Original Research

# Influence of Air-Ions on People Subjected to Physical Effort and at Rest

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### Abstract

This work analyzes the influence of air-ions of different types and concentrations on people subjected to physical effort and at rest. The outcome of the conducted research indicates that air-ions at a concentration level of 7.5 million ions/cm$^3$ decrease the consumption of $O_2$ by around 20%, and release $CO_2$. Furthermore, the positive air-ions shorten the period necessary to achieve the anaerobic change threshold by almost 70%, at a high significance ratio of 0.001. A secondary research outcome also shows that the change of these physiological indicators probably results from the permeation of ionized molecules to the lower parts of human lungs.

**Keywords:** air-ions, human, exercise, rest

## Introduction

Research into air-ions, which has been conducted for several dozen years, focuses around two issues: the analysis of the development and the activity of the ionized particles in the atmosphere and their influence on living organisms. The former has been satisfactorily described, chiefly thanks to the work of H. Tammet and his associates at the University of Tartu (Estonia). The research conducted there encompassed nearly all phenomena connected with the existence of ionized particles in the Earth's atmosphere, among others the creation, transformation, and vanishing, etc. [5, 6, 27-29]. Some of these phenomena (e.g. the periodic changes in air-ions concentration) have been examined by the author of this work [8, 31]. The research into the latter issue, the influence of air-ions on living organisms, has not been so extensive. While similar experiments on microorganisms have resulted in many significant outcomes [4, 35], knowledge of the influence of air-ions on people is still very limited. This is despite the fact that the issue is so widely described in scientific publications. However, each of the analyses of these publications leads to the conclusion that since the biggest monographs containing the compilations of the effects connected with the influence of air-ions on living organisms were published [3, 7], there has been no significant progress in the search for even the most basic answers concerning these particles; namely, if they are able to influence the human organism at all. For instance, this is evident in the list of documents published in a web portal: electrostatic.net (Air ion effect – Air ion effect on human performance – 02 August 2007). In each similar list the references are chiefly made either to Kröling, who believed that air-ions do not affect people at all, or Krueger, who was in favour of quite the opposite thesis. Kröling [10] justified his theories mainly by low concentration of air-ions (from several hundred per cubic centimeter of natural background [31], to maximally 8 million per 1cm$^3$ when using ozone-free ionizers, per $2.6 \cdot 10^{19}$ of all molecules in 1cm$^3$ of air). So small concentrations are to rule out the influence of these molecules on human beings, especially as it is theoretically impossible for them to reach human lungs. This assumption, on the other hand, is probably based on Reiter's thesis [18-20], who assumed in his works that all ionized molecules are neutralized already in nasal and pharyngeal cavities and on Bailey's experiments [17], who assessed the ratio of ions that deposit on alveolus to the number of inhaled air-ions to be 0.04 %. These and other reservations of Kröling connected with the influence of air-ions on living organisms are compiled in the mentioned biggest of the monographs on this subject published so far: Kavet's and Charry's [7] and Grabarczyk's [3]. However, Kröling's views are not dominant. Krueger, among others, conducted similarly extensive research into air-ions and his conclusions are quite contrary [11-16]. He claims that air-ions are able to affect living organisms considerably. He presents many premises for that: among other things, the growth stimulation of a large group of plants was observed, rats demonstrated better learning capabilities, air-ion therapy appeared to be effective in treating burns, asthma, ulcers etc. (the full compilation is available in works [3, 7]). At the same time, however, Krueger claims that only 25÷30% of the population exhibits susceptibility to the changes in air-ion concentration. This fact is of fundamental importance as it may explain the divergence of theories on the influence of ionized molecules on different kinds of living organisms. Apart from the diametrically opposite views of Kröling and Krueger, works of other authors also are not unanimous in interpreting this influence. This is particularly noticeable in the compilations of the outcomes of collaborative works [3, 7, 30]. The reason for that, apart from the aforementioned thesis that only 25÷30% of the population exhibits susceptibility to the changes in concentration, is undoubtedly the statement given already in the introduction to the monograph that most of the quoted research conclusions have no scientific value as they had been reached without taking into account fundamental criteria of scientific research. Indeed, many of the theories stated in different works, for example that negative air-ions make people feel better and the positive air-ions make them feel worse [3], that negative air-ions have advantageous influence on the condition of drivers while the positive worsen it [9], or that positive air-ions make people annoyed [2], are not verifiable in practice. The fact that there are big discrepancies among publications in the concentration levels which may trigger the mentioned effects (ranging from 1000 ions/cm$^3$ up to between 10 and 20 million of ions/cm$^3$) is another drawback of these theories.

