Original Research

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Effect of Air Pollutants on the Manifestation of Bronchial Reactivity in a Population Living in Proximity to a Power Plant

Arsim Haliti[1], Pëllumb Islami[2], Lirim Mustafa[3], Arta Dauti[4], Adnan Bozalija[1*] and Hilmi Islami[5]

[1]Department of Pharmacy, Faculty of Medicine, University of Prishtina, Clinical Centre, Prishtina, Kosova; adnan.bozalija@uni-pr.edu

[2]Department of Clinical Toxicology, Hospital of Mitrovica, Mitrovicë 40000, Kosova

[3]Institution KFLM, Agim Ramadani, Prishtine, Kosova

[4]QKUK - Clinical Centre, Prishtina, Kosova

[5]Department of Pharmacology, Faculty of Medicine, University of Prishtina, Clinical Centre, Prishtina, Kosova

Abstract

The discharge of pollutants into the air directly affects the bronchial reactivity of the population residing in the region around the power plants of Kastriot, Kosovo. Pollutants such as CO, CO_2, SO_2, NO_2, O_3, Particulate Matter (PM), free persistent radicals, toxic metals such as cadmium (K) and copper (Cu), and radioactive pollutants (for example, radioactive remains of radon (Rn)) are all discharged into the air by these power plants. In this research, parameters of lung function were determined by using body plethysmography. Resistance of the air ways (Raw), Intra-Thoracic Gas Volume (ITGV), specific airways resistance (SRaw), and specific conductance (SGaw) were measured and calculated. The study was performed with two groups, a control group consisting of 40 healthy students and an experimental group composed of 58 permanent residents of the Kastriot region. The results of the study indicated that the mean values for SRaw and SGaw were significantly affected in the experimental group ($p < 0.01$) relative to the control group for which the results were not significant ($p > 0.1$). The study confirmed that smoking aggravates the negative effects of air pollution on health ($p < 0.01$). The findings indicate that the situation of the population exposed to this level of air pollution is serious. Based on these findings, any further exposure to this level of air pollution represents a very high risk to the general health of this population and to their respiratory health in particular.

Keywords: Air Pollution, Kosovo, Power Plant, Respiratory Health

1. Introduction

Over last 100 years, greenhouse gases have been emitted into the atmosphere at a higher rate than such gases can be eliminated naturally. During this period, the level of these gases in the atmosphere has steadily increased, and it is expected that this will continue because of simultaneous growth in the global economy[1]. This escalation of greenhouse gases is causing an imbalance, and various negative effects are occurring. The World Health Organization has indicated that, worldwide, an estimated 2.4 million people die annually as a direct result of air pollution[2]. Epidemiological studies suggest that, in America, more than 500,000 people die annually from cardiovascular diseases correlating with air pollution levels[3]. In the UK, a study conducted by the University of Birmingham indicated a strong correlation between deaths from pneumonia and air pollution caused by motor vehicles[4]. Based on global statistics, more deaths are due to the effects of air pollution than to car accidents.

The effects of the emission of harmful particles, including mog and other toxic chemicals discharged into

*Author for correspondence

the air from various industries are, unfortunately, not only limited to those working on the site but also impact the environment and nearby communities. With most of the industrialized countries of the world, Kosovo is not excluded from the global influence of air pollution. Here, atmospheric pollution is derived from the activities of heavy industry and the uncontrolled usage of natural resources. Of the industrial contribution, the highest percentage of air pollution is caused by the generation of electrical energy from the combustion of charcoal. Furthermore, this charcoal is of poor quality (lignite) and large quantities must be burnt to generate a relatively small amount of energy[5].

Studies indicate that populations residing in urban areas show greater signs of respiratory distress, including hyper secretion of mucous, reduced respiratory function, and frequent diagnoses of chronic bronchitis and emphysema[6]. A Danish epidemiological study indicates an increased risk of lung cancer in patients residing in areas with high concentrations of nitrogen oxides. In this Danish study, the highest negative correlation was between non-smokers and smokers[7]. There is also a potential correlation between air pollution and other types of cancer, such cervical and brain cancer[8]. In many cities, worldwide, high levels of air pollution have been associated with a higher incidence of asthma, pneumonia, and other forms of respiratory infection, especially in children[9-11].

