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Assessment of acoustic signal characteristics in children with community-acquired pneumonia according to the prevalence and nature of lung tissue damage using the new device «Trembita-Corona»

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Relevance. According to the new orders and guidelines of 2022, radiography is not performed for all children. Therefore, the creation of a fully automated system of control and assessment of breathing sounds, without exposing patients to radiation, is currently an urgent task.
Purpose — to determine the features of the acoustic signal in segmental and focal pneumonia in children with a new acoustic diagnostic device «Trembita-Corona».
Materials and methods. 76 children aged from 1 month to 18 years were examined. The children were divided into two groups: the Group 1 — 47 patients with segmental pneumonia; the Group 2 — 29 patients with focal pneumonia. All children were also examined using the «Trembita-Corona» acoustic monitoring device.
Results. The acoustic signal was investigated in 12 octaves. The first 9 octaves were the most promising. Each octave was divided into third octaves. We found reliable differences in the average signal power in 0, 1, 4, 6, 7, 15, 20, 23–26 third octaves.
When studying the average signal power between children with segmental and focal pneumonia, the main differences were found precisely in the frequency of peaks in 0–3,10,11,14–16, 18,20,22 third octaves.
Conclusions. The use of the acoustic monitoring device «Trembita-Corona» in making a diagnosis is very promising method. The average signal power between children with segmental and focal pneumonia, the main differences were found precisely in the frequency of peaks in 0, 1, 2, 3, 10, 11, 14, 15, 16, 18, 20, 22 third octaves.
The research was carried out in accordance with the principles of the Helsinki Declaration. The study protocol was approved by the Local Ethics Committee of all participating institutions. The informed consent of the patient was obtained for conducting the studies.
No conflict of interests was declared by the authors.
Keywords: acoustic monitoring, «Trembita-Corona» device, community-acquired pneumonia, focal pneumonia, segmental pneumonia, children.

Визначення особливостей акустичного сигналу при негоспітальній пневмонії в дітей за поширеністю і характером ураження легеневої тканини за допомогою нового приладу «Trembita-Corona»

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Актуальність. Згідно з новими наказами і настановами 2022 року, рентгенографія проводиться не всім дітям і тільки в прямій проєкції. Отже, створення повністю автоматизованої системи контролю та оцінки дихальних шумів, без опромінення пацієнтів, наразі є актуальним завданням.
Мета — визначити особливості акустичного сигналу при сегментарній та вогнищевій пневмонії в дітей за допомогою нового приладу акустичної діагностики «Trembita-Corona».
Матеріали та методи. Обстежено 76 дітей віком від 1 місяця до 18 років. Дітей поділено на дві групи: I група — 47 пацієнтів із сегментарною пневмонією; II група — 29 пацієнтів із вогнищевою пневмонією.
Результати. За допомогою нового приладу акустичної діагностики «Trembita-Corona» виявлено особливості акустичного сигналу при позалікарняній пневмонії в дітей, зокрема, сегментарній та вогнищевій. Акустичний сигнал досліджено у 12 октавах. Найбільш перспективними були перші 9 октав. Кожну октаву поділено на третьоктави. Нами знайдено достовірні відмінності по середній потужності сигналу в 0,1,4,6,7,15,20,23,24,25,26 третьоктавах, що можуть пришвидшити і поліпшити диференційну діагностику між сегментарною і вогнищевою пневмонією.
За результатами дослідження середньої потужності сигналу між дітьми із сегментарною і вогнищевою пневмонією основні відмінності виявлено саме за частотою піків в 0,1,2,3,10,11,14,15,16,18,20,22 третьоктавах.
Висновки. У встановленні діагнозу застосування пристрою акустичного моніторингу «Trembita-Corona» та використання розробленого спеціалізованого програмного забезпечення мовою Python у середовищі «Google Codelabs» дають змогу діагностувати різницю між сегментарною і вогнищевою пневмонією. Під час дослідження середньої потужності сигналу між дітьми із сегментарною і вогнищевою пневмонією основні відмінності виявлені саме за частотою піків у 0, 1, 2, 3, 10, 11, 14, 15, 16, 18, 20, 22 третьоктавах.
Дослідження виконано відповідно до принципів Гельсінської декларації. Протокол дослідження ухвалено Локальним етичним комітетом зазначеної в роботі установи. На проведення досліджень отримано інформовану згоду батьків, дітей.
Автори заявляють про відсутність конфлікту інтересів.
Ключові слова: акустичний моніторинг, прилад «Trembita-Corona», позалікарняна пневмонія, вогнищева пневмонія, сегментарна пневмонія, діти.

