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CHARACTERISTICS OF ACOUSTIC SIGNALS IN HEALTHY CHILDREN USING THE NEW DEVICE "TREMBITA-CORONA"

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In 2016, the last revision of the nomenclature of breathing sounds took place at the Congress of the European Respiratory Society in Amsterdam.

Purpose: *to determine the features of the acoustic signal in healthy children using the new "Trembita-Corona" device.*

Materials and methods. *100 healthy children aged from 1 month to 18 years were examined. We have distinguished 3 main groups. The 1st research group included 700 acoustic signals that are characteristic of the vesicular type of breathing, the 2nd group - 100 acoustic signals that are characteristic of the tracheal type of breathing, the 3rd group - 200 acoustic signals that are characteristic of the bronchovesicular type of breathing.*

The results. *With the help of the new "Trembita-Corona" device, a reference computerized database of acoustic signals for lung condition monitoring in healthy children was created. The parameters of the acoustic signal during different types of breathing in healthy children were formalized. Differences were found between the vesicular and the tracheal type of breathing in the average signal power in 0.1, 2, 3, 4, 5, 7, 8 and 9 octaves, in the frequency of the acoustic signal - in 0, 4, 5, 8 octaves, amplitude of the acoustic signal - in 0,3,4,5, 8 octaves. Differences between the vesicular and the bronchovesicular types of breathing were found in the average signal power in 0, 1, 2, 4, 5, 6, 7, 8 and 9 octaves, in the frequency of the acoustic signal - in 0, 3.5, 6 and 7 octaves, amplitude of the acoustic signal - in all 8 octaves.*

Conclusions. *The "Trembita-Corona" acoustic monitoring device makes it possible to describe sound phenomena that normally occur in healthy children depending on the type of breathing based on the average signal power, amplitude and frequency of the acoustic signal in 11 octaves*

Keywords*: acoustic monitoring, diagnostics, "Trembita-Corona", children, pneumonia, laboratory-instrumental diagnostics*

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1. Introduction

Acoustics is one of the branches of physical and mathematical sciences that studies the properties of elastic vibrations and waves and their interaction with matter from 0 Hz to 1013 Hz [1]. The term "acoustics" also describes a system of equipment that reproduces sound. Acoustics has a significant impact on the development of medicine. In particular, it is important to know the patterns of generation and propagation of waves in different environments.

In the works of R. Bruce Lindcey, there is a graphic representation of the "Lindsey Wheel of Acoustics", where four areas of human activity are highlighted, in which the application of acoustics is important. These four fields include: life sciences (which include medicine), earth sciences, arts, and engineering. The central place in the diagram is occupied by physical acoustics [2]. Physical acoustics refers to the section of acoustics and highlights the phenomena of generation, propagation and dispersion of waves in various environments. Analyzing the properties of acoustic waves, it is possible to study the physical properties of various materials and create various acoustic devices.

Medical acoustics is closely related to physics. Medical acoustics is one of the sections of acoustics. Medical acoustics establishes certain general rules regarding the impact of acoustic factors on the human body. Thanks to medical acoustics, scientists create devices and technologies for the diagnosis and treatment of major diseases. The first such device was a stethoscope, developed by René Laennec in 1816 [3].

In 1819, René Laennec described the method of auscultation in his work "On mediated auscultation, or the recognition of diseases of the lungs and heart, based on a new method of research" [3].

Renne Laennec's research had a great impact on medicine, which is why the terminology of breath sounds has been unchanged for a long time. However, the era of analog electronics development began in the 1960s. Forgscs P. used microphones for the first time in his works and conducted the first measurement of the sound signal during breathing. In 1960, the author published the monograph Lung Sounds, which became a new basis for the study of types of breathing sounds [4].

The nomenclature of respiratory sounds, which was proposed by Forgscs P., was adopted as a basis for the diagnosis of diseases of the respiratory organs in 1987 at the International Symposium on Lung Sounds and remained unchanged for more than 30 years.