Air pollution is known to cause potentially fatal conditions, which may or may not be respiratory[1,2]. In addition to the harmful effects of air pollution directly on human health, it also creates environmental damage such as the greenhouse effect. This includes particulate matter contamination ($PM_{2.5}$ and PM_{10}), increase of UV radiation, acidic rainfall, increased ozone levels, and increased nitrogen oxide levels[12,13]. Children are particularly sensitive to air pollution, and those under the age of five constitute a particularly vulnerable population[14]. The most typical feature of both the asthma and the other respiratory disorders related to pollution is bronchial reactivity, or the exacerbated response of the airways to external particles. With this in mind, the key aim of this study was to compare the bronchial reactivity in a group of healthy individuals who were not exposed to high levels of air pollution with that of a second group of individuals living in an area with high levels of air pollutants. Undoubtedly, the most direct damage done by air pollution is reflected in the respiratory tract, and therefore our study focused on this aspect.

2. Materials and Methods

The Research was conducted with two groups:

- A control group, which included 40 people, all healthy students from the Medicine Faculty, and
- An experimental group, which included 58 individuals, all permanent inhabitants of a region in Kastriot, Kosovo around the power plants "A" and "B".

Individuals were randomly selected for the study, and all participants were informed about the procedures and purpose of the study. All individuals participation the study were instructed not to take any medication for at least 48 hours prior to the examination so that medication would not interfere with the results of tests.

For all participants, resting pulmonary function was determined. After that, the resistance of the airways (Raw) was measured, and specifically that of the lungs. Next the Intra-Thoracic Gas Volume (ITGV) was measured by applying body plethysmography. From the results obtained for the Raw and ITGV tests, the values for airways resistance (SRaw) and specific conductance (SGaw) were calculated[15-17].

One additional procedure was applied to the control group to prove that the selected individual was healthy and had no bronchial reactivity in their respiratory tracts. We demonstrated this by performing a test provoking broncho constriction through the use of a broncho constricting agent as a cholinergic agonist. In our situation, we used acetylcholine to constrict the airways.

Three key techniques were thus applied during the methodology: spirometry, body plethysmography, and a broncho constriction provocation test. In our situation, the body plethysmography and broncho constriction provocation test were most important because spirometry is only an initial procedure during the measurements of pulmonary function, and on its own does not provide enough information about the respiratory parameters, especially when considering bronchial reactivity. However, plethysmography is a very sensitive and precise technique commonly used in research into the conditions that affect bronchial reactivity.

2.1 Statistical Analysis

In this study we were considering the differences between two samples. For this reason, we used the t-test to differentiate between the significance levels of the two groups. The study was conducted with two groups: the control group (students from the medical faculty) and the experimental group (residents of the polluted region). For the control group, we had two sets of plethysmographic parameters, obtained from measurements taken before and after provocation with Acetylcholine (Ach). To calculate the significance level between these two measurements we used the paired t-test because we were dealing with one group under two different conditions (before and after provocation).

When we compared the significance levels of the control group with those of the experimental group, we used the t-test for independent samples (the unpaired t-test), because we were dealing with two separate groups that were independent of each other. The results of the t-tests were processed by using a statistical program called Graf Pad Prism.

3. Results

From our results, we were able to conclude that the group of healthy students showed no presence of bronchial reactivity in the respiratory tract and could therefore be used as a control against which to assess the condition of the experimental group (Table 1 and 2). The measurement data for the individuals from both groups are provided in Table 1 and 2. First, we present the results from the body-plethysmography with the control group with the aim of alleviating any doubts concerning the possible presence of bronchial reactivity in this group. These results are expressed in two series, prior to and after use of the bronchial constriction test, as shown in Figure1. Statistic calculations with the t-test indicate that there were no significant changes between conditions, namely prior and after provocation with acetylcholine. The value of probability, $p = 0.197$ ($p > 0.1$) confirms this. In order to present a clearer picture of the differences between these two series of plethysmography results with the control group, the same data are presented graphically. The statistic calculation of the SRaw, which was performed with the results from the control and experimental groups, indicates that there is an extremely significant change between the two groups. The value of probability, $p = 0.0001$ ($p < 0.01$) confirms this. These results indicate the presence of decided bronchial reactivity in the individuals from the experimental group. The parameters SRaw and SGaw for both groups analyzed are presented in charts in Figure 1 and 2.

