ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.5336/medsci.2020-78411

Vocal Mutation in Singing Boys: Diagnostics and Remote Monitoring

Şarkı Söyleyen Erkek Çocuklarda Ses Değişimi: Tanı ve Uzaktan Gözlemleme

Semyon CHERNOBELSKY[a]

[a]Department of Phoniatrics, Voice Research Laboratory of the State Opera and Ballet Theatre and the Music College, Krasnoyarsk, RUSSIA

ABSTRACT Objective: The aim of this study is confirmation of the two assumptions: 1) The possibility of using computerized acoustic speech analysis of singing boys to determine the onset of mutation; 2) The ability to monitor the mutation process remotely using a smart phone. **Material and Methods:** Thirty singing boys from two groups were examined. The first group consisted of 15 subjects aged 11 years 10 months to 12 years 4 months. The second group consisted of 15 subjects aged 12 years 10 months to 13 years 2 months. The investigation included laryngoscopy and an acoustic test. Fundamental frequency of speech (SF0) was determined using computer program Praat. Adolescents read standard text for 10-15 seconds. In 10 adolescents from the second group, who had difficulty while singing high notes, the mutation was monitored remotely. For this purpose, the text was recorded by the adolescent on a personal smartphone 4 times per year at 3 months' intervals. The sound files were sent via the Internet to the acoustic laboratory for SF0 estimation. **Results:** It was found that the mean SF0 value in subjects of the second group was lower than in subjects of the first group. This could be considered as the beginning of a mutation in the majority of adolescents of the second group. Remote monitoring of the mutation revealed a decrease in SF0 magnitudes in all subjects during 9th to 12th month. **Conclusion:** Acoustic speech analysis is suitable for determining the onset of vocal mutation in singing boys. This process can be monitored remotely using smartphones.

Keywords: Vocal mutation; fundamental frequency of speech

ÖZET Amaç: Bu çalışmanın amacı iki varsayımın doğrulanmasıdır: 1) Ses değişiminin ortaya çıkışını belirlemek için kompüterize akustik konuşma analizinin kullanılmasının olabilirliği; 2) Akıllı telefon kullanılarak ses değişimi sürecinin uzaktan gözlenebilirliği. **Gereç ve Yöntemler:** İki gruptan 30 çocuk değerlendirildi. İlk grup yaşları 11 yıl 10 ay ile 12 yıl 4 ay arasında olan 15 çocuktan oluşuyordu. İkinci grupta 12 yıl 10 ay ile 13 yıl 2 ay arasında 15 çocuk yer alıyordu. Araştırma laringoskopi ve akustik testten oluşuyordu. Temel konuşma frekansı (TKF) Praat bilgisayar programı kullanılarak belirlendi. Adolesanlar standart metni 10-15 saniye okudular. İkinci gruptan yüksek notaları okumakta zorlanan 10 adolesanda ses değişimi uzaktan gözlendi. Bu amaçla, metin adolesan tarafından her yıl 3 ay aralarla 4 kez akıllı telefona kaydedildi. TKF belirlenmesi için, ses dosyaları İnternet üzerinden akustik laboratuvarına gönderildi. **Bulgular:** Ortalama TKF değerinin ikinci gruptakilerde birinci gruptakilerden daha düşük olduğu bulundu. Bu, ikinci gruptaki adolesanların çoğunda ses değişiminin başlangıcı olarak düşünülebilir. Ses değişiminin uzaktan gözlemlenmesi tüm deneklerde 9.-12. aylarda TKF büyüklüğünde bir azalma olduğunu ortaya koydu. **Sonuç:** Şarkı söyleyen erkek çocuklarda ses değişiminin ortaya çıkışını belirlemede akustik ses analizi uygundur. Bu süreç akıllı telefon kullanılarak uzaktan gözlemlenebilir.

Anahtar Kelimeler: Ses değişimi; temel konuşma frekansı

Vocal mutation occurs due to hormonal changes in the body and leads to the rapid growth of the larynx. In girls, the vocal folds become longer by 3-4 mm, and in boys the vocal folds become longer by 10-12 mm. The thickness of the folds also increases. In boys, the mutation begins at about 13 years old, in girls at 11-12 years old. Prior to this period, the fundamental frequency of speech (SF0) is the same for both boys and girls, and is around 235-250 Hz. During the mutation, SF0 decreases due to an increase in the mass of the vocal folds. In boys, this process lasts from 6 to 12 months. At this

Correspondence: Semyon CHERNOBELSKY
Department of Phoniatrics, Voice Research Laboratory of the State Opera and Ballet Theatre and the Music College, Krasnoyarsk, RUSSIA/RUSYA
E-mail: semyon@krasopera.krsn.ru

Peer review under responsibility of Turkiye Klinikleri Journal of Medical Sciences.