Introduction

Currently, community-acquired pneumonia (CAP) in children is an urgent problem [13–16]. Early diagnosis of CAP is of great importance for correct diagnosis and initiation of appropriate therapy.

In Ukraine, the diagnosis of CAP is carried out in accordance with the order of the Ministry of Health of Ukraine No. 1380 of 02.08.2022. According to this order, doctors of all specialties must be aware of the main clinical manifestations of CAP, because the purpose of this order is precisely early diagnosis and adequate treatment to prevent the development of complications. According to the order, the diagnosis of CAP is established on the basis of the collection of anamnesis, clinical data, as well as the application of the results of instrumental and laboratory research methods [10].

The guideline «Pneumonia in children» 2022 is also used to diagnose CAP [9]. According to this guideline, the diagnosis of CAP is made clinically, and further examinations are carried out depending on the risk assessment and individual parameters [9]. The guidelines also cover the issue of chest X-rays in children. The guideline states that X-ray examination is not recommended for patients with a mild form of CAP [1–4,6].

However, in patients with persistent but non-pathognomonic symptoms of CAP, radiography should be performed to establish a final diagnosis [12].

Therefore, currently non-radiation methods of diagnosis have practical value and relevance [5,8,11]. For the diagnosis of CAP, the method of respiratory acoustics is currently promising. The main tasks of respiratory acoustics are the development of the theory of propagation and generation of sound in the lungs and the creation of objective acoustic methods, which in turn will improve the diagnosis of CAP in children [3,5,8,11].

We and leading specialists of National Aviation University have developed the «Trembita-Corona» acoustic monitoring device for the diagnosis of respiratory sounds above the lungs. This device carries out acoustic monitoring of the lungs, which in turn speeds up the diagnosis and helps to localize the zones of lung damage (Utility Model Patent No. 148836 Acoustic Monitoring Device with Axial Directional Pattern) [11]. In previous works, we discovered that for determining the inflammatory process in the lungs during pneumonia, the most promising are the studies of respiratory signals in the ranges of 0, 1, 2, 3, 4, 5, 6 octaves.

According to the 2022 guideline «Pneumonia in children» [9], CAP are divided into focal (bronchopneumonia), segmental, lobar and interstitial pneumonias according to the prevalence and nature of lung tissue damage. In our article, we investigated the acoustic signal in children with focal (bronchopneumonia) and segmental pneumonia. According to the definition, in focal pneumonia, infiltrative changes have the appearance of separate small foci on an X-ray, and in segmental pneumonia, an inflammatory lesion of the entire segment or several segments of the lung occurs. According to the new orders and guidelines of 2022, radiography is not performed for all children and only in direct projection. Therefore, the creation of a fully automated system of control and assessment of breathing sounds, without exposing patients to radiation, is currently an urgent task.

The purpose of the study — to determine the features of the acoustic signal in segmental and focal pneumonia in children using the new acoustic diagnostic device «Trembita-Corona».

Materials and methods of the study

47 children with segmental pneumonia (the Group 1) and 29 children with focal pneumonia (the Group 2) participated in the study. The children were aged from 1 month to 18 years (10.61±0.5 years). Among them, there were 20 boys and 27 girls in the Group 1, and 10 boys and 19 girls in the Group 2.

The diagnosis «CAP» (segmental or focal) was established on the basis of anamnestic, clinical laboratory and radiological data.

The criteria for including children in the examination are shown in Table 1.

Clinical examination included: collection and detailing of complaints, anamnesis of the disease, objective examination (percussion, palpation, auscultation), X-ray of lungs, laboratory tests (general blood test, biochemical blood test).

All children were also examined using the «Trembita-Corona» acoustic monitoring device to diagnose acoustic signals and determine the localization of lung lesions [3,5,11]. The general view of the «Trembita-Corona» acoustic monitoring device is shown in Fig. 1.

