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FUNDAMENTAL FREQUENCY OF THE VOICE IN RELATION TO HYPOXIA AS A STRESSOR

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Abstract. *The activity of vocal cords during speech production generates the basic fundamental frequency of the voice. Under the influence of any kind of stressors, the basic frequency features change. Hypoxia is a powerful stress factor. It causes a decline of the complete functional state of the organism. The aim of our research is to examine if there is any connection between the height of 1600m which is slightly hypoxic and the physical parameters of the basic frequency. The height of 1600m is generally called the threshold of reactions. At the height of 1600m and a bit higher, the first reaction of the organism to hypoxic conditions can be noticed. A group of subjects pronounced the vocals **I**, **E**, **A**, **O** and **U** at the heights of 400 and 1600 meters and we examined the changes in the contour, average frequency, intensity and the length of the fundamental frequency.The results show that there is an important effect of the 1600m height due to the fundamental voice frequency while pronouncing the vocals. Under these conditions, the distortion of the contour of the basic frequency occurs, the average value of the frequency is higher and the intensity and duration are reduced.*

Key words: *speech signal, fundamental frequency, stress, hypoxia*

INTRODUCTION

It is often emphasized that the increase of voice pitch indicates the influence of some physical and psychical stressor on human organism. The voice pitch depends on the speed of vocal chords' movements. During speech these movements generate the basic voice frequency which has its physical parameters. A large number of muscles that regulate the vocal chords' function perform like a fine motor, which can be easily affected by any intensive stressor. One of the physical stressogenic factors is hypoxia. Hypoxia is the lowering of the partial pressure of oxygen, that is, the reduction of molecular concentration of O2 in the organism's tissues. It is a powerful stressor. It exerts its influence on all levels of the living organism. The disorder of this fine motor, such as phonation (voice production) and articulation (speech production) are particularly perceivable.

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The aim of this research was to determine the effect of slightly hypoxical altitude of 1600 m on the fundamental voice frequency (Fo). This work is a part of a larger experiment that is still in progress, about the fundamental voice frequency features (Fo) in the function of altitude of 1600 meters. The 1600m altitude belongs to the lower altitudes above sea level. However, in the literature about hypoxia in a broader sense this altitude is called reaction threshold. At this altitude the air pressure, that is, the partial pressure of oxygen $p(O_2)$ is slightly lowered and the blood saturation by oxygen ranges between 90% and 95%. The elevation of 1600 m is an indifferent zone. The changes in the functioning of the organism can not be registered in this zone. The organism easily deals with the lack of oxygen in the air it breaths in, thanks to its compensating mechanisms. In this zone a man can preserve his full working ability. That is why the air stratum to 1600m is called a full compensation zone. The first reactions of the organism to hypoxic conditions were observed at the altitude of 1600 m and somewhat higher. The activity level of all functioning systems of the organism started to change.

Visible deviations of psycho-physiological functions from the normal ones were not registered while observing people who by origin live at the altitude of 1600 m above sea level. However, it is probable that specific ecological factors of this altitude characteristically affected some phylogenetically young and highly differentiated functions, such as, for example, voice and speech production.

The hypothesis given above indicated the specific aim of this research: to find out if there was any effect of the height of 1600 m above sea level on the vocal chords' function, i.e. fundamental voice frequency, first in case of acute and chronic exposition to this altitude and, second, on the subjects that live at this altitude by origin.

METHOD AND PROCEDURE

The subjects: Two groups of subjects were observed, each consisting of five (four male and one female). The first group consisted of the subject that lived at the altitude of 400 m above sea level by origin, and the second group consisted of subjects that lived at the altitude of 1600 m above sea level by origin.

The material: The samples of the speech material that was analyzed were the vocals: A, E, I, O and U, each pronounced separately. The group of subjects that live at the altitude of 400 m above sea level pronounced the vocals first at this altitude and then at the altitude of 1600 m in natural environment- in the mountain (Golija, west Serbia) - acute exposition. The subjects that live at the altitude of 1600 m above sea level pronounced the vocals at the same altitude- chronic effect of the height of 1600 m. Each subject from both groups pronounced these vocals three times with the pause of a few minutes between.

Instruments: While taking the samples of the speech material, the speech signal was being recorded on a tape recorder under the controlled conditions. The distance between the microphone and the mouth was 30 cm. The speech signal was drawn from the tape recorder through the 1/3 octave frequency-intensity digital analyzer that had been produced by Bruel&Kjaer, type 2131. The analyzer was connected to the computing machine produced by HP (Hewlett Packard 9825B Calculator and HP Plotter 9872A). The vocal that entered the analyzer was analyzed in accordance with its three fundamental acoustic parameters: frequency, intensity and duration.

Extraction of Fo: The fundamental frequency, i.e. the frame of fundamental frequency of the vocal that had been analyzed, was extracted from the frequency band of 60-300 Hz, i.e. from the range where it appeared. The extraction was carried out by marking the frequency of the highest intensity in that frequency range for a certain time sample of the speech signal.