Received: 07 Aug 2020 ***Received in revised form:*** 15 Feb 2021 ***Accepted:*** 19 Feb 2021 ***Available online:*** 02 Mar 2021

time, SF0 decreases by an octave and averages 125 Hz. In girls, the mutation lasts 3 to 6 months and occurs unnoticed. SF0 decreases by 3-4 semitones and is around 230 Hz.

For singing boys, a mutation is a signal to stop vocalizing, since singing at this time can disrupt the physiological development of the voice.[1] An actively occurring mutation is easy to identify by ear. A significant decrease in SF0, hoarseness, phonation in the chest and falsetto registers are its signs. Examination of the larynx frequently determines the appearance of acute laryngitis. Meanwhile, pubertal changes in the voice do not occur immediately and have three periods: premutation, mutation and postmutation. It is very difficult to determine premutation subjectively by ear. According to Wilson et al., even experienced musicians can detect a difference in SF0 only when it is at least 25.08 Hz.[2] In vocal pedagogy, it is very important to define the premutation, when any signs of this phenomenon are not yet subjectively or laryngoscopically detected.

Singing teachers, boys and their parents are actively interested not only in the beginning of the mutation, but also in its course and completion. To accomplish this, they need to periodically visit the phoniatrician where they undergo the acoustic voice analysis which is mandatory for assessing the vocal ability of the larynx.[3]

In recent years, a large number of smartphones that are equipped with voice recorders have appeared. Given the comparable technical characteristics of acoustic computer programs and smart phones, the latter can be used to record voice and speech samples for the purpose of their further computer analysis.[4-6] In this case, the signal recorded by the microphone of one digital system (smartphone) is analyzed by another digital system (computer program). Ambient noise is a major factor negatively affecting the accuracy of acoustic voice analysis, but it has minimal impact on SF0.[7,8] Therefore, to determine the SF0 does not require a well-damped room. The present study was carried out in order to solve two tasks: (1) confirmation of the assumption that the mutation begins with a decrease in SF0 values; and (2) the possibility of remote monitoring of this process.

MATERIAL AND METHODS

SUBJECTS

Thirty healthy boys singing in various vocal ensembles were examined. They were divided into two groups. The first one included 15 boys aged 11 years 10 months to 12 years 4 months. The second one included 15 boys aged 12 years 10 months to 13 years 2 months. Ethics committee approval was obtained for the research from Krasnoyarsk Medical University. Permission was obtained from the director of the music school where this study was conducted.

This study was carried out in accordance with the Helsinki Declaration principles.

MEASUREMENTS

To test the first assumption, all subjects underwent indirect laryngoscopy. SF0 was determined using a Hewlett-Packard 630 laptop, Pentium B960, 2.2 GHz and soft packet Praat.[9] The boys read the standard text at a comfortable frequency and volume for 10-15 seconds. An external microphone Gembird EMIC-111 was used for this goal. The distance between the microphone and the subject was 25-30 cm. The obtained data were statistically processed using the student t-test and are shown in Table 1. Statistical significance was defined using p values less than 0.05.

To test the second assumption, 10 boys were selected from 15 subjects of the second group. All of them noted difficulties with singing high notes. This allowed to predict the beginning of a mutation, so singing was forbidden.The text was recorded by the teenager at home using the recording capabilities of a personal smartphone. After that, the sound file was sent over the Internet to an acoustic laboratory to determine SF0. The resulting file was converted to the "WAV" format which was used by Praat. The con-

TABLE 1: Fundamental frequency of speech data from 30 adolescents to determine the onset of mutation (in Hz).

Groups	n	Range	Mean	SD
1	15	193-265	232.6	21.1
2	15	182-234	207.3	17.7

SD: Standard deviation.

TABLE 2: Fundamental frequency of speech data of 10 adolescents obtained by monitoring the process of a mutation (in Hz).

Test number	Subjects									
	1	2	3	4	5	6	7	8	9	10
1	200	190	200	195	200	180	190	185	190	196
2	175	165	170	163	155	152	160	153	160	166
3	150	148	150	147	140	124	130	130	136	138
4	125	130	115	135	120	124	130	130	120	138

version was carried out using the online converter of sound files https://online-audio-converter.com/ru/. Monitoring was performed 4 times during the year at 3 months intervals. The obtained data are shown in Table 2.