There is yet another problem connected with the discrepancies in interpretations of the research into the influence of air-ions on people. It has not been established which physicochemical processes that ensue physiological effects are caused by contact of the living organism with ionized molecules. It is not even certain if the possible impact of the air-ions is solely connected with introducing them into the respiratory system. Previous research conducted by the authors of this work indicated that the ion current running on the surface of human body can also assume intensity comparable to the concentration of ions that enter human lungs [22]. However, even assuming the more probable thesis that only the air-ions entering the respiratory system are able to cause any kind of physiological effect gives rise to further questions: in which part of this system and in effect of what processes? Currently, there is a prevalent tendency among researchers to reject the original theories of Krueger and Sulman, which were based on the assumption that air-ions permeate alveoli and directly influence blood [12, 13, 16, 24-26]. This is a consequence of the research which indicated the already mentioned fact that ionized molecules are hardly capable of permeating to the lower parts of the respiratory tract [17]. Such an approach is most probably wrong, which is elaborated upon further in this work. The defect of that method lies in the fact that the percentage measurements of the concentration of air-ions in particular parts of the respiratory system (nose and throat: 34%, trachea: 25%, intrasegmental bronchi: 7%, alveoli 0.04 %) [3] were taken in artificially built models of the respiratory system. Therefore, the credibility of such data is doubtful. Furthermore, when applying, as in experiments described below, concentrations of millions of air-ions in the inhaled air, even the mentioned 0.04 % gives the concentration of several thousand air-ions in alveoli. Such a level, in turn, was considered by Sulman [24-26] to be capable of triggering physiological reactions, even if it was reached in the air surrounding human organisms. In his further research, Sulman [24], similarly to Krueger [11], elaborated his theses assuming that increasing air-ion concentration to several thousand in 1cm$^3$ of air triggers in human organisms the modification to levels of both the neurohormonal serotonin in the central nervous system and the peripheral serotonin. These suspicions were to be confirmed by the research of Sulman and his team into the influence of the ionization of air during the desert wind sharav: 1−2 days before the wind starts blowing the concentration of air-ions of both types rises rapidly to around 4000−5000/cm$^3$ [1, 24-26]. This, in turn, causes human organisms to react in a way similar to serotonin stimulation reactions: migraine, breathlessness, intensification of allergic reactions including bronchial asthma, lowering physical and mental aptitude and annoyance.

Despite the extensive research, Sulman's conclusions are not considered to be convincing. Reiter, among others, severely detracted them. He negated ascribing the ailments triggered by the sharav to the increase in air ionization [19, 20]. He considers this assumption to be similarly erroneous to the assumption that the varying ionization of the foehn winds affects physical and mental state. According to Reiter, similar changes in the level of ionization accompany also other atmospheric phenomena and do not cause similar symptoms [18]. At any rate, the increase in the air-ion concentration to 4000÷5000/cm$^3$ during the blowing of the sharav or the foehn appears to be too small to be able to affect human organisms through the respiratory tract in any noticeable way.

The doubts connected with the possibility of air-ions to permeate deep into the respiratory tract induced Kavet and Charry [7] to form another thesis concerning the capability of air-ions to cause biological effects. This theory is based on the assumption that animal and human respiratory tracts contain non-specific nervous receptor cells sensitive to the presence of air-ions. Neuroendocrinological cells (NEC), present in respirator tracts singularly (the K cells) or in clusters of 2 to 100 cells (neuroepithelial bodies, NEB), are supposed to participate in the reception. The NEC are suspected to be chemoreceptors used to analyze the inhaled air. This is why they are present in the respiratory tract's epithelium, which has direct contact with air. They are related to serotonin and dopamine secretion and may send signals to the central nervous system through the afferent tracts of the autonomic nervous system. This would explain the numerous biological effects concerning air-ions, such as their influence on the concentration of neurosecreting substances and their metabolites in lungs, blood, urine and brain. This in turn could influence the frame of mind, aggression, well-being, mental aptitude, motor functions, etc., in other words, the factors that (according to many authors) vary depending on the concentration of air-ions of specific polarizations. On the other hand, even Kavet himself indicated that credible confirmation of his thesis would require tests on people eliminating other possible stressors such as the weather, an environment's physical factors, ozone, etc. and most of all, emotional factors. However, this would be extremely difficult, especially in the case of the emotional factors. This is the reason why Kavet's theory has not been credibly confirmed until now.

The analysis of all the reservations concerning research into the possible influence of air-ions on people leads to the conclusion that not only it is unknown what scheme air-ions use to influence people but also whether air-ions influence people at all. The research whose outcome is presented in this work was conducted to provide answers to the above questions.

## Experimental Procedures

One of the most common accusations from people negating the possibility that air-ions influence human organisms is that the effects perceived during the experiments with ionized molecules could be caused by ozone. Therefore, the research described here was conducted exclusively with the use of electrical ionizers, which had been tested for ozone emission (through the iodometric method). They all had zero levels of $O_3$ emission at voltages reducing concentrations of air-ions of both types to 7.5 million ions per $cm^3$. Furthermore, the fact that given biological effects are not more intense in case of using negative ionization which requires six times greater ozone concentration can be an additional criterion indicating that it was not ozone that caused them [3]. The result of this kind may additionally confirm that the given reactions of the organism are not caused by some trace quantities of ozone, which cannot be recorded with the use of the iodometric method.

If the thesis that serotonin is secreted in larger quantities when people inhale ionized air was true, experiments with people might be disrupted by the above-mentioned external factors, e.g. the mental state changes of a given person [24, 26]. In order to avoid this, an assumption was made that the shorter the time of the experiment the more reliable the outcome. This imposes automatically the necessity of introducing air of relatively high concentration of air-ions to the respiratory tract of the examined person.