ANALYSIS AND DISCUSSION OF RESULTS

The modifications of the following parameters were analyzed: average Fo (Hz), contour Fo (Hz), summary intensity Fo (dB) and the intensity-time curve Fo.

The analysis of **acute** effect of the altitude of 1600m on Fo, gave the following results. **1. Average Fo(Hz)**: There is no significant difference between the average values Fo (Hz) for the articulation at these two altitudes, $F(1,46) = 0.102$. The average values Fo (Hz) of the vocals pronounced at the height of 400m have a slight deviation from the central value, while the deviation of pronouncing below the height of 1600m is significant. This might have been the consequence of the lack of vocal chords' synchronization under the acute conditions of 1600m height (Figure 1).

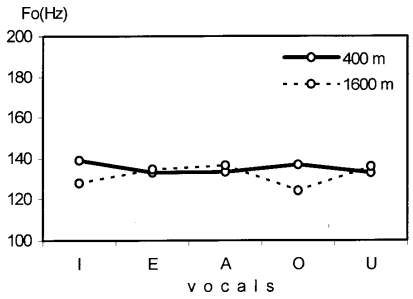

Fig. 1

2. Contour Fo - the frequency flow in the function of time (frequency-time curve): The analysis of contour Fo, averaged by subjects, of the vocals pronounced at 400 m and 1600m showed that the increase of Fo (Hz) in the initial phase of pronouncing is characteristic for all the vocals pronounced at 1600 m (Figure 2, example vocal **I**).

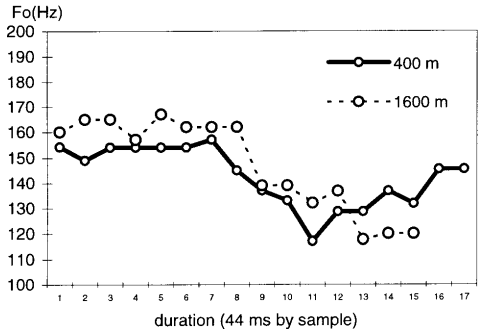

Fig 2.

3. The summary intensity - Fo (dB): While determining the significance of the differences for summary intensity Fo under the acute influence of the altitude of 1600 m, the application of ANOVA showed that the differences of the altitude effects on the intensity Fo were not significant $F(1,46) = 0.23$. The intensity of the vocals I, E and U was lower when pronounced under the acute conditions of the 1600 m height, while the vocals A and O as the most balanced ones, had similar intensity at both altitudes. The stressogenic effects of this height on man's phonation mechanism cause the lower intensity of Fo for these vocals at 1600 m height (Figure 3).

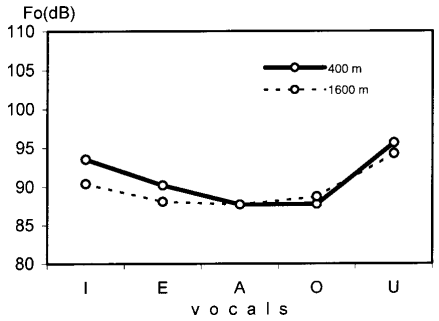

Fig. 3.

4. The amplitude-time analysis (intensity flow in the function of time): The amplitude-time curves of the subjects who live at the 400m height pronouncing at 400 m and 1600 are not the same for all vocals. The 400 m pronouncing curves are usually a bit more intensive than the 1600 m pronouncing curves (Figure 4, example vocal **I**)

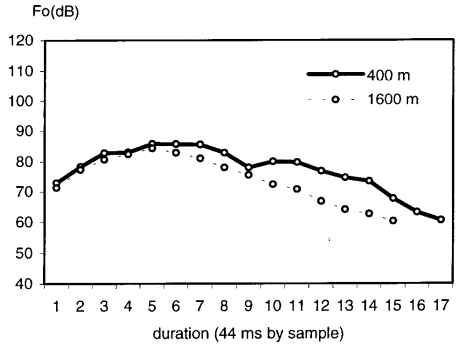

Fig. 4.

The effects of the **chronicle** influence of 1600 metres altitude on fundamental frequency (Fo) are:

1. Average Fo (Hz): Diagram shows the average values for Fo (Hz) for all five vocals averaged by subjects, for the pronouncing at 400 m by the subjects that live at that altitude (full line) and by the subjects that live at 1600m (intermittent line)- chronic influence. Fo (Hz) for all vocals of the subjects that live at 1600m was significantly higher if compared to Fo (Hz) of the vocals of subjects that live at 400m. So, one of the chronic influence effects of 1600m altitude is the increase of Fo (Hz) (Figure 5).

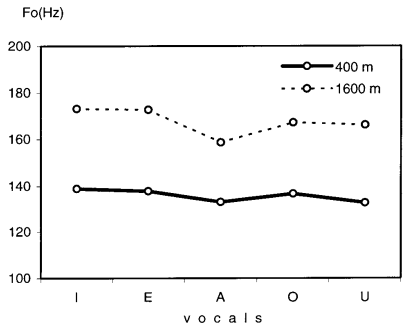

Fig. 5.