To analyze the acoustic characteristics of the recorded signals, select the characteristic frequency ranges, and mathematically process the signal

Table 1

Criteria for inclusion and exclusion of patients in the study

The inclusion criteria	The exclusion criteria
a diagnosis of «CAP» (segmental or focal), confirmed by anamnestic, clinical laboratory and radiological data; the age of children is from 1 month to 18 years; informed consent of the child's parents or guardians.	congenital pneumonia; endocrine diseases (hypothyroidism, hypocorticism, pseudohypoparathyroidism, growth hormone deficiency); genetic syndromes (Prader—Willi, Kogan, Carpenter, etc.); congenital heart defects and organic brain diseases.

parameters, specialized software was developed in the Python language in the Google Codelabs environment. Further statistical calculations were performed in specialized programs Medstart and EZR (R-Statistics).

The study was conducted in accordance with the international principles of conducting clinical studies GCP, GLP, the protocol was approved at the meeting of the Commission on Bioethical Expertise at the Bogomolets National Medical University. Informed consent of parents/guardians was obtained for conducting the study, which was approved at the same meeting of the Commission on Bioethical Expertise at Bogomolets National Medical University.

Fig. 1. A sample of the «Trembita-Corona» acoustic monitoring device

Results and discussion of the study

Using the «Trembita-Corona» acoustic monitoring device, sounds are analyzed in different octaves, and an octave was considered to be an interval in which the frequency ratio between sounds is one to two, that is, the frequency of a high sound is twice as high [3,5,9,13,15]. Subjectively by ear, the octave is perceived as a stable, basic acoustic interval. Successive octaves make up sounds that are similar to each other, although they differ in pitch. A frequency of 1000 Hz was taken as the base frequency.

Table 2 presents the limit frequencies of the band (f_1 and f_2) in Hz of the first 11 octaves, and in the calculations it was assumed that the lowest and highest octaves include frequencies from 0.1 Hz to 30 kHz, respectively.

For more precise diagnosis, all octaves were divided into third octaves. The limiting frequencies of each third octave are presented in Table 3.

0 octave is in the interval from 0.1 to 11.2208 Hz. When comparing the average values of the signal power at 0 octaves in children from the Groups 1 and 2 according to the Student's test, it

Table 2

Minimum and maximum frequencies (f_1 and f_2) in the first 11 octaves, which are presented in Hz

Octaves	f_1	f_2
0	0.1	11.22018
1	11.22018	22.38721
2	22.38721	44.66836
3	44.66836	89.12509
4	89.12509	177.8279
5	177.8279	354.8134
6	354.8134	707.9458
7	707.9458	1412.538
8	1412.538	2818.383
9	2818.383	5623.413
10	5623.413	11220.18
11	11220.18	30000

Notes: f_1 — is the minimum frequency in the octave; f_2 — is the maximum frequency in the octave.

Table 3

Minimum and maximum frequencies (f_1 and f_2) in third octave from 1–9 oktaves in Hz

1 octave (11.2208 — 22.38721 Hz)			
	1 third octave	**2 third octave**	**3 third octave**
f_1	11.22018	14.12538	17.78279
f_2	14.12538	17.78279	22.3872
2 octave (22.38721 — 44.66836 Hz)			
	4 third octave	**5 third octave**	**6 third octave**
f_1	22.3872	28.1838	35.4813
f_2	28.1838	35.4813	44.6683
3 octave (44.66836 — 89.12509 Hz)			
	7 third octave	**8 third octave**	**9 third octave**
f_1	44.66836	56.23413	70.79458
f_2	56.23413	70.79458	89.12509
4 octave (89.12509 — 177.8279 Hz)			
	10 third octave	**11 third octave**	**12 third octave**
f_1	89.12509	112.2018	141.2538
f_2	112.2018	141.2538	177.8279
5 octave (177.8279 — 354.8134 Hz)			
	13 third octave	**14 third octave**	**15 third octave**
f_1	177.8279	223.8721	281.8383
f_2	223.8721	281.8383	354.8134
6 octave (354.8134 — 707.9458 Hz)			
	16 third octave	**17 third octave**	**18 third octave**
f_1	354.8134	446.6836	562.3413
f_2	446.6836	562.3413	707.9458
7 octave (707.9458 — 1412.538 Hz)			
	19 third octave	**20 third octave**	**21 third octave**
f_1	707.9458	891.2509	1122.018
f_2	891.2509	1122.018	1412.538
8 octave (1412.538 — 2818.383 Hz)			
	22 third octave	**23 third octave**	**24 third octave**
f_1	1412.538	1778.279	2238.721
f_2	1778.279	2238.721	2818.383
9 octave (2818.383 — 5623.413 Hz)			
	25 third octave	**26 third octave**	**27 third octave**
f_1	2818.383	3548.134	4466.836
f_2	3548.134	4466.836	5623.413