In order to minimize any external factors, it was assumed that the test should be conducted on a maximally uniform group of people in laboratory conditions, i.e. in the same closed room, at physical parameters (temperature, humidity, etc.) altering in a possibly smallest degree. It was also established that if one person were to be submitted to tests several times, the time span between the tests should not be longer than 1 week.

In order to meet the above criteria, after a series of preliminary tests on around 120 persons, the researchers decided to conduct proper tests on a group of 30 students of AWFiS (Academy of Physical Education and Sport in Gdańsk) submitting them to physical effort tests on a cycloergometer. The tested persons were from 20 to 23 years old and at the time of the tests none of them was in a cycle of intense physical training at the level of a sports class. Their physical activity was confined to the obligatory classes at AWFiS and occasional extra-curricular, non-competitive activities. Therefore, the tested persons should be classified as people of increased or even intense physical activity, above the average in this age group. In general, the group can be considered as uniform.

The test consisted in monitoring physical indicators when individual students were exercising for 10 minutes on a cycloergometer with constant, submaximal strain of 2W per 1 kg of body mass and during the 10 minutes' rest period directly after exercise. The test was conducted in 5 variants: with the non-ionized air and with the direct introduction of negative (or positive) air-ions at concentrations of 4 million ions per $cm^3$ and 7.5 million ions per $cm^3$ to the tested person's respiratory tract in several-minute intervals. Using several million concentrations of air-ions in the tests was dictated by the relatively short duration of a single measurement and by the results obtained by the author of this work both during the mentioned series of preliminary tests on people and in earlier tests on lymphocytes in vitro [33] and microorganisms [35] (in the first case, the concentration of air-ions had to reach the level of 80 thousand ions per $cm^3$ and in the latter, 4 million ions per $cm^3$ to observe any biological effects). A computerized respiratory gases' analyzer EOS-Sprint manufactured by Jaeger combined with a cardiomonitor and a cycloergometer E900 (also manufactured by Jaeger) was used to record the physiological indicators of the tested persons. The data were recorded in three states: in the rest period (before the exercise), in each minute of the exercise and in each minute of rest after the exercise. The following indicators were recorded: Heart Rate (HR), $O_2$ consumption ($VO_2$) and $CO_2$ expelling ($VCO_2$). Through the compilation of the above, the Respiratory Quotient RQ (RER) was calculated. In the analyses, the critical value of RQ = 1, being similar to AR (the Anaerobic Threshold PPA) and rAT, was considered to be a reversed anaerobic threshold [21, 23].

The used physical effort test along with the measured and calculated physiological indicators were selected to constitute a certain standard which could be repeated after several days without submitting the tested persons to too much strain and obtain sufficient information on the effort and rest reactions.

Table 1. Physiological indicators of persons subjected to physical effort in non-ionized air.

| No. | Body weight (kg) | Age (years) | Pre-effort state HR (1/min) | Pre-effort state $VO_2$ (1/min) | Pre-effort state $VCO_2$ (1/min) | Exercise Power (W) | Exercise HR2' (1/min) | Exercise HR5' (1/min) | Exercise HR10' (1/min) | Exercise Time RQ=1 | Exercise $VO_2$ 10' | Exercise $VCO_2$ 10' | Rest HR2' (1/min) | Rest HR5' (1/min) | Rest HR10' (1/min) | Rest Time rAT | Rest $VO_2$ 10' | Rest $VCO_2$ 10' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 68 | 21 | 73 | 0.25 | 0.23 | 136 | 137 | 152 | 161 | 10 | 2.12 | 2.08 | 124 | 106 | 105 | 7 | 0.40 | 0.38 |
| 2 | 69 | 21 | 60 | 0.56 | 0.49 | 138 | 118 | 134 | 136 | 9 | 2.01 | 2.01 | 117 | 78 | 78 | 10 | 0.28 | 0.28 |
| 3 | 70 | 21 | 88 | 0.37 | 0.32 | 140 | 120 | 144 | 166 | 7 | 2.82 | 3.11 | 111 | 98 | 88 | 10 | 0.40 | 0.45 |
| 4 | 70 | 21 | 74 | 0.32 | 0.34 | 140 | 124 | 136 | 142 | 10 | 2.46 | 2.45 | 108 | 96 | 90 | 10 | 0.43 | 0.43 |
| 5 | 80 | 22 | 64 | 0.34 | 0.35 | 160 | 128 | 134 | 142 | 10 | 2.59 | 2.52 | 86 | 75 | 75 | 8 | 0.47 | 0.43 |
| 6 | 80 | 21 | 77 | 0.38 | 0.39 | 160 | 132 | 140 | 148 | 10 | 2.82 | 2.70 | 110 | 86 | 86 | 9 | 0.54 | 0.52 |
| 7 | 80 | 21 | 67 | 0.36 | 0.35 | 160 | 130 | 144 | 150 | 10 | 2.58 | 2.53 | 112 | 96 | 94 | 8 | 0.46 | 0.45 |
| 8 | 82 | 23 | 68 | 0.43 | 0.40 | 164 | 127 | 134 | 133 | 10 | 2.46 | 2.24 | 105 | 97 | 97 | 6 | 0.42 | 0.40 |
| 9 | 85 | 21 | 75 | 0.30 | 0.25 | 170 | 119 | 134 | 143 | 10 | 2.87 | 2.78 | 107 | 96 | 93 | 6 | 0.40 | 0.37 |
| 10 | 100 | 20 | 75 | 0.56 | 0.58 | 200 | 120 | 134 | 146 | 9 | 3.20 | 3.22 | 100 | 82 | 82 | 10 | 0.41 | 0.41 |
| $\overline{x}_o$ | 78.40 | 21.20 | 72.10 | 0.39 | 0.37 | 156.80 | 125.50 | 138.60 | 146.70 | 9.50 | 2.59 | 2.56 | 108.00 | 91.00 | 88.80 | 8.40 | 0.42 | 0.41 |
| σ | 9.82 | 0.79 | 7.84 | 0.10 | 0.10 | 19.65 | 6.36 | 6.26 | 10.27 | 0.97 | 0.36 | 0.40 | 10.13 | 10.09 | 9.05 | 1.65 | 0.07 | 0.06 |