2. Contour of Fo (Hz): During the chronic influence of 1600 m altitude on the subjects, contour Fo (Hz) was significantly above the contour of the vocal pronounced at 400 m for the subjects who lived at that altitude (Figure 6, example vocal **I**).

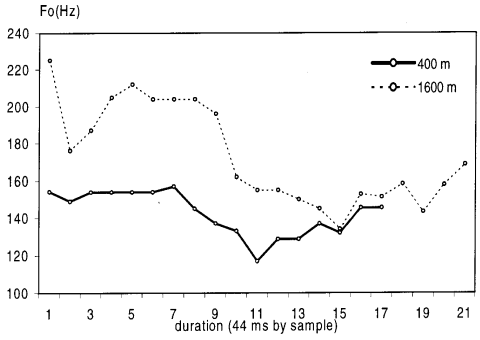

Fig. 6.

3. The summary intensity: There was a significant effect of the chronic influence at the 1600m altitude on the summary intensity Fo (dB) of the vocals, F (1,46)=7.762; p - 0.01. Greater intensity Fo (dB) under the conditions of chronic influence was a sign of beneficial effect of this altitude on human organism (Figure 7).

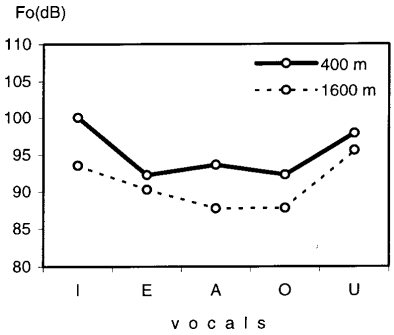

Fig. 7.

4. The amplitude-time analysis of Fo: The intensity Fo (dB) of vocals pronounced by highlanders during any time sample was significantly above the intensity Fo for the control group (400m). The intensity curves were almost identical in their peaks, which were in the same time sample of the speech for both altitudes. That probably means that the intensity of the Fo vocal in that time sample was most resistant to the changes effected by that altitude and so it represented a constant phonological feature of the Fo vocals (Figure 8, example vocal **I**).

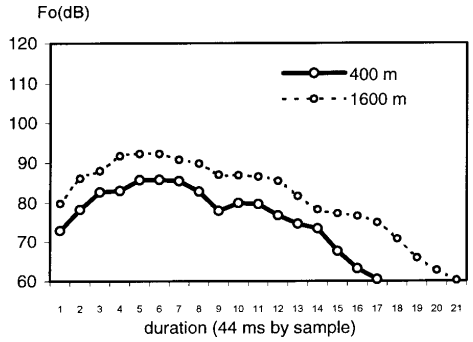

Fig. 8.

CONCLUSION

Hypoxia, as well as other stressors cause the increase of Fo (Hz), that is, the voice pitch. There is the effect of slightly hypoxical altitude of 1600 m on Fo of the voice. These effects are not the same for acute and chronic influence of the altitude of 1600 m on the vocal chords' performance, i.e. the Fo of the voice. During the acute effect of the 1600 m altitude on human organism, in the initial phase of articulation, the increase of Fo (Hz) and slight decrease of the intensity Fo (dB) were observed. During the chronic effect of the 1600 m altitude on human organism, i.e. the phonation, the pitch Fo (Hz) and intensity Fo (dB) of the fundamental frequency of voice were significantly increased. The increase in Fo (Hz) during the acute and chronic effect of the 1600 m altitude is a common characteristic. However, the decrease of the intensity Fo (dB) during the acute effect and the significant increase of Fo intensity during the chronic effect suggest that the acute effect of 1600 m altitude is stressogenic, while the chronic effect has a beneficial influence over the human organism.

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OSNOVNA FREKVENCIJA GLASA U FUNKCIJI HIPOKSIJE KAO STRESORA

Joviša Obrenović

Rad glasnih žica pri produkciji govora generiše osnovnu frekvenciju glasa. Pod dejstvom bilo kakvog stresora menjaju se karakteristike osnovne frekvencije govora. Hipoksija je moćan stresogeni faktor. Ona uslovljava menjanje kompletnog funkcionalnog stanja organizma. Cilj našeg istraživanja je da se utvrdi postoji li veza između blago hipoksične visine 1600 m i fizičkih parametara osnovne frekvencije glasa, odnosno vokala. Visina 1600 m se u širem smislu naziva pragom reakcija. Na visini 1600 metara i nešto iznad nje zapažaju se prve reakcije organizma na hipoksične uslove. Grupa ispitanika izgovarala je vokale I, E, A, O i U na visinama 400 i 1600 m. Ispitivane su promene konture, prosečne frekvencije, intenziteta i trajanja osnovne frekvencije vokala pri izgovoru u navedenim uslovima. Rezultati pokazuju da postoji značajan efekat visine 1600 m na osnovnu frekvenciju (Fo) glasa pri izgovoru vokala. Dolazi do distorzije konture osnovne frekvencije, srednja vrednost frekvencije je povećana, a intenzitet i trajanje izgovora vokala su smanjeni.

Ključne reči: *govorni signal, osnovna frekvencija, stres, hipoksija*