RESULTS

The results of the study showed that none of the subjects complained of hoarseness. Examination of the larynx did not reveal any deviations from the norm in any of the subjects. Analysis of the data in groups 1 and 2 found significant intergroup variability of SF0 values (Table 1). In the first group, the range of the variants was between 193 Hz and 265 Hz. In the second group, the range of the variant was between 182 Hz and 234 Hz. The average SF0 value in the first group was 232.6 Hz, which closely corresponded to the note A # 0 (233.1 Hz) of the musical scale. The average SF0 value in the second group was 207.3 Hz and closely corresponded to the note G # 0 (207.7 Hz) of the musical scale. The difference in these SF0 values was statistically significant ($p<0.05$) and was 25.3 Hz, which equals two semitones.

During the remote control of the mutation, decrease in SF0 magnitudes was determined in each of the 10 boys (Table 2). In subject № 1, SF0 decreased from 200 Hz to 125 Hz over 12 months. In subject № 2, SF0 decreased from 190 Hz to 130 Hz over 12 months. In subject № 3, SF0 decreased from 200 Hz to 115 Hz over 12 months. In subject № 4, SF0 decreased from 195 Hz to 135 Hz over 12 months. In subject № 5, SF0 decreased from 200 Hz to 120 Hz over 12 months. In subject № 6, SF0 decreased from 180 Hz to 124 Hz over 9 months. The follow up investigation of this boy did not reveal any further decrease in SF0. SF0 remained equal to 124 Hz. In subject № 7, SF0 decreased from 190 Hz to 130 Hz over 12 months. In subject № 8, SF0 decreased from 185 Hz to 130 Hz over 9 months. The follow up investigation of this adolescent did not reveal any further decrease in SF0. This magnitude remained at 130 Hz. In subject № 9, SF0 decreased from 190 Hz to 120 Hz over 12 months. In subject № 10, SF0 decreased from 196 Hz to 138 Hz over 9 months. The follow up investigation did not reveal a further decrease in SF0. SF0 value remained at138 Hz.

Determining the degree of dysphonia during a mutation was not performed in this study. Meantime a perceptual assessment of speech samples was carried out. None of the adolescents had significant hoarseness. This could be explained by the fact that the mutation in singing boys passes, as a rule, smoothly and without obvious signs of mutational laryngitis.[1]

DISCUSSION

SF0 is an important indicator of the biomechanical characteristics of the vibration of the vocal folds and is the sum of the frequencies of all sound waves divided by their number.[10,11] Increase or decrease in SF0 occurs with various functional and organic diseases of the larynx.[12-14] Few scientific papers are dedicated to puberty changes in the voice. But one of them allows to create a model to obtain information about the beginning, duration and end of the mutation process.[15] Determining the first onset of a mutation is quite difficult. For this purpose, the phonetography method and the measurement of testosterone levels in the bloodwas used.[16,17] Willis EC and Kenny DT found a correlation between the increase in body mass of adolescents and the change in the range of their voices.[18] So, with a body weight of 42.7-44.9 kg, the range was between 117 Hz and 216 Hz. If the body weight exceeded 54.8 kg, the range was between 99.5 Hz and 151 Hz.

Fachs et al. were the first to use acoustic voice analysis to determine the onset of voice mutation in singing boys.[19] According to their data, the beginning of the mutation can be determined by acoustic parameters, including SF0.

The results of our study confirmed the data of Fachs M et al.[19] The main advantage of the method is its non-invasiveness and simplicity. Any vocal teacher who has certain computer skills can independently determine the SF0 of their students. This requires a simple computer and any program that can extract the SF0. It is advisable to conduct a periodic check of SF0 in boys at set periods of 3-4 months from the age of 11. To standardize the study, three conditions are necessary: 1) use the same computer, soft packet, and microphone; 2) reading the same text in a quiet environment is required; 3) the adolescent should not have respiratory diseases. A decrease of two semitones can be considered as the beginning of mutation. From this moment, teachers should reduce the vocal load, but not stop it completely, since about 6 months elapse before the start of the main phase of mutation.[19]

The monitoring of the mutation process can be carried out remotely using smartphones. The portability of these devices allows to record speech samples in any quiet place. After that, sound files are sent over the Internet to an acoustic laboratory to determine SF0. Data on the current SF0 value are compared with a previous one. If the decrease in SF0 no longer occurs, the main part of the mutation is over.

CONCLUSION

1. SF0 measurement is suitable for determining the onset of voice mutation in singing boys.

2. Monitoring of SF0 changes can be carried out remotely using smartphones.

Acknowlegements

The author is grateful to Ms. Inna Gliksberg for revision of the English text

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

This study is entirely author's own work and no other author contribution.