In 2016, the last revision of the nomenclature of breathing noises took place at the Congress of the European Respiratory Society in Amsterdam. All data were published by Hans Pasterkamp et al. in the European Respiratory Journal [5].

According to the European Respiratory Society, the following types of normal breathing are distinguished during auscultation: vesicular (normal), tracheal (physiological bronchial), bronchovesicular [5].

In our previous works [6, 7], we determined, described and digitized the vesicular type of breathing using the "Trembita-Corona" acoustic monitoring device. This device is used to diagnose breathing sounds. The main constructive technical solutions of this device are protected by a patent [8]. We determined the main physical parameters of the vesicular type of breathing, namely the average signal power, frequency and amplitude of the acoustic signal. Characteristic ranges of all parameters were determined to define exactly the vesicular type of respiration. In this work, it is planned to continue the creation of a reference computerized database of acoustic signals for monitoring the condition of the lungs in healthy children, as well as digitization and mathematical processing of the received data.

The aim of the research was to determine the features of the acoustic signal in healthy children using the new "Trembita-Corona" device.

2. Materials and Methods

100 healthy children aged from 1 month to 18 years were examined. In healthy children, 10 basic points were allocated for determining the acoustic signal and 1 additional point. With the help of an acoustic monitoring device "Trembita-Corona", acoustic phenomena that are characteristic of each type of normal breathing were determined, according to the data of the European Respiratory Society in 2016. Vesicular breathing is heard in points 1, 2, 3, 7, 8, 9, 10 and auxiliary point 4 (in this article we did not take it into account). Tracheal breathing is heard at point T. Bronchovesicular breathing at points 5 and 6.

Each child, out of 100, had 10 points, i.e. 10 audio signals, which were further processed. Therefore, we had 1000 audio signals, which were already divided into groups depending on the type of breathing in healthy children. We have distinguished 3 main groups that correspond to the types of normal breathing during auscultation. The 1st research group included 100 children with 700 acoustic signals that are characteristic of the vesicular type of breathing, the 2nd group – included 100 children with 100 acoustic signals that are characteristic of the tracheal type of breathing, the 3rd group – included 100 children with 200 acoustic signals that are characteristic of the bronchovesicular type of breathing.

Study design. Observational case-control study was conducted at KNP "Children's Clinical Hospital No. 5 of Sviatoshyn district of Kyiv".

Study Duration. Three years from September 2020 to May 2023.

Inclusion Criteria. A physically healthy child aged 1 month to 18 years, whose parents or guardians have given consent for the study.

Exclusion Criteria. Exclusion criteria were: congenital pneumonia, organic brain diseases, kidney diseases, endocrine diseases, congenital heart defects, genetic syndromes.

Statistical analysis. Mathematical processing was carried out on specialized software, developed in the Python language in the Google Codelabs environment. In the work, multiple comparisons were made for 3 groups using variance analysis and Scheffe's method of multiple comparisons using specialized programs Medstart, EZR (R-Statistics) and "Matlab".

Ethical considerations. The study was conducted in compliance with the international principles of GCP, GLP for clinical research. The protocol and Informed consent of parents/guardians was approved at the meeting of the Commission on Bioethical Expertise at the National Medical University named after O. O. Bogomolets (138 protocol of November 10, 2020).

3. Results

We developed an experimental model of the acoustic monitoring device "Trembita Corona" for diagnosing acoustic signals in the lungs [8].

The "Trembita Corona" acoustic monitoring device improves disease diagnosis and carries out acoustic lung monitoring. The method of processing sound signals involves an automated system of their monitoring and evaluation, which excludes the influence of the human factor [7].

In this work, we determined the features of the acoustic signal in healthy children depending on the type of breathing in terms of the average signal power, frequency and amplitude of the acoustic signal in 11 octaves using the "Trembita Corona" acoustic monitoring device.