Notes: f_1 — is the minimum frequency in the third octave; f_2 — is the maximum frequency in the third octave.

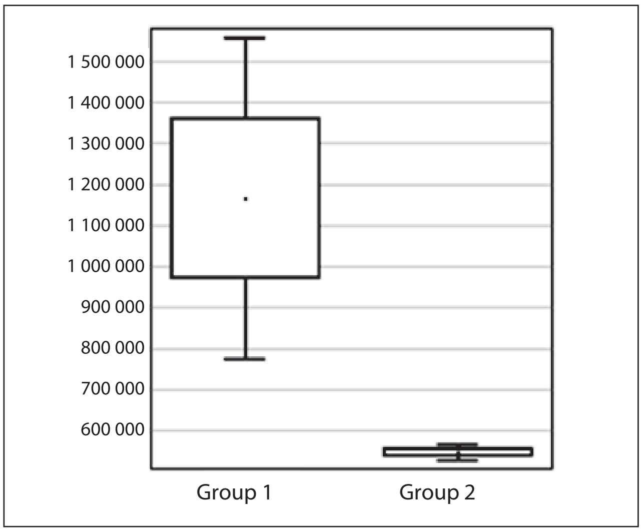

Fig. 2. Probable interval when comparing central tendencies for two independent samples, namely children of the Groups 1 and 2 in the 0 octave (p=0.003)

was found that the averages differ at the significance level of p=0.003, which is presented in Fig. 2. As can be seen from Fig. 2, the acoustic signal of patients is characterized by high signal uniformity at the Group 2, but in the Group 1 there are additional influencing factors that depend on the location of the segment when recording the acoustic signal.

In 0 octave, in the frequency range from 0.1 to 11.2208 Hz, it was found that in the Group 1, the characteristic frequency peak was at 9.59±0.3 Hz, and in the Group 2, this peak was at the frequency 10.74±0.01 Hz (p<0.001). The amplitude of peaks in children of both groups also differed p=0.003.

1 octave is in the interval from 11.2208 to 22.38721 Hz. For more precise diagnosis, 1 octave was divided into third octaves.

When comparing the average values of the signal power in the **1 third octave** in children of the Groups 1 and 2 according to the Student's test, it was found that the averages differ at the level of significance **p<0.001**, which is presented in Fig. 3. As can be seen from the graph, the acoustic signal of patients is characterized by high signal uniformity at the Group 2, however, with the Group 1, the homogeneity of the signal is lost, which may be related to the large area of the location of the pathological focus.

In addition, the acoustic signal in the Group 1 can be characterized by the fact that in 1 third octave in 80.86% of cases, a characteristic peak at a frequency of 12.08±0.13 Hz is observed. And the other 19.14% of cases do not have this characteristic peak.

In the 1 third octave, children of the Group 1 can be divided into two characteristic subgroups, depending on the peak frequency:

— the subgroup 1 from 11 to 12 Hz,

— the subgroup 2 from 12 to 13.5 Hz.

When conducting multiple comparisons using the Scheffe method in the 1 third octave between two subgroups of the Groups 1 and 2, it was found that peak frequencies of subgroups 1 and 2 differ from each other (p<0.01), peak frequencies of the subgroup 1 and the Group 2 differ from each other at the level of significance p<0.01 and frequency of peaks the subgroup 2 and the Group 2 are also differ from each other at the level of significance p<0.01, which is presented in Fig. 4.

