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Analysis of the cough sound frequency in adults and children with bronchial asthma

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It is well known that the frequency distribution of cough sound varies in different pathological conditions. Its identification could have diagnostic value. In this study the cough sound frequency in adults (n=20, 51.7±11 yrs), children (n=21, 11.8±0.4 yrs) asthmatics and healthy volunteers (n=25, 21 yrs) was explored. All patients were suffering from bronchial asthma. They were on a stable therapeutic regime and in a quiet status. Voluntary cough sound was recorded by a microphone and a tape recorder and digitally processed. Overlapping technique and Fast Fourier Transform were used to estimate the sound spectra. The records were smoothed by the method of Pascal triangle. They demonstrate the mean values of cough sound spectra. The registered pseudo three-dimensional plots of cough sound frequency (1 K spectra as function in time) of adults showed that the intensity of frequencies increased from 100 to 900 Hz in 3–4 waves. These frequencies afterwards decreased and between 1 to 2 kHz a smaller elevation was present. The spectra of children resembled to the spectrum of adults but had a smoother course. The spectra of asthmatics had some specificity and differed from the spectrum of healthy volunteers.

Keywords: cough sound frequency, spectrogram in asthmatics, adult asthmatics, children asthmatics

The timbre of the cough sound could be typical and characteristic in some diseases of the airways and lungs. The sound timbre is determined by its frequency, the distribution of which varies in different pathological conditions. If it is properly identified, it could be of value for the diagnosis. However, some of the authors (10) who studied the spontaneous and voluntary cough sound in patients with chronic lung diseases by means

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of the Fast Fourier Transform (FFT) analysis stated, that the sound frequency considerably varied between subjects and within different cough from the same subject. The inter- and intra-subject heterogeneity of the characteristics of the cough sound might pose an obstacle in the development of a reliable method of cough detection based on acoustic parameters. We studied recently this problem in patients who suffered from chronic bronchitis (5). We found the same problem that Olia et al. (10) had pointed out. That made us to study the cough sound frequency in adult and children asthmatics.

Subjects and Methods

The 1st group consisted of 20 adult patients (12 females, 8 males; 51.7±11 yrs). The 2nd group consisted of 21 child patients (11 females, 10 males; 11.8±0.4 yrs).

In adults and children bronchial asthma had previously been diagnosed on the basis of clinical criteria (8, 9, 16). The patients were in quiet clinical status and on stable therapeutic regimen for the four weeks prior to their admission to Sanatorium Helios (High Tatras, Slovakia); the treatment for asthma was prescribed by the Health dispensaries. The patients for the study were selected with approximately equal degree of asthma and therapy (all had been on corticoids with individual differences in bronchodilators), from a group of 200 asthmatics. This basic therapy could not be omitted according to the decision of the Medical Ethical Committee of Sanatorium.

Prior to our study the child patients were subjected to experimental therapy by pulsatile electromagnetic field. It has been applied by the equipment MTU 500H (Therapic System, Brno, Czech Republic) twice daily for 20 m with a magnetic induction of 3 m T and a frequency of 4.5 Hz, for 5 days (one complete cure), as recommended by the manufacturer (Biotrop parameters for MTU 500H). The magneto therapy was permitted to children by the Medical Ethical Committee of Sanatorium.

The 3rd group was composed of 25 healthy volunteers (12 females, 13 males, 21 yrs) without symptoms or signs of chest infection.

Cough sound

The voluntary cough from all the patients and healthy volunteers was recorded on tape and digitalized in an IBM-compatible personal computer with 8 bit resolution at a sampling rate of 10 kHz. These sounds were subjected to spectral analysis through Fast Fourier Transform on an overlapping window of 256 samples (12.8 ms). The records were smoothed by a method of PASCAL's Triangle. The used method was basically identical with literary data (2, 11, 13, 17, etc.).