Table 1. General characteristics of the people involved in this study.

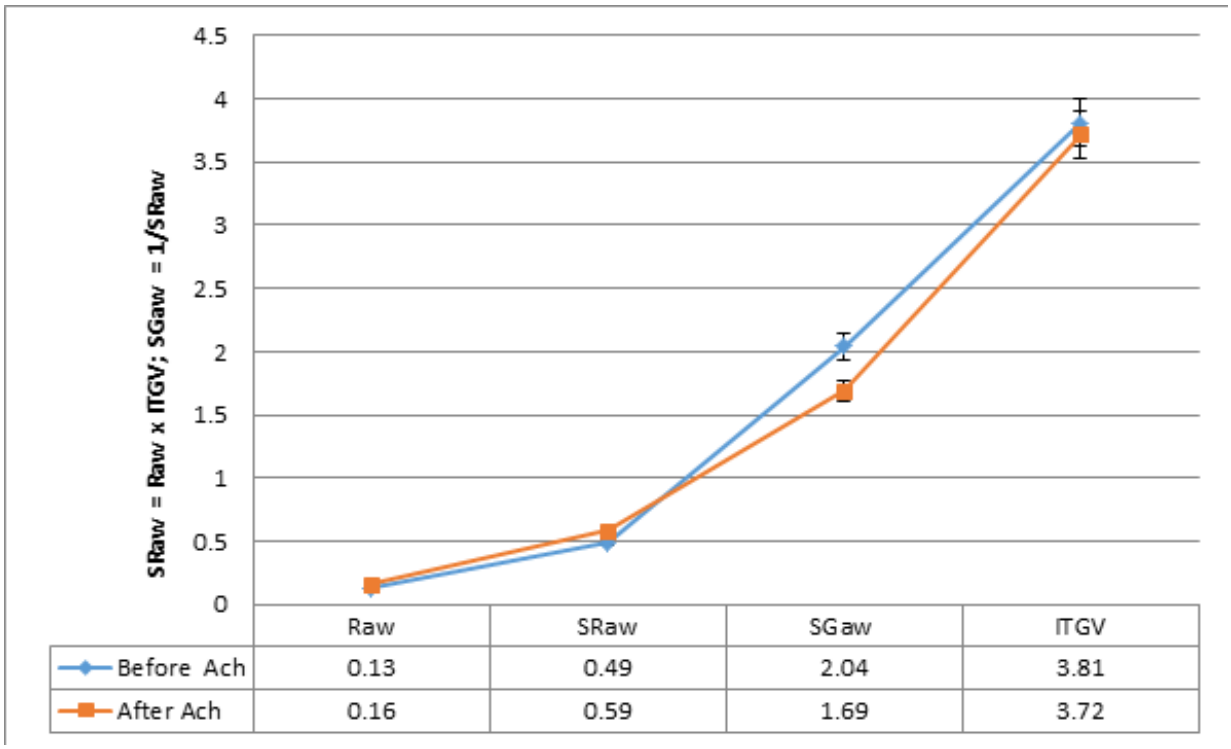
Group	N	Age (years)	Height (cm)	Weight (kg)	VC (L)	FEV1 (L)
Control	40	21.9 ± 0.44	171 ± 1.37	65.6 ± 1.6	4.58 ± 0.176	3.92 ± 0.152
Experimental	58	35.44 ± 1.44	169.77 ± 0.84	68.81 ± 1.34	4.56 ± 0.12	3.72 ± 0.13

Generalized mean values for: Control group n = 40, X ± SEM; Experimental group n = 58, X ± SEM. The general starting values for: VC (L) and FEV_1 (L) are also given.
- VC =Vital capacity expressed in liters,
FEV_1 - Enhanced expiratory volume in the first second, expressed in liters.