In addition, the peak amplitudes in children of the Group 1 can be characterized by the fact that in 1 third octave in 80.86% of cases, a characteristic amplitude of 250392.09±58154.85 is observed. And the other 19.14% of cases do not have this characteristic peak.

Children of the Group 1 in the first third octave can be divided, depending on the amplitude, into two characteristic subgroups:

— the subgroup 1 from 0 to 200,000

— the subgroup 2 from 200,000 to the maximum

When conducting multiple comparisons using the Scheffe method between two subgroups of the Group 1 and 2, it was found that the peak amplitudes of the subgroups 1 and 2 differ from each other (p<0.01) and the peak amplitudes of the subgroup 2 and the Group 2 also are differ from each other at the level significance p<0.01, which is presented in Fig. 5. Differences in amplitude between the subgroup 1 and the Group 2 were not found (p=0.91).

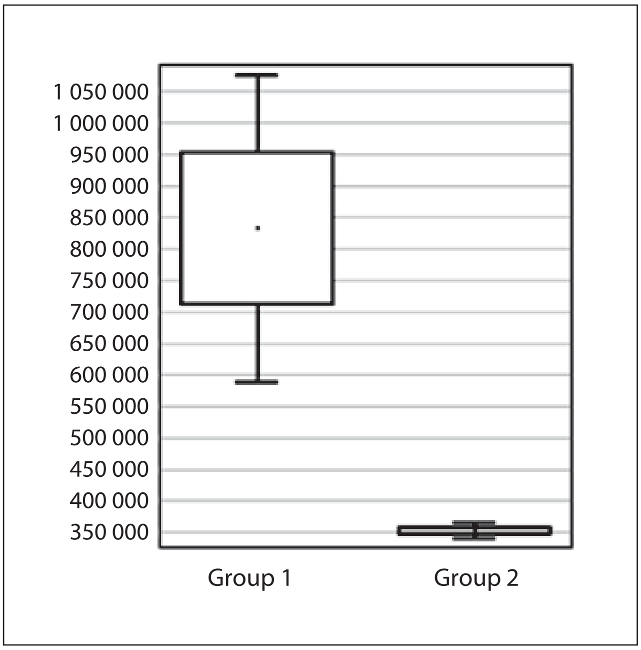

Fig. 3. Probable interval when comparing central tendencies for two independent samples, namely children with segmental (the Group 1) and focal pneumonia (the Group 2) in 1 third octave (p<0.001)

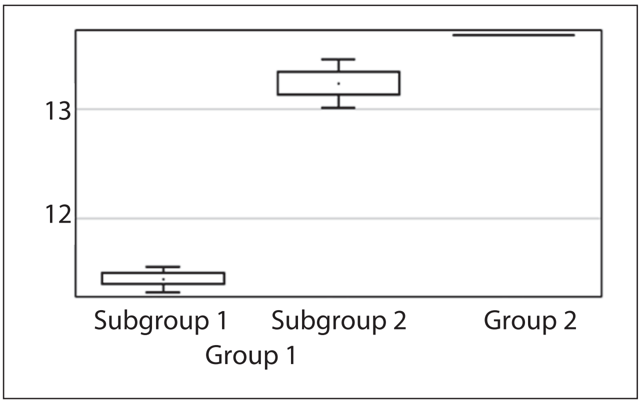

Fig. 4. Probable interval when comparing the central tendencies of peak frequency for two independent samples, namely children with segmental (the subgroups 1 and 2) and focal pneumonia (the Group 2) in 1 third octave

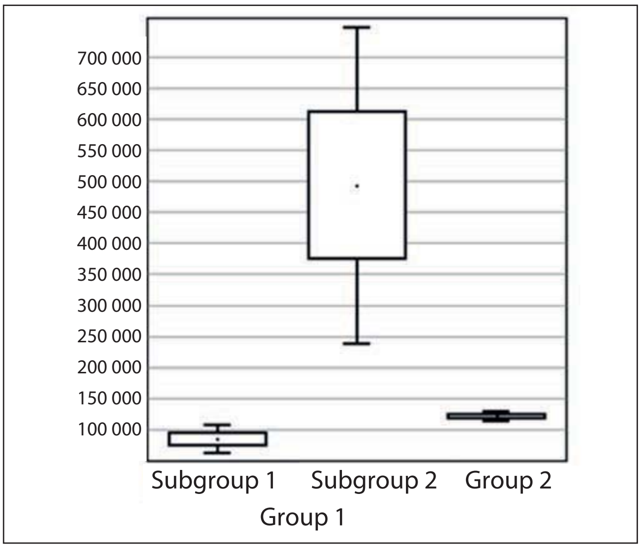

Fig. 5. Probable interval when comparing the central tendencies of peak amplitude for two independent samples, namely children with segmental (the subgroups 1 and 2) and focal pneumonia (the Group 2) in 1 third octave