As the tested group needed to stay uniform during the whole experiment, submitting the same students to the full series of tests turned out to be unfeasible. Therefore, the group had to be complemented by additional persons matching the required uniformity.

## Results

The values of the physiological indicators of the test group of 10 males (in ascending sequence according to body weight), breathing non-ionized air in three states: before exercise, during the cycloergometer exercise and during rest after the exercise are compiled in Table 1. The Heart Rates indicated in this Table and also in Tables 2, 3, 4 and 5 were measured in the second, fifth and tenth minutes. The $O_2$ consumption and $CO_2$ expelling were measured in the tenth minute. Under each column of particular values, their arithmetic mean is given as $\overline{x}_0$ (for the test group), or $\overline{x}$ and the standard deviation value σ.

An identical test, conducted with the simultaneous introduction of positive and negative air-ions of the 4 million per $cm^3$ concentrations to the tested persons' respiratory tracts gave only minute, statistically negligible changes of the recorded physiological indicators in comparison with the results of the test group. This level, however, can be assumed to be a threshold. Beyond this threshold, changes in some of these indicators are clearly oriented. This applies above all to the explicit results in Tables 2 and 3 that diminish time of the anaerobic change threshold (RQ = 1) and the increase in the time of rAT. Changes in these indicators, small as they are, at the 4 million ions per 1 $cm^3$ concentration start to be of constant character, oriented in the same way in case of air-ions of both types. This was observed not only among persons whose indicators are compiled in Tables 2 and 3, but also in the course of the mentioned preliminary tests on the group of around 120 students. This is why the concentration of 4 million ions per 1$cm^3$ had been established to be the lowest possible level of the planned tests whose results are presented in this work.

Much more significant discrepancies between the results of the test group and the one submitted to the influence of air-ions started to appear after increasing the concentration of air-ions to 7.5 million ions per 1$cm^3$. Admittedly, introducing negative air-ions to the respiratory tract influenced only two indicators: the reduction of oxygen consumption in the tenth minute of the exercise by 20.96% and the decreased carbon dioxide expelling in the same minute by 15.15% but with a considerable, according to the t-Student test, level of α significance equaling to 0.01 and 0.05, respectively (Table 4 and also Tables 5 and 6):

$$\Delta \overline{x}\,(\%) = ((\overline{x} - \overline{x}_o)/\,\overline{x}_o)\cdot 100\ \%$$

At a lower, but also considerable level of significance: 0.1, negative air-ions of this concentration managed to increase the time of rAT by 12.25%. Other changes, even if significant, did not meet the condition of the uniformity of

Table 2. The physiological indicators of persons subjected to physical effort in the air with negative air-ion concentration of 4 million ions per 1cm$^3$.