Experiments were initiated to evaluate the energy expanded in cough by integrating the power spectral in the frequency domain from 50–2 500 Hz.

The frequency distributions were compared between each other, in asthmatics and between asthmatics and healthy volunteers.

Statistics

To compare unpaired values of spectra of cough sounds Student's test was used, setting $p<0.05$ as the limit of statistical significance. The data are given as means ± S.E.M.

Results

The registered mean values of pseudo three-dimensional plots of cough sound frequency in adult asthmatics (1st group) showed that the intensity of frequencies increased (elevation of amplitude) in 3–4 waves over a span of the frequency range from 100 to 900 Hz. The intensity of frequencies afterwards decreased. They appeared again between 1000–2000 Hz in the further spectrum, but with a lower amplitude (Fig. 1A).

The spectrogram in children (2nd group) before the pulsatile electromagneto-therapy was less typical. The records had a smoother course except for a large response at the last time of sound (Fig. 1B). The spectrum of cough sound in children after electromagneto-therapy was more pronounced, and resembled the spectrum in adults (Fig. 1C). Thus the spectrograms from asthmatics showed some similarity.

The visual similarity was also statistically confirmed. The power spectra compared among asthmatics showed only sporadic statistical differences, totally about 1% (Fig. 2A). On the other hand, comparison of power spectra of asthmatics with those of healthy volunteers (3rd group) showed pronounced, statistically significant differences, about 40% (Fig. 2B). The difference between percentages is also statistically significant.

Discussion

The results showed that the mean values of the cough sound spectra in patients suffering from bronchial asthma had a similar character, which distinctly differed from healthy volunteers. Particularly different is the difference of the mean values of the cough sound spectra between asthmatics and bronchitics. The cough sound spectrum of bronchitic patients was the matter of our previous studies (5). Similarly we did not analyse the sound spectrum in healthy volunteers because it had been already studied before (3, 4, 6, 11, 12, etc.).

We have found that the FFT spectra of the voluntary cough sound spectrum of patients suffering from asthma showed higher frequencies in comparison with healthy volunteers and *vice versa* the spectrum of asthmatics was shown to be lower in frequency than those with chronic bronchitics, in agreement with literature (13, 14).

We had ascertained that the registered mean values of pseudo three-dimensional plots of cough sound frequency in adult asthmatics showed the increased spectra in two parts. At first between 100 to 900 Hz and secondly between 1–2 kHz.