Table 4

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 2 and 3 third octaves

Indexes	2 third octave	3 third octave
The average values of the signal power	p=0.952	p=0.317
Frequency of peaks	**p<0.001***	**p=0.044***
Amplitude of peaks	p=0.445	p=0.571

Note: * — the difference between the both groups is statistically significant.

Table 5

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 4, 5, 6 third octaves

Indexes	4 third octave	5 third octave	6 third octave
The average values of the signal power	**p=0.003***	p=0.147	**p=0.004***
Frequency of peaks	p=0.850	p=0.976	p=0.108
Amplitude of peaks	**p<0.001***	p=0.091	p=0.538

Note: * — the difference between the both groups is statistically significant.

In addition, the peak amplitudes in children of the Group 1 can be characterized by the fact that in 1 third octave in 80.86% of cases, a characteristic amplitude of 250392.09±58154.85 is observed. And the other 19.14% of cases do not have this characteristic peak.

Children of the Group 1 in the first third octave can be divided, depending on the amplitude, into two characteristic subgroups:

— the subgroup 1 from 0 to 200,000

— the subgroup 2 from 200,000 to the maximum

When conducting multiple comparisons using the Scheffe method between two subgroups of the Group 1 and 2, it was found that the peak amplitudes of the subgroups 1 and 2 differ from each other ($p<0.01$) and the peak amplitudes of the subgroup 2 and the Group 2 also are differ from each other at the level significance $p<0.01$, which is presented in Fig. 5. Differences in amplitude between the subgroup 1 and the Group 2 were not found ($p=0.91$).

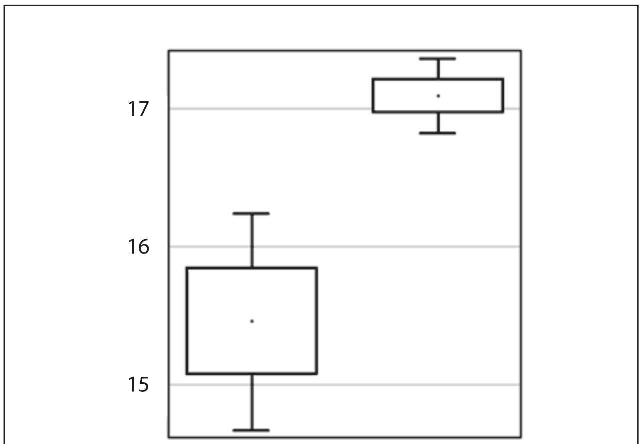

Fig. 6. Probable interval when comparing the central tendencies of peak frequency for two independent samples, namely children Groups 1 and 2 in the 2 third octave

When comparing the average values of the signal power, frequency and amplitude of peaks of two samples, of children from the Groups 1 and 2, characteristic features of the acoustic signal in the octaves 2 and 3, which are presented in Table 4, were revealed using the Student's test.

As can be seen from the 2 third octave, a significant difference in the frequency of peaks was found between children from the Groups 1 and 2 ($p<0.001$), which is presented in Fig. 6. In the 3 third octave, a difference in the frequency of peaks was also revealed between children from the Groups 1 and 2 ($p=0.044$).

2 octave is in the interval from 22.38721 to 44.66836 Hz. For a more accurate diagnosis, 2 octave was divided into third octaves.

When comparing the averages of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 4, 5, and 6 third octaves were revealed, which are presented in Table 5.

As can be seen from the table, in the 4 third octave, differences were found in the average values of the signal power ($p=0.003$) and peak amplitude ($p<0.001$) between the both studied groups. However, no significant difference was found in the 5 third octave. In the 6 third octave, differences were found in the average values of the signal power ($p=0.004$).