The method of measuring acoustic signals using the "Trembita Corona" acoustic monitoring device was as follows: the sound receiver of the device is placed on symmetrical areas of the front chest wall at the level of the II intercostal space, then the device is rearranged on the right in the III intercostal space, and on the left in the 5th intercostal space in the future, they are placed symmetrically in the middle interscapular space and symmetrically under the shoulder blades (points 5, 6, 7, 8) and further placed along the midaxillary line in the 6th intercostal space (points 9, 10). The main points for listening to acoustic signals above the surface of the lungs with the "Trembita-Corona" device are presented in Fig. 1.

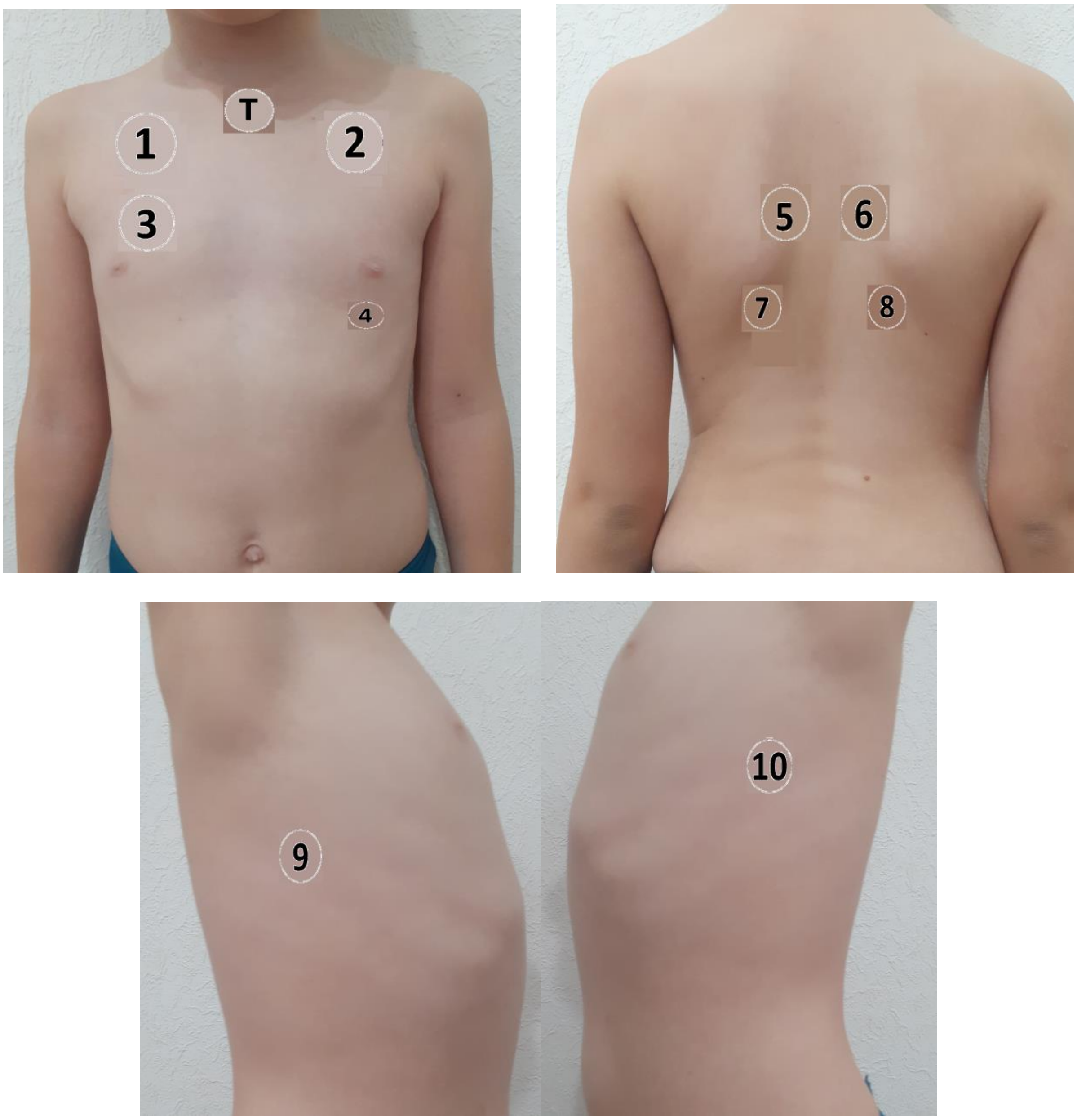

Fig. 1. The main points for listening to the lungs with the "Trembita-Corona" device (front surface, back surface, side surfaces).

Vesicular breathing is heard at points 1, 2, 3, 7, 8, 9, 10 and auxiliary point 4. Tracheal breathing is heard at point T. Bronchovesicular breathing at points 5 and 6.

With the help of the "Trembita-Corona" acoustic monitoring device, sounds are analyzed at different octaves. When conducting multiple comparisons for 3 samples using variance analysis and Scheffe's method of multiple comparisons, we obtained differences in octaves.

Table 1 shows the acoustic characteristics of normal breathing types using the "Trembita-Corona" acoustic monitoring device.

Table 1

Acoustic characteristics of normal breathing types using the acoustic monitoring device

Octave	The acoustic characteristic	Vesicular breathing (normal breathing)	Tracheal breathing (physiological bronchial)	Bronchovesicular breathing
1	2	3	4	5
0 (0.1-11.22 Hz)	The average signal power, C.U.	263443.07±2029.4*	1224492.3±37210.5	1321052.3±68280.09**
	Frequency of the acoustic signal, Hz	3.9±0.06*	6.9±0.1	6.2±0.1**
	Amplitude of the acoustic signal, C.U.	30455.7±733.9*	258926.5±12499.2***	102993.1±3048.08**

Continuation of Table 1

1	2	3	4	5
1 (11.22-22.38 Hz)	The average signal power, C.U.	1059222.1±2854.03*	2373265.8±51448.4***	4544421.6±190927.8**