REFERENCES

1. Dmitriev LB, Telelaeva LM, Taptapova SL, Ermakova II. Phoniatrics and logopaedics. Medicina, 1990, [in Russian].
2. Wilson FB, Wellen CJ, Kimbarow ML. Perception of the fundamental frequencies of children's voices by trained and untrained listeners. J Otolaryngol. 1983;12(5):341-4. [PubMed]
3. Leong K, Hawkshaw MJ, Dentchev D, Gupta R, Lurie D, Sataloff RT. Reliability of objective voice measures of normal speaking voices. J Voice. 2013;27(2):170-6. [Crossref] [PubMed]
4. Uloza V, Padervinskis E, Vegiene A, Pribuisiene R, Saferis V, Vaiciukynas E, et al. Exploring the feasibility of smart phone microphone for measurement of acoustic voice parameters and voice pathology screening. Eur Arch Otorhinolaryngol. 2015;272(11):3391-9. [Crossref] [PubMed]
5. Lin E, Hornibrook J, Ormond T. Evaluating iPhone recordings for acoustic voice assessment. Folia Phoniatr Logop. 2012;64(3):122-30. [Crossref] [PubMed]
6. Mat Baki M, Wood G, Alston M, Ratcliffe P, Sandhu G, Rubin JS, et al. Reliability of operaVOX against Multidimensional Voice Program (MDVP). Clin Otolaryngol. 2015;40(1):22-8. [Crossref] [PubMed]
7. Deliyski DD, Shaw HS, Evans MK. Adverse effects of environmental noise on acoustic voice quality measurements. J Voice. 2005;19(1):15-28. [Crossref] [PubMed]
8. Deliyski DD, Evans MK, Shaw HS. Influence of data acquisition environment on accuracy of acoustic voice quality measurements. J Voice. 2005;19(2):176-86. [Crossref] [PubMed]
9. Boersma P. The use of Praat in corpus research. In: Durand J, Gut U, Kristoffersen G, eds. The Oxford Handbook of Corpus Phonology. 1st ed. Oxford: Oxford University Press; 2014. p.342-60. [Link]
10. Brockmann M, Drinnan MJ, Storck C, Carding PN. Reliable jitter and shimmer measurements in voice clinics: the relevance of vowel, gender, vocal intensity, and fundamental frequency effects in a typical clinical task. J Voice. 2011;25(1):44-53. [Crossref] [PubMed]

11. Wermke K, Robb MP. Fundamental frequency of neonatal crying: does body size matter? J Voice. 2010;24(4):388-94. [Crossref] [PubMed]
12. Guzman M, Rubin A, Cox P, Landini F, Jackson-Menaldi C. Neuromuscular electrical stimulation of the cricothyroid muscle in patients with suspected superior laryngeal nerve weakness. J Voice. 2014;28(2):216-25. [Crossref] [PubMed]
13. Bhalla RK, Watson G, Taylor W, Jones AS, Roland NJ. Acoustic analysis in asthmatics and the influence of inhaled corticosteroid therapy. J Voice. 2009;23(4):505-11. [Crossref] [PubMed]
14. Hamdan AL, Deeb R, Sibai A, Rameh C, Rifai H, Fayyad J. Vocal characteristics in children with attention deficit hyperactivity disorder. J Voice. 2009;23(2):190-4. [Crossref] [PubMed]
15. Hollien H. On pubescent voice change in males. J Voice. 2012;26(2):e29-40. [Crossref] [PubMed]
16. Pabst F. Development of the singing voice in children: phonetographic investigation in a boy's choir. In: White P, ed. Child Voice. 1st ed. Stockholm: KTH Voice Research Centre; 2000. p.69-73. [Link]
17. Fuchs M, Behrendt W, Keller E, Kratzsch J. Methoden zur vorhersage des eintrittszeitpunktes der mutation bei knabenstimmen: untersuchungen bei sängern des thomanerchores Leipzig. [Prediction of the onset of voice mutation in singers of professional Boys' choirs: investigation of members of the Thomaner choir, Leipzig]. Folia Phoniatr Logop. 1999;51(6):261-71. [Crossref] [PubMed]
18. Willis EC, Kenny DT. Relationship between weight, speaking fundamental frequency, and the appearance of phonational gaps in the adolescent male changing voice. J Voice. 2008;22(4):451-71. [Crossref] [PubMed]
19. Fuchs M, Fröehlich M, Hentschel B, Stuermer IW, Kruse E, Knauft D. Predicting mutational change in the speaking voice of boys. J Voice. 2007;21(2):169-78. [Crossref] [PubMed]