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Change of Voice in Puberty in Choir Girls

A Cross-sectional Study of Electroglottographical Measured Fundamental Frequency in Reading Compared with Phonetograms, Pubertal Stages and Endocrine Analysis

M.F. PEDERSEN, S. MØLLER, S. KRABBE, E. MUNK, P. BENNET and P. KITZING

From Copenhagen Singing School, Skt. Annae Gymnasium, Department of Paediatrics, Rigshospitalet, University of Copenhagen, Hormone and Biostatistical Departments, Statens Seruminstitut, Copenhagen, Denmark, and Department of Phoniatrics, University ENT Clinic General Hospital, Malmö, Sweden

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Forty-seven girls in Copenhagen Singing School were chosen by strafification on class level from their 3rd to 12th school year. Examination was carried out of fundamental frequency (Fo) in a reading situation with registration of about 2000 electroglottographical signals with means expressed in Hz and with 95% deviation in semitones, phonetograms according to UEP standard proposal with analysis of conditions of intensity together with lower, middle and upper frequency. By comparison with evaluation of state of puberty and androgen and oestrogen status it was found that Fo was significantly correlated to age ($r=0.40$) and to Fmin ($r=0.51$) and Fmiddle ($r=0.45$). Furthermore, the phonetogram area was significantly correlated to age ($r=0.65$). This corresponds to $P < 0.01$ for all values. There was no significant correlation between change of voice and hormonal conditions. Supplementary examinations using multivariate analysis will be carried out as it was previously done for boys.

M.F. Pedersen, Copenhagen Singing School, Sjællør Blvd. 135, DK-2500 Valby, Denmark.

Puberty conditions have always been of interest in connection with singing. It has been documented earlier that fundamental frequency (Fo) decreases with age[1, 2, 3, 4], while the tone range increases[5, 6]. The difference between boys and girls is not sufficiently elucidated[7]. Since better methods have appeared for analysis of both voice conditions and hormonal changes we wanted to obtain an impression of the possibilities of predicting the occurrence of voice puberty in girls. This has been possible to a certain degree in boys, in whom the Fo was always correlated to a total serum testosterone < 10 nmol/l.

MATERIALS AND METHODS

Forty-seven girls aged 8-19 years from the Copenhagen Singing School participated in our cross-sectional examination. The girls were chosen by stratification with similar numbers from each school class. The girls are admitted to the school at the 3rd class level with criteria of good musicality according to standardized examination and a good voice. They can remain there until the 12th class level. All participants were healthy and had vocal cords without organic changes and none took medicine. An informal written consent from the girls' homes, including information on menarche, was obtained. Blood sampling for hormone status was carried out on day 3-6 in the menstruation circle. Development of puberty was evaluated with height, weight, pubes hair and mamma development according to Tanner[10]. Stroboscopy was performed on all the girls in order to exclude presence of abnormalities. Fo was recorded by means of electroglottography together with the vocal range by reading of a phonetically well balanced text. A computer program based on consecutive analyses of a mean of 2000 electroglottographical cycles states the mean Fo in Hz and the 95% deviation in semitones. The equipment is commersially available. Phonetograms were made by a phoniatrician and an experienced singing master according to proposed international standard[11]. Calculation of the area was performed in cm^2 on the

standard paper. Further examinations were carried out on a phonetograph developed by a Danish engineering firm. The hormone investigation was performed at Statens Seruminstitut. The observations were recorded with geometric means in three age groups.

All observations were logarithmicly transformed in order to obtain a normal distribution. A one-way analysis of variance was performed and correlation co-efficients were calculated for all parametres.

Equipment

Electroglottograph FJ Electronics type 830
Microdatamate Digisys type 2205, Cybernex model LGD-1
Spectral analyzer, Nicolet 440 A mini ubequitous
Sound level meter with microphone, Brüel and Kjaer type 2205
Oscilloscope Tectronix type 510 3n, storage with polaroid camera
Text: IPA book "The North Wind and the Sun"
Stroboscope: Brüel and Kjaer type 5066
Phonetograph Voice Profile instruments type 8301

RESULTS

Height and weight corresponded to other investigations of Danish and Swedish school-children[12, 13]

Fig. 1.