	Frequency of the acoustic signal, Hz	14.4±0.08	13.4±0.1	13.4±0.07
	Amplitude of the acoustic signal, C.U.	171394.7±1094.7	338774.9±8596.7***	664930.9±34690.5**
2 (22.38-44.66 Hz)	The average signal power, C.U.	944130.6±5744.4*	2010873.2±69427.2***	2984611.3±140566.2**
	Frequency of the acoustic signal, Hz	25.6±0.08	27.08±0.2	26.4±0.1
	Amplitude of the acoustic signal, C.U.	136955.2±1683.5	151630.3±4673.2***	215760.5±8826.6**
3 (44.66-89.12 Hz)	The average signal power, C.U.	62062.7±298.4*	1135767.9±127039.8***	439274.7±20498.9
	Frequency of the acoustic signal, Hz	49.6±0.1	49.8±0.2***	45.05±0.01**
	Amplitude of the acoustic signal, C.U.	6802.6±60.08*	93962.2±7917.9	61907.6±2893.7**
4 (89.12-177.82 Hz)	The average signal power, C.U.	483.7±2.5*	7918.6±588.09****	4976.1±178.7**
	Frequency of the acoustic signal, Hz	93.1±0.04*	94.3±0.1	94.2±0.1
	Amplitude of the acoustic signal, C.U.	40.7±0.3*	546.8±43.1***	257.5±8.1**
5 (177.82-354.81 Hz)	The average signal power, C.U.	58.2±0.5*	267.09±9.5***	447.9±17.09**
	Frequency of the acoustic signal, Hz	202.7±0.1*	209.4±0.6	211.07±0.5**
	Amplitude of the acoustic signal, C.U.	2.07±0.02*	8.2±0.2***	15.8±0.7**
6 (354.81-707.94 Hz)	The average signal power, C.U.	0.23±0.002	1.76±0.07***	8.4±0.5**
	Frequency of the acoustic signal, Hz	444.03±1.5	444.2±4.2***	510.6±2.1**
	Amplitude of the acoustic signal, C.U.	0.005±0.0001	0.02±0.001***	0.27±0.01**
7 (707.94-1412.53 Hz)	The average signal power, C.U.	0.199±0.0002	0.196±0.0001***	0.223±0.002**
	Frequency of the acoustic signal, Hz	1392.09±0.1	1386.2±0.9***	1296.7±7.6**
	Amplitude of the acoustic signal, C.U.	0.003±3E-05*	0.002±3.4E-05	0.002±3.2E-05**
8 (1412.53-2818.38 Hz)	The average signal power, C.U.	6.98±0.02*	9.03±0.1	8.2±0.05**
	Frequency of the acoustic signal, Hz	1894.8±1.3*	1926.3±2.5	1914.7±1.1
	Amplitude of the acoustic signal, C.U.	0.003±0.0002*	0.02±0.0002	0.02±0.0001**
9 (2818.38-5623.41 Hz)	The average signal power, C.U.	4.25±0.03*	7.6±0.26	6.5±0.08**
	Frequency of the acoustic signal, Hz	0	0	0
	Amplitude of the acoustic signal, C.U.	0	0	0