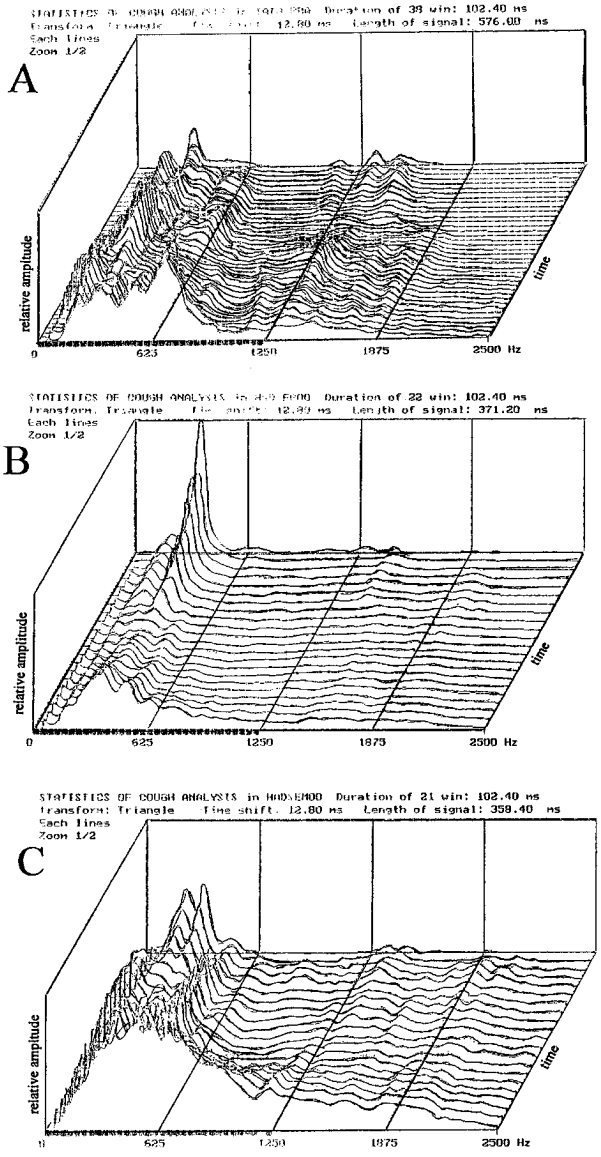

Fig. 1. Comparison of the spectrograms from adults (A) and children before (B) and after (C) treatment by pulsatile electromagnetic field
(A-duration of 39 win.: 102.40 ms, time shift: 12.80 ms, length of signal: 576.00 ms;
B-duration of 22 win.: 102.40 ms, time shift: 12.80 ms, length of signal: 371.20 ms;
C-duration of 21 win.: 102.40 ms, time shift: 12.80 ms, length of signal: 359.40 ms)

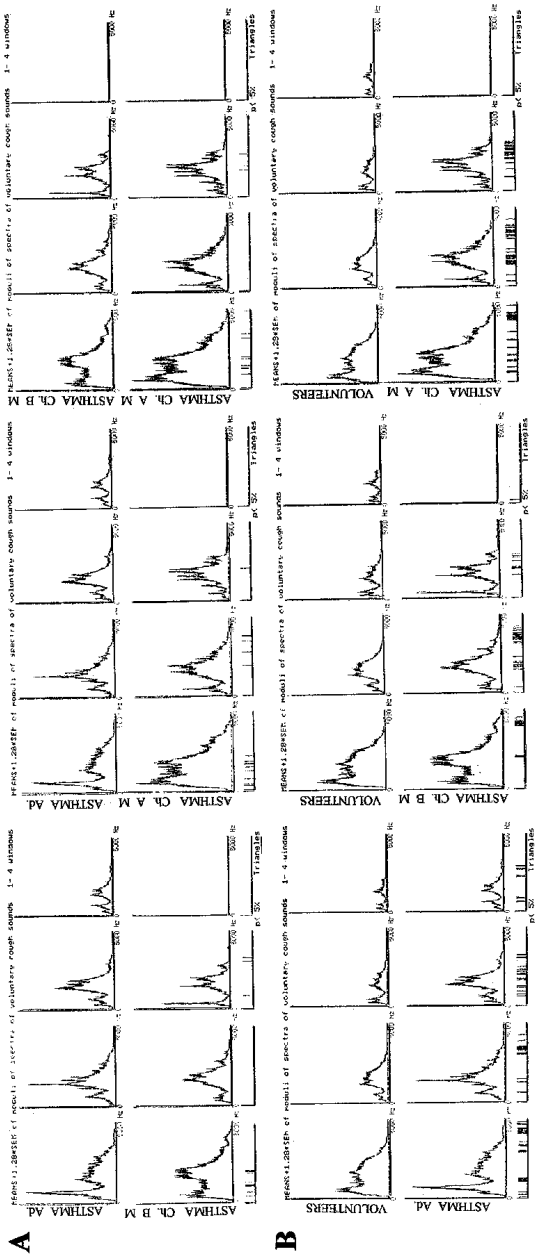

Fig. 2. Comparison of the power spectra between each other in asthmatic patients (A) and between volunteers and asthmatics (B)
(Adult asthmatics- [ASTHMA Ad], Children before electromagnetic treatment- [ASTHMA Ch.B.M] and children after treatment- [ASTHMA Ch.A.M]. Healthy volunteers- [VOLUNTEERS])