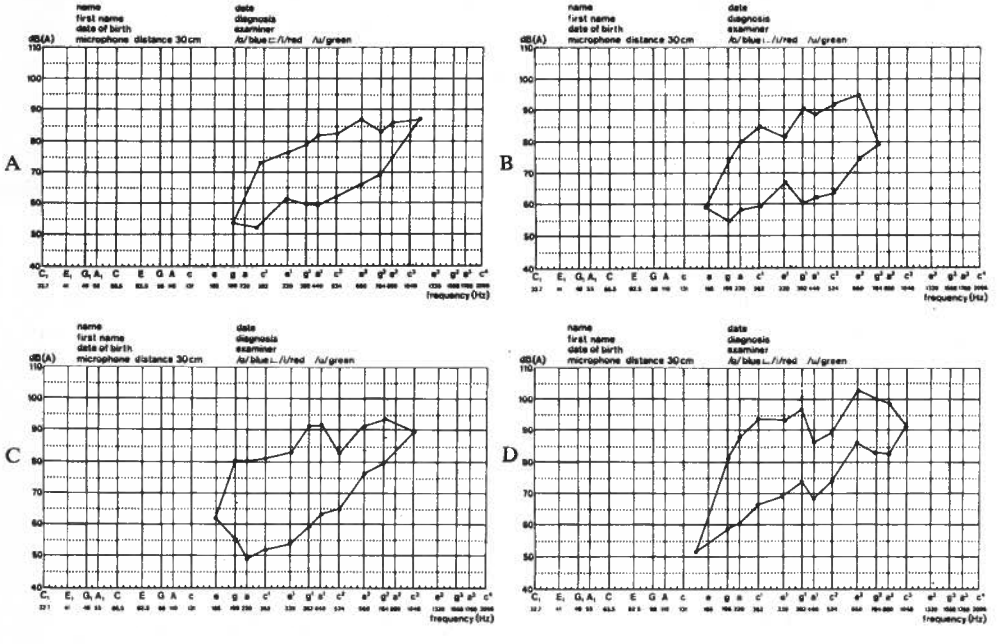

Fig. 1 illustrates phonetograms at different age levels:

A) 8.9 years: The time when the untrained girl gets into the choir
B) 11.7 years: Typical child's voice with register change at fis^1 (between 330-392 Hz)
C) 13.8 years: Absolutely well functioning girl's goice without break of register at week intensities
D) 14.8 years: Change of register at gis^1 (between 392-440) and d^2 (between 524-660) evaluated as puberty voice by singing master.

Table 1

Geometric means of androgen oestrogen pubertal stage and voice

Age		8.6-12.9	13-15.9	16-19.8
Number		22	14	11
Oestrone	(nmol/1)	78 (10<40)	113	113
Oestradiol	(nmol/1)	103(9 <40)	185	167
Testosterone	(nmol/1)	0.576	0.74	0.94
Oestrone sulphate	887 (3<200)	2261	2521	
Dihydro epi androsterone	(nmol/1)	2990	3500	7200
Androsten dione	(nmol/1)	1.39	3.19	3.43
Menarche (No.)		+4	—3	+all
Pubic hair (stage)		1-4	2-5	4-6
Mamma development (stage)		1-4	2-5	5
Fundamental frequency (Fo) in speech (Hz)		257	248	197
Voice range (semitones) in speech		3.2	3.2	5.2
Voice range (semitones) in singing		23	30	38
Phonetogram area (cm^2)		17.5	22.2	28.3
Lower biological tone (Hz)		166	153	145
Middle biological tone (Hz)		434	406	413
Higher biological tone (Hz)		1134	1136	1263

Table 1 shows results in three age a groups of the parametres in question. Fo was correlated to age ($r=0.40$, $p < 0.001$) and to Fmin ($r= 0.51$, $P < 0.001$) and Fmiddle ($r=0.45$, $P < 0.01$). Correlation between phonetogram area and age was $r=0.65$, $P < 0.001$. Analysis of intensity conditions in the phonetograms and the other results showed to significant circumstances. No correlation between hormone status and Fo during reading was found in this study. However, supplementary multivariate statistical analyses of hormone values in relation to voice parametres will be carried out. This may possibly show predictive values.

DISCUSSION

Fo was significantly related to age showing a mean decrease from 257 to 197 Hz and was related to the lower biological tone in the phonetogram with $P < 0.001$. The phonetogram was similarly significantly related to age with the same significance in these girls who were all maximally trained in singing. 2-3 years after menarche a change of the areas was seen at the same time as the girls were moved from child to adult choir.

Fo and phonetography should be included as sex characteristics in routine analyses of puberty due to the accuracy of the method and the reproducibility of the phonetograms[14]. They also provide a better possibility of evaluating the pathological deviation[15].

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