*Note: * the difference between vesicular and tracheal types of breathing;*
*** difference between vesicular and bronchovesicular type of breathing;*
**** difference between tracheal and bronchovesicular type of breathing*

In 0 octave (0.1–11.22 Hz), significant differences were found in the mean values of the average signal power between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type breathing ($p<0.01$). At 0 octave, significant differences in the frequency of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p=0.03$). Also, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p=0.01$) and between the tracheal type of breathing and the bronchovesicular ($p<0.01$).

In 1 octave (11.22–22.38 Hz), significant differences in mean values of the average signal power were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p=0.03$), as well as between the vesicular type of breathing and bronchovesicular type breathing ($p<0.01$) and between tracheal breathing and bronchovesicular breathing ($p=0.03$). In 1 octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular type of breathing ($p<0.01$ and $p=0.01$, respectively).

In the 2nd octave (22.38–44.66 Hz), significant differences in mean values of the average signal power were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p=0.02$), as well as between the vesicular type of breathing and bronchovesicular type breathing ($p<0.01$) and between tracheal breathing and bronchovesicular breathing ($p=0.04$). Also, in the 2nd octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular type of breathing ($p<0.01$ and $p=0.01$, respectively).

In the 3rd octave (44.66–89.12 Hz), significant differences in mean values of the average signal power were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the tracheal type of breathing and the bronchovesicular ($p<0.01$). Also, in the 3rd octave, significant differences in the frequency of the acoustic signal were found between children with the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular type of breathing ($p<0.01$). In the 3rd octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$).

In the 4th octave (89.12–177.82 Hz), significant differences in mean values of the average signal power were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type breathing ($p<0.01$) and between tracheal breathing and bronchovesicular breathing ($p=0.04$). In this octave, significant differences in the frequency of the acoustic signal were found between children with the vesicular type of breathing and the bronchovesicular type of breathing ($p=0.04$). In the 4th octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between vesicular type of breathing and bronchovesicular type of breathing ($p=0.02$ and $p<0$ .01, respectively) and between the tracheal and the bronchovesicular type of breathing ($p<0.01$).

In the 5th octave (177.82–354.81 Hz), significant differences were found in the average signal power between all studied groups of patients ($p<0.01$). Also, significant differences in the frequency of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$). In the 5th octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p=0.02$ and $p<0$ .01, respectively) and between the tracheal and the bronchovesicular type of breathing ($p<0.01$).

In the 6th octave (354.81–707.94 Hz), significant differences were found in the average signal power between the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular ($p<0$, 01). In this octave, significant differences in the frequency of the acoustic signal were found between children with the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular type of breathing ($p<0.01$). In the 6th octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular type of breathing ($p<0.01$).