3 octave is in the interval from 44.66836 to 89.12509 Hz. For a more accurate diagnosis, 3 octave was divided into third octaves.

When comparing the averages of two samples, the children Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 7, 8 and 9 third octaves were found, which are presented in Table 6.

Table 6

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 7, 8, 9 third octaves

Indexes	7 third octave	8 third octave	9 third octave
The average values of the signal power	**p=0.009***	p=0.272	p=0.968
Frequency of peaks	p=0.929	p=0.402	p=0.288
Amplitude of peaks	**p=0.009***	p=0.328	p=0.060

Note: * — the difference between the both groups is statistically significant.

Table 7

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 10, 11, 12 third octaves

Indexes	10 third octave	11 third octave	12 third octave
The average values of the signal power	p=0.981	p=0.121	p=0.088
Frequency of peaks	**p<0.001***	**p=0.045***	p=0.101
Amplitude of peaks	p=0.154	p=0.102	p=0.106

Note: * — the difference between the both groups is statistically significant.

Table 8

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 13, 14, 15 third octaves

Indexes	13 third octave	14 third octave	15 third octave
The average values of the signal power	p=0.057	p=0.422	**p=0.017***
Frequency of peaks	p=0.412	**p<0.001***	**p<0.001***
Amplitude of peaks	p=0.062	p=0.992	**p=0.028***

Note: * — the difference between the both groups is statistically significant.

Table 9

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 16, 17, 18 third octaves

Indexes	16 third octave	17 third octave	18 third octave
The average values of the signal power	p=0.538	p=0.059	p=0.156
Frequency of peaks	**p<0.001***	p=0.053	**p=0.020***
Amplitude of peaks	p=0.532	**p=0.010***	p=0.308

Note: * — the difference between the both groups is statistically significant.

As can be seen from the table, in the 7 third octave differences were found in the average values of the signal power (p=0.009) and peak amplitude (p=0.009) between the two studied groups. However, no significant difference was found in the 8 and 9 third octaves.

4 octave is in the interval from 89.12509 to 177.8279 Hz. For more accurate diagnosis, 4 octave was divided into third octaves.

When comparing the averages of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 10, 11, 12 third octave were revealed, which are presented in Table 7.

As can be seen from the table, in the 10 third octave, differences in the frequency of peaks were found **(p<0.001)**, as well as in the 11 third octave, differences in the frequency of peaks were also found **(p=0.045)**.

5 octave is in the interval from 177.8279 to 354.8134 Hz. For more accurate diagnosis, the 5 octave was divided into third octaves.

When comparing the averages of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 13, 14, and 15 third octaves were revealed, which are presented in Table 8.

As can be seen from the table, no significant differences were found in the 13 third octave. In the 14 third octave, differences in peak frequency were found **(p<0.001).** And in the 15 third octave, differences were found in all three parameters: average values of the signal power **(p=0.017)**, frequency **(p<0.001)** and peak amplitude **(p=0.028)**.

6 octave is in the interval from 354.8134 to 707.9458 Hz. For more accurate diagnosis, the 6 octave was divided into third octaves.

When comparing the average of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 16, 17 and 18 third octaves were revealed, which are presented in Table 9.

As can be seen from the table, differences in peak frequency were found in the 16 third oc-

Table 10

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of 2 studied groups in 19, 20, 21 third octaves

Indexes	19 third octave	20 third octave	21 third octave
The average values of the signal power	p=0.128	p=0.044*	p=0.743
Frequency of peaks	p=0.508	**p<0.001***	p=0.782
Amplitude of peaks	**P=0.048***	p=0.052	**p=0.007***

Note: * — the difference between the two groups is statistically significant.

Table 11

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 22, 23, 24 third octaves

Indexes	22 third octave	23 third octave	24 third octave
The average values of the signal power	p=0.224	**p=0.003***	**p=0.002***
Frequency of peaks	**p=0.035***	p=0.669	–
Amplitude of peaks	p=0.162	p=0.462	–

Note: * — the difference between the both groups is statistically significant.