Table 2. Body-plethysmography features of the people involved in this study

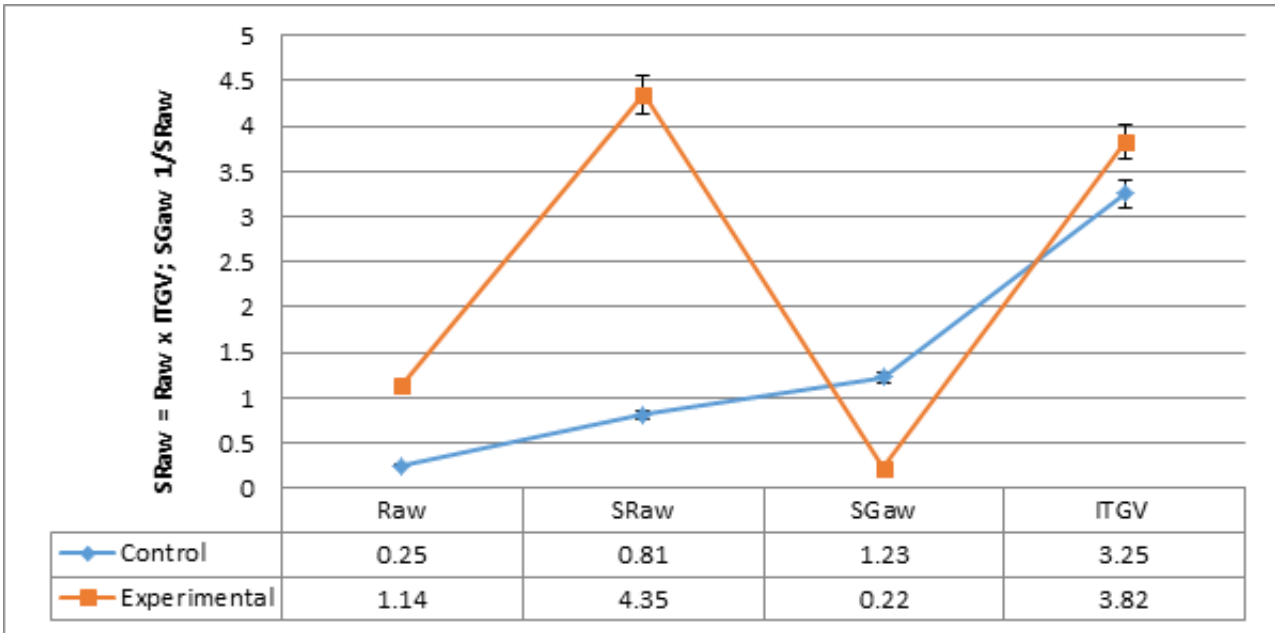
Group	N	Raw (kPa × s/L)	ITGV (L)	SRaw (kPa × s)	SGaw (kPa × s)
Control	40	0.25 ± 0.8	3.25 ± 0.1	0.81 ± 0.05	1.23 ± 0.14
Experimental	58	1.14 ± 0.7	3.82 ± 0.1	4.35 ± 0.08	0.23 ± 0.11

Mean values: Control group n = 40, X ± SEM; Experimental group n = 58, X ± SEM. General Values for: Raw (kPa × S/L); ITGV (L); SRaw = Raw × ITGV; SGaw = 1/SRaw.
- Raw - Airway resistance expressed in kilo pascal/second/liter,
- ITGV - Volume of intrathoracic gas expressed in liters,
- SRaw - Specific airway resistance which is the relationship between resistance and the volume of intrathoracic gas,
- SGaw - expresses the relationship between 1/specific resistances. SGawcan also be referred to as specific airway passage or conductivity.