In the 7th octave (707.94–1412.53 Hz), significant differences were found in the average signal power between the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular ($p<0$, 01). Also, significant differences in the frequency of the acoustic signal were found between children with the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$) and between the tracheal type of breathing and the bronchovesicular type of breathing ($p<0.01$). In the 7th octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$).

In the 8th octave (1412.53–2818.38 Hz), significant differences in the average signal power were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between vesicular type of breathing and bronchovesicular type breathing ($p<0.01$). In this octave, significant differences in the frequency of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$). In the 8th octave, significant differences in the amplitude of the acoustic signal were found between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type of breathing ($p<0.01$).

In the 9th octave (2818.38–5623.41 Hz), significant differences were found in the average signal power between healthy children with the vesicular type of breathing and the tracheal type of breathing ($p<0.01$), as well as between the vesicular type of breathing and the bronchovesicular type breathing ($p<0.01$).

4. Discussion

In 2016, at the Congress of the European Respiratory Society in Amsterdam, the nomenclature of breathing noises was revised [5].

According to the rules of auscultation, the type of breathing is first determined. According to the modern updated recommendations of the European Respiratory Society in healthy people, sound phenomena arise in the larynx and trachea, due to the turbulent movement of air and depending on the state of the lung tissue, they are transmitted to the chest to the very head of the stethoscope. Due to these fluctuations, breathing noises are formed, and the type of breathing can be determined [5].

According to the European Respiratory Society [5], the following types of normal breathing during auscultation are distinguished:

– Vesicular (normal)
– Tracheal (physiological bronchial)
– Bronchovesicular

According to the authors [9, 10], during **vesicular breathing (normal breathing)**, sound is formed in the trachea and larynx due to turbulent air movement. Then the air passes to the final parts of the respiratory tract (alveoli). The sound intensity decreases as air passes from the larynx to the alveoli. That is, according to the guidelines of the European Respiratory Society, sound does not originate in the alveoli, but is produced from the larynx. Alveoli form the final part of the respiratory tract, where air movement is minimal and gas exchange takes place. This explains the fact that sound phenomena cannot occur in the alveoli with almost no air movement, but occur higher in the larynx and trachea. That is why, according to the new guidelines, the term normal breathing (of the European Respiratory Society) better describes the type of breathing in healthy people. The term vesicular breathing, which was introduced by René Laennec, is becoming obsolete and does not describe the mechanism of sound phenomena in the lungs. We found on the Trembita-Corona acoustic monitoring device that the acoustic signal at points 1, 2, 3, 7, 8, 9, 10 has common properties in terms of average signal power, frequency and amplitude of the acoustic signal, which are clearly visible in all 9 octaves.

Tracheal breathing (physiological bronchial) can be heard in healthy people above the larynx, the handle of the sternum and behind the paravertebral to the level of the 3rd thoracic vertebrae. The main characteristics of tracheal (physiological bronchial) breathing, according to the data of the European Respiratory Society, are very similar to the characteristics of vesicular (normal) breathing. However, there are differences in the ratio of the duration of inhalation and exhalation 1:1 with a pause between phases and it is heard only over certain areas above the lungs.

We found on the "Trembita-Corona" acoustic monitoring device that the acoustic signal at point T characterizes the tracheal type of breathing and is statistically different from the vesicular type of breathing. The main differences were found in the average signal power in 0,1,2,3,4,5,7,8 and 9 octaves, in the frequency of the acoustic signal there were differences in 0.4, 5 and 8 octaves, the amplitude of the acoustic signal differed in 0, 3,4,5,7 and 8 octaves. It was also found that the indicators of the average signal power during vesicular breathing have the lowest values when compared with the indicators during the bronchovesicular and tracheal types of breathing. According to the pathogenesis of the spread of air in the lungs, it is the tracheal type of breathing that has the highest indicators of the average signal power in all the studied octaves, which is why we auscultately hear that it is tracheal breathing that is the loudest and most powerful type of normal breathing.