Table 12

Statistical differences in the average values of the signal power, frequency and amplitude of peaks in children of both studied groups in 25, 26, 27 third octaves

Indexes	25 third octave	26 third octave	27 third octave
The average values of the signal power	**p=0.002**	**p=0.002**	–
Frequency of peaks	–	–	–
Amplitude of peaks	–	–	–

Note: * — the difference between the both groups is statistically significant.

tave **(p<0.001)**. In the 17 third octave, differences in peak amplitude were found **(p=0.010)**. And in the 18 third octave, differences in peak frequency were found **(p=0.020)**.

7 octave is in the interval from 707.9458 to 1412.538 Hz. For more accurate diagnosis, the 7 octave was divided into third octaves.

When comparing the averages of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 19, 20, 21 third octaves were revealed, which are presented in Table 10.

As can be seen from the table, in the 19 third octave, differences in peak amplitude were found **(p=0.048)**. Differences in average signal power **(p=0.044)** and peak frequency **(p<0.001)** were found in the 20 third octave. And in the 21 third octave, differences in peak amplitude were found **(p=0.007)**.

8 octave is in the interval from 1412.538 to 2818.383 Hz. For more accurate diagnosis, the 8 octave was divided into third octaves.

When comparing the averages of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 22, 23 and 24 third octaves were revealed, which are presented in Table 11.

As can be seen from the table, differences in peak frequency were found in the 22 third octave (p=0.035). In the 23 and 24 third octaves, differences in average signal power were detected (p=0.003 and p=0.002, respectively).

9 octave is in the interval from 2818.383 to 5623.413 Hz. For more accurate diagnosis, the 9 octave was divided into third octaves.

When comparing the averages of two samples, the Groups 1 and 2, using the Student's test, characteristic features of the acoustic signal in the 25, 26, 27 third octaves were revealed, which are presented in Table 12.

As can be seen from the table, in the 25 and 26 third octave, differences in the average signal power were found (p=0.002 and p=0.002, respectively).

So, with the help of the new «Trembita-Corona» acoustic diagnostic device, the features of the acoustic signal in community-acquired pneumonia in children, namely Groups 1 and 2, were revealed. The acoustic signal was investigated in 12 octaves. The first 9 octaves were the most promising. Each octave was divided into third octaves. The acoustic signal of patients is characterized by high signal homogeneity in children from the Group 2, however, in children from the Group 1 there were additional influencing factors that depended on the location of the segment where the pathological focus was detected. We found reliable differences in the average values of the signal power in 0, 1, 4, 6, 7, 15, 20, 23, 24, 25, 26 third octaves, which can speed up and improve the differential diagnosis between segmental and focal pneumonia.

When studying the average values of the signal power between children from the Groups 1 and 2, the main differences were found precisely in the frequency of peaks in 0, 1, 2, 3, 10, 11, 14, 15, 16, 18, 20, 22 third octaves. From this it can be concluded that despite minor differences in average signal strength, children with the Groups 1 and 2 differ precisely in frequency characteristics such as peak frequency and amplitude. Therefore, the use of the «Trembita-Corona» acoustic monitoring device and the use of the developed specialized software in the Python language in the Google Codelabs environment together make it possible to diagnose the difference between segmental and focal pneumonia and to specify the localization of the affected segments and foci of inflammation in each specific case.

Conclusions

When making a diagnosis, the use of the «Trembita-Corona» acoustic monitoring device and the use of the developed specialized software in the Python language in the Google Codelabs environment together make it possible to diagnose the difference between segmental and focal pneumonia.

When studying the average values of the signal power between children with segmental and focal pneumonia (the Groups 1 and 2), the main differences were found precisely in the frequency of peaks in 0, 1, 2, 3, 10, 11, 14, 15, 16, 18, 20, 22 third octaves. From this it can be concluded that despite minor differences in the average values of the signal power, children with segmental and focal pneumonia differ precisely in frequency characteristics such as peak frequency and amplitude.

Prospects for further research

1. The «Trembita-Corona» acoustic monitoring device is a new and promising acoustic method for determining the location of the pathological process in the lungs with CAP.

2. Using the «Trembita-Corona» acoustic monitoring device, investigate the average values of the signal power, peak frequency and peak amplitude in third octaves in the dynamics of disease development and recovery.

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