	Raw	SRaw	SGaw	ITGV
Before Ach	0.13	0.49	2.04	3.81
After Ach	0.16	0.59	1.69	3.72

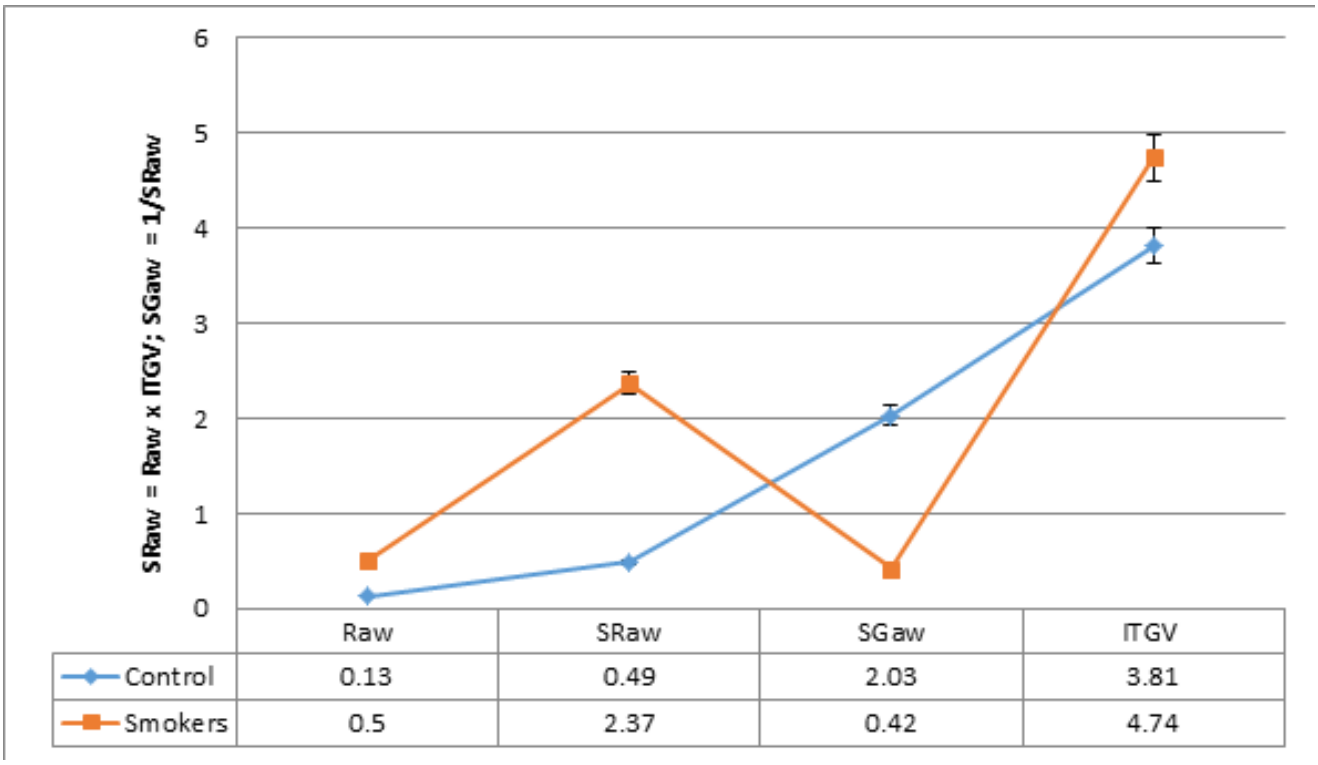
Figure 1. Comparison of body plethysmography parameters prior to and after provocation with Acetylcholine (ACh) in individuals of the control group (n = 40; X ± SEM) ($p > 0.1$).