| | | | Pre-effort state | | | Exercise | | | | | | | Rest | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Body weight (kg) | Age (years) | HR (1/min) | $VO_2$ (1/min) | $VCO_2$ (1/min) | Power (W) | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time RQ=1 | $VO_2$ 10' | $VCO_2$ 10' | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time rAT | $VO_2$ 10' | $VCO_2$ 10' |
| 1 | 68 | 21 | 69 | 0.34 | 0.30 | 136 | 132 | 140 | 149 | 9 | 2.02 | 2.04 | 115 | 95 | 86 | 10 | 0.39 | 0.42 |
| 2 | 69 | 22 | 82 | 0.40 | 0.39 | 138 | 135 | 140 | 150 | 8 | 2.51 | 2.62 | 117 | 100 | 88 | 9 | 0.37 | 0.35 |
| 3 | 70 | 21 | 80 | 0.48 | 0.46 | 140 | 130 | 142 | 151 | 9 | 2.16 | 2.14 | 112 | 101 | 98 | 10 | 0.40 | 0.42 |
| 4 | 70 | 21 | 85 | 0.30 | 0.31 | 140 | 122 | 138 | 143 | 10 | 2.42 | 2.40 | 120 | 104 | 91 | 8 | 0.38 | 0.36 |
| 5 | 80 | 21 | 77 | 0.38 | 0.40 | 160 | 130 | 138 | 146 | 10 | 2.35 | 2.30 | 105 | 96 | 82 | 8 | 0.40 | 0.38 |
| 6 | 80 | 21 | 67 | 0.36 | 0.34 | 160 | 140 | 151 | 153 | 10 | 2.79 | 2.70 | 110 | 92 | 82 | 9 | 0.38 | 0.36 |
| 7 | 80 | 20 | 81 | 0.50 | 0.48 | 160 | 131 | 145 | 152 | 8 | 2.53 | 2.63 | 108 | 95 | 88 | 10 | 0.52 | 0.54 |
| 8 | 81 | 21 | 80 | 0.39 | 0.40 | 162 | 134 | 146 | 154 | 9 | 2.74 | 2.76 | 112 | 105 | 90 | 9 | 0.53 | 0.50 |
| 9 | 82 | 23 | 78 | 0.46 | 0.44 | 164 | 116 | 122 | 140 | 6 | 2.40 | 2.51 | 119 | 100 | 89 | 10 | 0.52 | 0.56 |
| 10 | 83 | 22 | 79 | 0.50 | 0.49 | 166 | 121 | 137 | 152 | 10 | 2.41 | 2.40 | 120 | 99 | 83 | 9 | 0.45 | 0.40 |
| 11 | 84 | 21 | 87 | 0.39 | 0.38 | 168 | 124 | 135 | 141 | 9 | 2.75 | 2.77 | 111 | 98 | 94 | 10 | 0.40 | 0.42 |
| 12 | 100 | 22 | 74 | 0.54 | 0.58 | 200 | 128 | 136 | 148 | 10 | 3.27 | 3.25 | 110 | 91 | 87 | 9 | 0.55 | 0.55 |
| 13 | 100 | 21 | 80 | 0.56 | 0.58 | 200 | 127 | 137 | 151 | 7 | 2.35 | 2.53 | 103 | 93 | 84 | 10 | 0.44 | 0.42 |
| $\bar{x}$ | 80.54 | 21.31 | 78.38 | 0.43 | 0.43 | 161.08 | 128.46 | 139.00 | 148.46 | 8.85 | 2.52 | 2.54 | 112.46 | 97.62 | 87.85 | 9.31 | 0.45 | 0.44 |
| σ | 10.37 | 0.75 | 5.66 | 0.08 | 0.09 | 20.75 | 6.49 | 6.86 | 4.61 | 1.28 | 0.32 | 0.31 | 5.50 | 4.41 | 4.72 | 0.75 | 0.07 | 0.08 |

Table 3. The physiological indicators of persons subjected to physical effort in the air with positive air-ion concentration of 4 million ions per 1cm³.

| | | | Pre-effort state | | | Exercise | | | | | | | Rest | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Body weight (kg) | Age (years) | HR (1/min) | $VO_2$ (1/min) | $VCO_2$ (1/min) | Power (W) | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time RQ=1 | $VO_2$ 10' | $VCO_2$ 10' | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time rAT | $VO_2$ 10' | $VCO_2$ 10' |
| 1 | 68 | 21 | 69 | 0.34 | 0.30 | 136 | 134 | 141 | 152 | 10 | 2.24 | 2.14 | 111 | 102 | 99 | 10 | 0.37 | 0.39 |
| 2 | 69 | 21 | 60 | 0.51 | 0.51 | 138 | 117 | 137 | 132 | 9 | 2.02 | 2.02 | 116 | 90 | 74 | 10 | 0.25 | 0.26 |
| 3 | 70 | 21 | 85 | 0.50 | 0.49 | 140 | 129 | 141 | 150 | 10 | 2.18 | 2.15 | 120 | 108 | 86 | 8 | 0.40 | 0.40 |
| 4 | 70 | 21 | 78 | 0.47 | 0.39 | 140 | 123 | 135 | 140 | 10 | 2.40 | 2.29 | 122 | 117 | 115 | 9 | 0.53 | 0.50 |
| 5 | 70 | 21 | 74 | 0.30 | 0.36 | 140 | 122 | 136 | 142 | 10 | 2.45 | 2.40 | 101 | 95 | 89 | 10 | 0.41 | 0.42 |
| 6 | 71 | 21 | 64 | 0.23 | 0.22 | 142 | 117 | 132 | 140 | 10 | 1.92 | 1.85 | 95 | 80 | 76 | 8 | 0.40 | 0.39 |
| 7 | 76 | 21 | 62 | 0.41 | 0.41 | 152 | 114 | 118 | 120 | 9 | 2.10 | 2.29 | 90 | 84 | 78 | 9 | 0.38 | 0.37 |
| 8 | 80 | 21 | 67 | 0.35 | 0.34 | 160 | 131 | 144 | 153 | 10 | 2.63 | 2.53 | 110 | 92 | 92 | 9 | 0.46 | 0.41 |
| 9 | 80 | 21 | 77 | 0.38 | 0.40 | 160 | 131 | 139 | 147 | 10 | 2.80 | 2.71 | 105 | 95 | 82 | 8 | 0.54 | 0.51 |
| 10 | 80 | 20 | 91 | 0.39 | 0.38 | 160 | 141 | 151 | 154 | 4 | 2.39 | 2.61 | 119 | 111 | 105 | 10 | 0.45 | 0.46 |
| 11 | 82 | 23 | 78 | 0.46 | 0.44 | 164 | 113 | 121 | 142 | 10 | 2.49 | 2.48 | 110 | 100 | 91 | 10 | 0.31 | 0.36 |
| 12 | 84 | 21 | 87 | 0.39 | 0.36 | 168 | 126 | 135 | 140 | 5 | 2.74 | 2.96 | 103 | 96 | 97 | 10 | 0.46 | 0.51 |
| 13 | 100 | 20 | 74 | 0.54 | 0.63 | 200 | 120 | 132 | 145 | 10 | 3.29 | 3.21 | 95 | 87 | 80 | 10 | 0.55 | 0.57 |
| $\bar{x}$ | 76.92 | 21.00 | 74.31 | 0.41 | 0.40 | 153.85 | 124.46 | 135.54 | 142.85 | 9.00 | 2.43 | 2.43 | 107.46 | 96.69 | 89.54 | 9.31 | 0.42 | 0.43 |
| σ | 8.94 | 0.71 | 9.72 | 0.09 | 0.10 | 17.88 | 8.43 | 8.80 | 9.35 | 2.04 | 0.37 | 0.38 | 10.34 | 10.77 | 12.11 | 0.85 | 0.09 | 0.08 |

