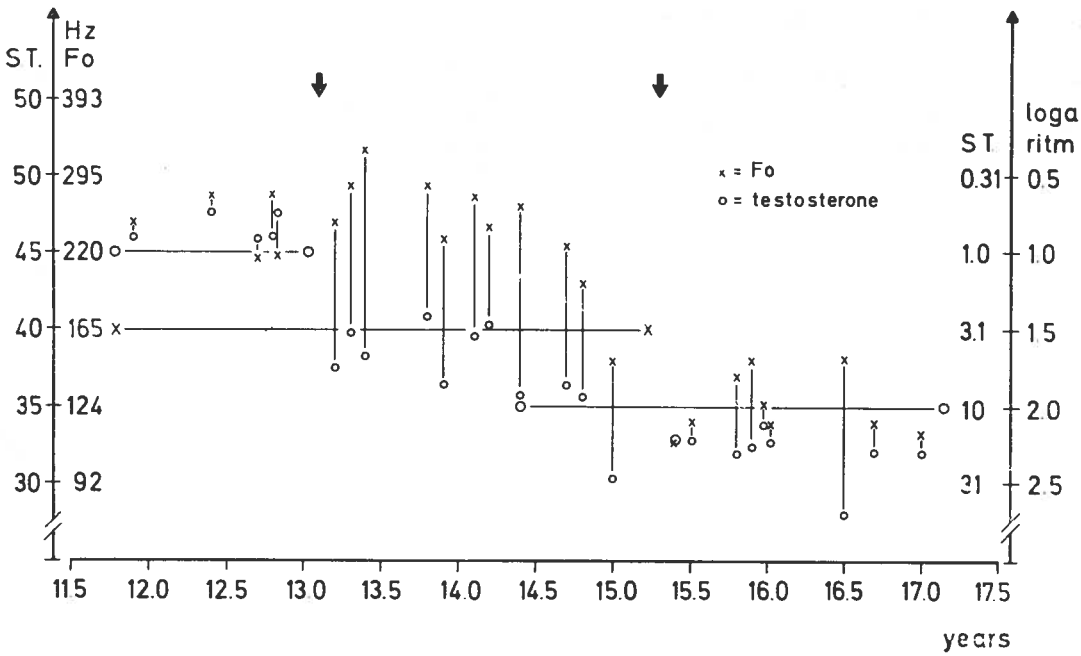
The results of the measurings of average fundamental frequency in speech are

	Serum-testosterone $\bar{x}$ nmol SD	Testicular vol. ml. Right/left	Pubeshair	Weight $\bar{x}$ kg SD	Height $\bar{x}$ cm SD	Age $\bar{x}$ years SD	Fo $\bar{x}$ Hz SD	Voicerange $\bar{x}$ Semitones SD	% of $\bar{x}$	Tonerange x Hz
11—12 years 1 pupils	0.80	8.0/8.0	P 1	40.0	155.0	11.8	244	4.3	10.5	147—1568
12—13 years 4 pupils	0.7 / 0.2	4.0/3.8	P 2	37.9 / 4.6	151.4 / 8.0	12.68 / 0.19	245 / 33	4.0 / 0.7	11.0	132.8—1141.4
13—14 years 5 pupils	4.7 / 1.8	8.5/8.5	P 2**	50.3** / 8.9	163.4** / 4.1	13.52 / 0.31	272.6 / 35	4.1 / 1.1	10.2	140.4—1514.7**
14—15 years 5 pupils	6.1 / 2.6	13.6/12.0	P 3	52.9 / 7.1	165.7 / 6.5	14.44 / 0.31	234.2 / 26.2	4.3 / 0.7	12.7	105.3— 802.6
15—16 years 6 pupils	19.2 / 5.5	19.3/17.2	P 5	58.2 / 5.1	172.3 / 8.5	15.60 / 0.37	128.7 / 15.1	4.7 / 1.2	15.0	80.1— 388.4
16—17 years 4 pupils	24.8 / 14.0	22.5/18.8	P 5	69.4 / 12.2	175.4 / 3.9	16.53 / 0.39	122.8 / 17.0	4.6 / 0.9	16.6	79.3— 493.8*

r — 0.72 Fo/serumtestosterone
r — 0.90 Fo/pubeshair
r — 0.79 Fo/testicular vol.

* 3 ptt.
** 4 ptt.





comparable to Hollien & Hollien (1972). The fundamental frequency of the 15—16 years old are a little lower in our material.

The voice ranges are lower than in Southern Swedish adults (Kitzing, 1979). The heights and weights of the boys together with pubic hair lies inside the normal range after Taranger. The tone ranges after Hartlieb & Oordt (1963) correspond to ours. As in Oordt's material the speeking frequency lies

in the lowest 1/3 of the tone range in boys, whereas the variation during mutation should be analysed together with changes of registers to get exact information.

The increase of serum testosterone causes growth of pubic hair as well as the mutation of the voice. These parameters are highly correlated ($p. < 0.001$). The fundamental frequency is the most caracteristic parameter for the evaluation of whether a voice is the one of a boy or an adult male person (Sundberg, 1980; Coleman, 1976; Naidr, 1965).

The results are very well related to Weiss' three periods (child-adolescence-adult). The variables of voice are in good correlation biologically, and physiologically as well. But the three parts of puberty as described by Weiss must certainly be analysed in relation to registers and formants to get an alround picture of what is going on in puberty in the physiological respect of voice. Therefore it is of great value that we now have an objective measuring method which shows results that can be used also in a clinical setting.

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