	Raw	SRaw	SGaw	ITGV
Control	0.25	0.81	1.23	3.25
Experimental	1.14	4.35	0.22	3.82

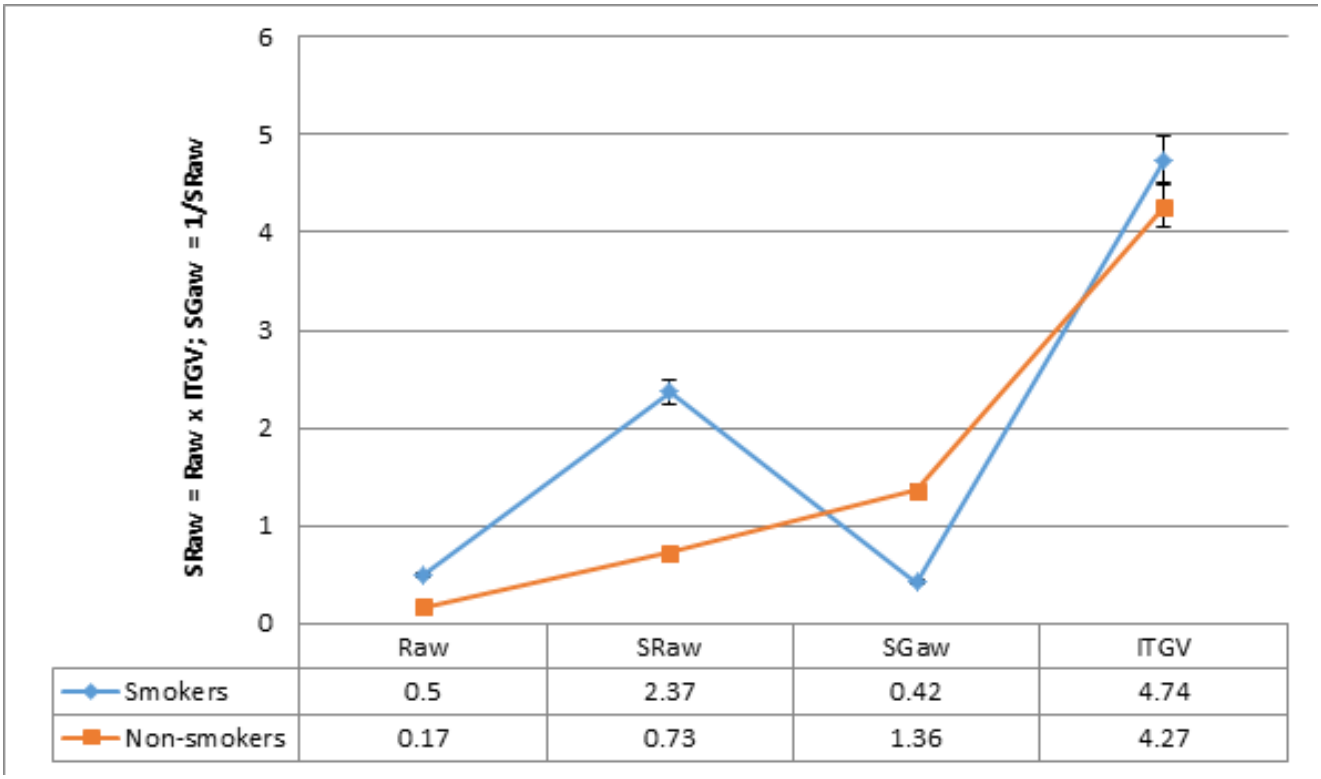
Figure 2. Comparison of SRaw and SGaw values in the control group (n = 40; X ± SEM) and the experimental group (n = 58; X ± SEM); ($p < 0.01$).

The statistical calculations with the Raw, SRaw, SGaw and ITGV scores for the smokers in the control and experimental groups indicate very significant differences between these two groups. The value of probability, p – 0.0003 ($p < 0.01$) confirms this**.** This confirms the strong presence of bronchial reactivity in the experimental group relative to the healthy student group. The parameters of the plethysmography for these two groups are presented as charts in Figure 3 and 4.



	Raw	SRaw	SGaw	ITGV
Control	0.13	0.49	2.03	3.81
Smokers	0.5	2.37	0.42	4.74

Figure 3. Comparison of SRaw and SGaw values in the control group (n = 40; X ± SEM) and the experimental smoking group (n = 58; X ± SEM), ($p < 0.01$).



	Raw	SRaw	SGaw	ITGV
Smokers	0.5	2.37	0.42	4.74
Non-smokers	0.17	0.73	1.36	4.27

Figure 4. Comparison of values for smokers and non-smokers (n = 58; X ± SEM; ($p < 0.01$).