Table 4. The physiological indicators of persons subjected to physical effort in the air with negative air-ion concentration of 7.5 million ions per 1cm³.

| | | | Pre-effort state | | | Exercise | | | | | | | Rest | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Body weight (kg) | Age (years) | HR (1/min) | $VO_2$ (1/min) | $VCO_2$ (1/min) | Power (W) | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time RQ=1 | $VO_2$ 10' | $VCO_2$ 10' | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time rAT | $VO_2$ 10' | $VCO_2$ 10' |
| 1 | 68 | 20 | 60 | 0,44 | 0,44 | 136 | 111 | 118 | 129 | 4 | 1.65 | 1.69 | 96 | 82 | 76 | 10 | 0.38 | 0.42 |
| 2 | 68 | 20 | 62 | 0,35 | 0,39 | 136 | 119 | 121 | 138 | 5 | 1.92 | 1.98 | 114 | 102 | 88 | 9 | 0.38 | 0.36 |
| 3 | 70 | 20 | 80 | 0,27 | 0,33 | 140 | 139 | 140 | 145 | 3 | 1.80 | 2.07 | 101 | 98 | 95 | 8 | 0.31 | 0.30 |
| 4 | 70 | 21 | 76 | 0,34 | 0,34 | 140 | 114 | 117 | 119 | 3 | 1.55 | 1.76 | 94 | 86 | 82 | 10 | 0.35 | 0.39 |
| 5 | 70 | 21 | 70 | 0,30 | 0,29 | 140 | 138 | 138 | 146 | 8 | 2.01 | 2.05 | 94 | 85 | 86 | 10 | 0.33 | 0.34 |
| 6 | 76 | 20 | 62 | 0,41 | 0,41 | 152 | 114 | 117 | 117 | 10 | 1.92 | 1.89 | 86 | 72 | 72 | 10 | 0.37 | 0.38 |
| 7 | 77 | 21 | 80 | 0,41 | 0,41 | 154 | 128 | 134 | 138 | 6 | 1.94 | 2.12 | 118 | 96 | 90 | 10 | 0.52 | 0.52 |
| 8 | 77 | 21 | 68 | 0,39 | 0,37 | 154 | 152 | 162 | 166 | 2 | 1.82 | 1.84 | 118 | 115 | 111 | 10 | 0.38 | 0.40 |
| 9 | 80 | 21 | 70 | 0,43 | 0,41 | 160 | 112 | 115 | 119 | 4 | 1.92 | 2.06 | 91 | 84 | 71 | 10 | 0.36 | 0.39 |
| 10 | 80 | 21 | 71 | 0,28 | 0,28 | 160 | 126 | 133 | 142 | 10 | 2.34 | 2.33 | 92 | 77 | 80 | 10 | 0.33 | 0.33 |
| 11 | 85 | 21 | 78 | 0,47 | 0,44 | 170 | 109 | 127 | 133 | 5 | 2.18 | 2.42 | 87 | 80 | 80 | 10 | 0.46 | 0.58 |
| 12 | 93 | 22 | 77 | 0,39 | 0,39 | 186 | 120 | 138 | 152 | 3 | 2.71 | 3.29 | 116 | 105 | 96 | 10 | 0.43 | 0.48 |
| 13 | 100 | 21 | 62 | 0,40 | 0,45 | 200 | 133 | 134 | 134 | 10 | 2.39 | 2.10 | 100 | 79 | 78 | 5 | 0.50 | 0.47 |
| 14 | 101 | 21 | 74 | 0,40 | 0,44 | 202 | 130 | 134 | 137 | 3 | 2.51 | 2.81 | 95 | 84 | 83 | 10 | 0.39 | 0.49 |
| $\bar{x}$ | 79.64 | 20.79 | 70.71 | 0.38 | 0.39 | 159.29 | 124.64 | 130.57 | 136.79 | 5.43 | 2.05 | 2.17 | 100.14 | 88.93 | 84.86 | 9.43 | 0.39 | 0.42 |
| σ | 11.28 | 0.58 | 7.10 | 0.06 | 0.06 | 22.57 | 12.76 | 12.71 | 13.51 | 2.90 | 0.33 | 0.43 | 11.51 | 12.31 | 10.70 | 1.40 | 0.06 | 0.08 |
| $\Delta\bar{x}$ (%) | | | | | | | | | | | – 20.96 | – 15.15 | | | | 12.25 | | |
| α | | | | | | | | | | | 0.01 | 0.05 | | | | 0.1 | | |