Bronchovesicular breathing has common characteristics with the vesicular and bronchial types of breathing. Bronchovesicular breathing is heard in the interscapular area, as well as in asthenic children. The formation of bronchovesicular breathing occurs above the larynx and trachea and is then carried to the chest. However, it is in the interscapular area that the degree of sound frequency filtering decreases and the pause between breathing phases disappears, but the duration of exhalation does not change.

We found on the "Trembita-Corona" acoustic monitoring device that the acoustic signal at points 5 and 6 characterizes the bronchovesicular type of breathing and is statistically different from the vesicular and tracheal type of breathing. It was also found that the indicators of the average signal power with the bronchovesicular type of breathing are in the middle between the indicators of the vesicular and tracheal types of breathing. These changes were detected due to the proximity to the trachea and large bronchi in relation to the back surface of the chest and the moderate development of muscles in this area. With the help of the new "Trembita-Corona" device, differences between the tracheal and the bronchovesicular type of breathing were detected in the average signal power in 1, 2, 3, 4, 5, 6 and 7 octaves, in terms of frequency of the acoustic signal the differences were in 3, 6 and 7 octaves, amplitude of the acoustic signal – in 0, 1, 2, 4, 5 and 6 octaves.

Therefore, in order to carry out more accurate comparisons of acoustic signals between healthy children and children with diseases of the respiratory system, we created a reference computerized database of acoustic signals for monitoring the condition of the lungs in healthy children. The database includes more than 1,000 records, each of which has been digitized and processed. The parameters of the acoustic signal during different types of breathing in healthy children were formalized, which can be widely used for telemedicine with the help of artificial intelligence.

Limitations of the study. External noise in the room can potentially affect the sound signal fluctuations during the recording of acoustic phenomena, but with the acoustic signal analysis procedure this limitation can be overcome.

Prospects for further studies. To determine the acoustic characteristics of the types of breathing in pathology during auscultation using the new acoustic monitoring device "Trembita-Corona".

5. Conclusions

1. The "Trembita-Corona" acoustic monitoring device makes it possible to describe the sound phenomena that occur in healthy children based on the average signal power, amplitude and frequency of the acoustic signal in 11 octaves.

2. A reference computerized database of acoustic signals for lung condition monitoring in healthy children was created. The database includes more than 1,000 records, each of which was digitized and processed. The parameters of the acoustic signal during different types of breathing in healthy children were formalized, which can be widely used for telemedicine with artificial intelligence. It was determined that the vesicular type of breathing is heard at points 1,2,3,7,8,9,10 and auxiliary point 4. The tracheal type of breathing is heard at point T. Bronchovesicular breathing at points 5 and 6.

3. Using the new "Trembita-Corona" device, differences were found between the vesicular and the tracheal type of breathing in the average signal power in 0,1,2,3,4,5,7,8 and 9 octaves, the differences in the frequency of the acoustic signal were in 0.4, 5 and 8 octaves, the amplitude of the acoustic signal – in 0.3, 4, 5, 7 and 8 octaves. Differences between the vesicular and bronchovesicular types of breathing were found in the average signal power in 0, 1, 2, 4, 5, 6, 7, 8 and 9 octaves, in the frequency of the acoustic signal there were differences in 0, 3.5, 6 and 7 octaves, the amplitude of the acoustic signal -in all 8 octaves. Differences were found between the tracheal and the bronchovesicular type of breathing in terms of the average signal power in 1, 2, 3, 4, 5, 6, and 7 octaves, in terms of frequency of the acoustic signal, there were differences in 3, 6, and 7 octaves, amplitude of the acoustic signal – in 0.1, 2,4, 5 and 6 octaves.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results, presented in this article.

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Data availability

Data will be made available on reasonable request.

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