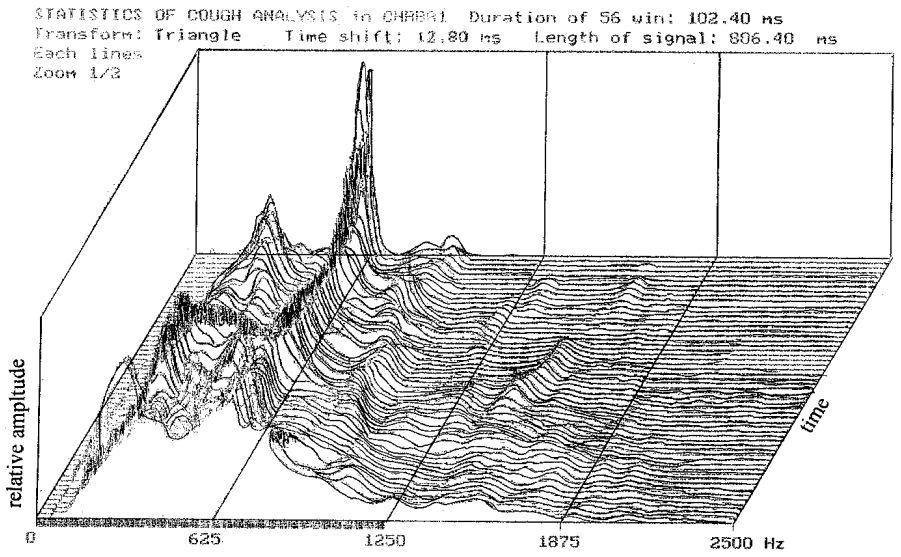

Fig. 3. Spectrogram from patients suffering from chronic bronchitis
(Duration of 56 win.: 102.40 ms, time shift: 12.80 ms, length of signal: 806.40 ms)

The spectrogram in children showed similar pattern. It was less expressive in children before treatment by pulsatile electromagnetic field, which therapy we used for experimental treatment of bronchial asthma. The cough spectrum in children after the mentioned therapy was more expressed. We have supposed that it was in consequence of higher congestion and secretion in the airways. This assumption has already been described (7).

This similarity we have found in spectrograms in asthmatics was confirmed indirectly by statistical methods. Statistically significant differences between power spectra of adult and child asthmatics were sporadic only, but the comparison of power spectra with volunteers and asthmatics was significant. Particularly evident is the difference between spectrograms of asthmatics and bronchtics.

Surprisingly, despite of our efforts, we have not found any direct statistical method for testing the similarity (1).

Originally the aim of our study was to find some typical features of the spectrogram in asthmatics, which could have some diagnostic value. In our view this “asthma feature” must be present regardless of age, sex or therapy, which can only be partially effective. The difficulties in reaching our aim were based on the differences of cough spectra among asthmatics (insufficient knowledge of pathogenesis), on

differences in the architecture and individual properties of the airways and lungs not recognized and on the differences resulting from different clinical stage of asthma, which usually are not taken into consideration.

We have found only striking similarity of cough sound spectra among the observed groups in average. Another problem emerges when the values are averaged which can obscure the diagnostic value of cough sound spectra typical for asthma.

The description of the effectivity of pulsatile electromagnetic field in asthmatic children is the topic of another paper. The young patients after this therapy were without respiratory symptoms and coughing but also without statistically significant improvement in pulmonary function test indices. We suppose that the repetition of the cure as was recommended by experts, could significantly improve the pulmonary function tests. We recommended this therapy as a complementary cure.

With regard to the basic methodology of respiratory analysis there are marked similarities in the main world centres (11, 13, 17, etc.). However, there are many variations in the details of sound capture and analysis techniques between researchers, which make the comparison of results from the different centres difficult (2). We suppose that this fact could be some other cause of incomparability of sound spectra, except the mentioned before.

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