Table 5. The physiological indicators of persons subjected to physical effort in the air with positive air-ion concentration of 7.5 million ions per 1cm³.

| | | | Pre-effort state | | | Exercise | | | | | | | Rest | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Body weight (kg) | Age (years) | HR (1/min) | $VO_2$ (1/min) | $VCO_2$ (1/min) | Power (W) | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time RQ=1 | $VO_2$ 10' | $VCO_2$ 10' | HR2' (1/min) | HR5' (1/min) | HR10' (1/min) | Time rAT | $VO_2$ 10' | $VCO_2$ 10' |
| 1 | 60 | 22 | 75 | 0.28 | 0.29 | 120 | 120 | 134 | 141 | 4 | 1.73 | 1.88 | 100 | 94 | 86 | 10 | 0.29 | 0.30 |
| 2 | 66 | 21 | 64 | 0.21 | 0.19 | 132 | 124 | 139 | 154 | 4 | 1.94 | 2.05 | 117 | 110 | 106 | 7 | 0.42 | 0.41 |
| 3 | 68 | 22 | 55 | 0.22 | 0.24 | 136 | 120 | 122 | 124 | 4 | 1.72 | 1.88 | 64 | 64 | 60 | 10 | 0.24 | 0.25 |
| 4 | 71 | 21 | 64 | 0.23 | 0.26 | 142 | 115 | 117 | 121 | 2 | 1.60 | 1.83 | 77 | 76 | 74 | 10 | 0.40 | 0.44 |
| 5 | 71 | 21 | 65 | 0.33 | 0.32 | 142 | 130 | 142 | 146 | 3 | 1.76 | 1.89 | 97 | 88 | 84 | 10 | 0.29 | 0.33 |
| 6 | 77 | 22 | 75 | 0.39 | 0.38 | 154 | 132 | 141 | 145 | 3 | 2.11 | 2.20 | 90 | 88 | 79 | 9 | 0.35 | 0.34 |
| 7 | 80 | 21 | 62 | 0.16 | 0.16 | 160 | 116 | 133 | 138 | 4 | 2.20 | 2.39 | 100 | 89 | 87 | 10 | 0.36 | 0.37 |
| 8 | 81 | 21 | 59 | 0.27 | 0.27 | 162 | 118 | 135 | 140 | 2 | 1.91 | 1.95 | 105 | 92 | 78 | 9 | 0.28 | 0.33 |
| 9 | 82 | 21 | 63 | 0.28 | 0.29 | 164 | 125 | 128 | 129 | 2 | 2.01 | 2.08 | 91 | 89 | 91 | 10 | 0.34 | 0.39 |
| 10 | 87 | 23 | 82 | 0.35 | 0.43 | 174 | 116 | 130 | 133 | 3 | 2.19 | 2.46 | 105 | 96 | 96 | 10 | 0.41 | 0.46 |
| $\bar{x}$ | 74.30 | 21.50 | 66.40 | 0.27 | 0.28 | 148.60 | 121.60 | 132.10 | 137.10 | 3.10 | 1.92 | 2.06 | 94.60 | 88.60 | 84.10 | 9.50 | 0.34 | 0.36 |
| σ | 8.43 | 0.71 | 8.30 | 0.07 | 0.08 | 16.87 | 5.97 | 8.09 | 10.35 | 0.88 | 0.21 | 0.22 | 15.14 | 12.10 | 12.59 | 0.97 | 0.06 | 0.06 |
| $\Delta\bar{x}$ (%) | | | | – 30.26 | – 23.51 | | | | | – 67.37 | – 25.98 | – 19.49 | – 12.41 | | | | – 19.52 | – 11.71 |
| σ | | | | 0.01 | 0.1 | | | | | 0.001 | 0.001 | 0.01 | 0.05 | | | | 0.02 | 0.2 |

the tested population's variance in comparison to the test group resulting from the F Snedecor test. For this reason, they were not placed in Table 4.

In the discussed experiments, the most significant effects appeared after introducing positive air-ions in the concentration of 7.5 million ions per $cm^3$ to the respiratory tracts of the tested persons – cf. Table 5. Statistically significant decrease in the volume of consumed oxygen (on average, above 30%) and expelled carbon dioxide (by around 23.5 %) occurred directly after switching on the ionizers, before the actual exercise on the cycloergometer started. These parameters remained reduced during the exercise and in the rest period at a considerable level of significance: $\alpha = 0.001 \div 0.05$ (exception: $CO_2$ expelling in the tenth minute, where $\alpha = 0.2$). The most radical change occurred for the time RQ = 1, reducing the value of this parameter by almost 70% in all persons submitted to the experiment at a considerable level of significance $\alpha = 0.001$.

## Discussion of Results

The demanding requirements for the uniformity of the group submitted to the experiment (completely healthy men, well-rested males between 20 and 23 years of age, currently practicing only curricular, non-competitive sport activities at AWFiS, able to endure the assumed physical effort test without damaging their health) allowed relatively few people to undergo the final tests. Nonetheless, the obtained results clearly indicate that introducing air-ions of sufficient concentration to the human respiratory tract (in the case of this research, 7.5 million ions per $1cm^3$), can trigger significant changes of specific physiological indicators – above all, reducing the volume of oxygen inhaled in a time unit ($VO_2$) and the volume of the expelled carbon dioxide ($VCO_2$). These changes were not caused by ozone emission, because they occurred also when the experiment was conducted with the use of ionizers not emitting $O_3$. The lack of ozone influence was also confirmed by results, which show that the recorded reduction in physiological indicators (both those described above and others that also changed) occurred to a larger extent in people who inhaled positive air-ions. At creating positive air-ions, the possible $O_3$ liberation (although usually too small to be recorded) is around six times smaller than the case of negative air-ions. Both the preliminary and the more detailed tests indicated that the first visible, initially small changes in the mentioned physiological indicators ($VO_2$ and $VCO_2$) start to appear when the concentration of air-ions introduced to the respiratory tract exceeds 5 million ions per $1cm^3$. The question whether exposing people to air-ions of lower concentrations but for a longer period of time would give any recordable physiological effects remains still unanswered. Unfortunately, conducting such experiments is difficult and the obtained results are unreliable. This is because there is always a risk that changes in physiological indicators of a person submitted to longer exposure to air-ions may be caused by some other factors.

The research did not confirm Krueger's thesis that only 25–30 % of the population are susceptible to the influence of air-ions. The comparison of the results compiled in Tables 1–4 shows the bigger the concentration of the ionized molecules, the more people are affected by them. Beyond a certain level of concentration, 100% of the population are susceptible (e.g. considerable reduction of the values of reaching the time RQ=1 when submitting the tested students to the influence of positive air-ions at the concentration of 7.5 million ions per $1cm^3$). This is also observable when analyzing the values of reaching the time RQ=1 under the influence of negative air-ions at the concentration of 7.5 million ions per $1cm^3$. The inconsistent alteration does not allow the classic statistical analysis but assuming that negative air-ions of this concentration affect only some people, it is possible to interpret this measurement too. After excluding from Table 4 the results of the 3 persons whose time RQ=1 did not change in comparison to the test group (positions 6, 10 and 13), the mean value 4.18 of this indicator id obtained at the alteration equaling 2.9636. According to the t-Student test, the value of RQ=1 is therefore reduced by 56% in comparison to the test group meeting the F-Snedecor variance uniformity requirement at the significance level of $\alpha = 0.05$.

The conducted research did not reveal opposite direction of changes in physiological indicators after the application of air-ions of opposite charges. No matter what their type, at the concentration of 7.5 million ions per $1cm^3$, the values of $VO_2$ and $VCO_2$ as well as the time of reaching RQ=1 decreased considerably while the rAT time got longer. Therefore, the general conclusion can be drawn that the above-mentioned level of air-ion concentration, irrespective of their type, triggers negative effects in people submitted to physical effort (it considerably lowers the potential of oxygen metabolism). The question whether observed changes of specific physiological indicators could have different directions after exposure to air-ions of lower concentrations but during longer period of time remains unanswered. Such a possibility is implied by the outcomes of different experiments compiled in the joint monographs [3, 7].

The obtained results did not bring definite answer to the question, "what is the biophysical or biochemical mechanism of the influence of the ionized molecules on specific human organism cells, and where does it take place in the respiratory tract?" However, as breathing ionized air lowers oxygen consumption and carbon dioxide expelling, an assumption can be made that this is an effect of the processes taking place in the alveoli. Therefore, contrary to the common theories, air-ions most probably permeate to the lower parts of lungs. Assuming the findings from the previous work that only 0.04% of air-ions introduced to the respiratory tract reach the alveoli gives in this case a concentration of around 3,000 ions per $1cm^3$. This means that the number of air-ions that permeated to the lower parts of lungs in the course of the conducted research oscillated around $1.15 \cdot 10^{-14}$% of all air molecules ($2.6 \cdot 10^{19}/cm^3$). Consequently, even if the suggested permeation value

0.04% is only approximate, the obtained results prove that human organisms are extremely sensitive to shifts in the ionization of the air introduced to their respiratory tracts.

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