4. Discussion

The negative impact of air pollution on human health in general and on the respiratory tract in particular has been shown by many authors and scientific projects worldwide. The conclusions of most of these works are based on correlations between the level of air pollution and mortalities derived from cardiovascular and respiratory morbidity.

Most of these studies have been performed in heavily industrialized countries. In research carried out[18] in six major metro politan cities in the United States, a strong correlation was established between the degree of pollution (especially the concentration of particulate matter) and mortality from cardiopulmonary disease. A similar project conducted in 20 major US cities demonstrates the same correlation between the concentration of air pollutants and respiratory health[19]. Similar projects have been conducted in European countries. One such example is a study[20] conducted in 12 European cities. According to this study, in the cities of Western Europe, for every increase of 50 μg/m^2 in SO_2 level there is a 3% increase in mortality. In central European cities, for the same increase, the mortality rate increased by 0.8%. The effects of air pollution have been shown to be greater during summer. Similar results were found in a study of 13 Italian cities which confirmed the effect of air pollution on human health[21]. Large international scientific studies such as these support the results of our research in Kosovo.

From the facts presented here, it can be concluded that air pollution is a problem of global proportion. The adverse impact of poor air quality on health, which is mentioned in most of the scientific research, is usually attributed to high levels of PM_{10} and $PM_{2.5}$ and to gases such as SO_2, NO, and ozone. These same pollutant agents have also been identified in Kosovo, and particularly around the power plants in the Kastriot region. Our findings regarding general morbidity and effects on the respiratory tract are similar to the results of other studies around the world[12]. Due to concerns about air pollution, tests have also been conducted to see whether the harmful effects on human health are reduced following a reduction in air pollution resulting from environmental interventions undertaken in many countries of the world. Research[22] in this area: according to this research, it was shown in six different cities that a reduction in $PM_{2.5}$ levels in the atmosphere is accompanied by a reduction in the level of risk for cardiovascular morbidity and lung cancer. Work carried out in Hong Kong among primary school children who as a sub-group are particularly sensitive to air pollution, showed similar beneficial effects following a reduction in pollution levels[14].

All the studies described above have used prevalence of morbidity to prove the correlation between air pollution and damage to health. There are few studies that have measured concrete parameters in assessing the general condition of respiratory health. This is a possible deficiency in the comparisons drawn by the above-mentioned authors. Our research shows that it is possible to measure bronchial reactivity as a pathophysiological element. We have therefore used bronchial reactivity to evaluate the impact of air pollution on people's general respiratory function. The correlation between this pathophysiological phenomenon (bronchial hyper-reactivity) and pollution has been used in many other studies[11,14]. Based on the results of our own research and that of many other authors, bronchial hyper-reactivity can be regarded as a suitable indicator for identifying individuals or groups particularly susceptible to air pollution. A study whose results are comparable with our own is that published[23] who arrived at much the same conclusions. Their paper indicated that increased levels of pollution correlated with the prevalence of respiratory symptoms arising from bronchial hyper-reactivity. Two factors that favor the comparison of the results of these two studies are the similar ages of the individuals in the samples and the similar air quality in the local environments. This study confirmed that both variability in Peak Expiratory Flow (PEF) and bronchial hyper-reactivity are adequate tools for examining the effects of pollutants on the respiratory tract.

Bronchial reactivity can be used as a parameter for analyzing not only the air pollution that comes from heavy industry, such as coal burning to generate electricity, but also other forms of pollution. This has been confirmed by authors[11] who showed that pollution from urban traffic has an effect on bronchial hyper-reactivity. According to Janssen et al., the most vulnerable group to traffic pollution is children, especially those with persistent respiratory problems (revealing the development of bronchial reactivity). These results suggest that, due to the permanent intake of air polluted with harmful particles, inflammatory reactions occur in the respiratory tract, involving the release of chemical mediators such as histamine, serotonin, bradykinin, leukotriene LTD4,

PGF2-alpha SRS, thromboxane, and prostacyclin. Therapeutic measures are required to reduce this inflammation[24-26]. As a result of the inflammatory reaction, the airways permeability parameters such Rt, SRT and SGaw obtained from plethysmography showed significant statistical changes in our study ($p < 0.01$). (Our experiment showed this was due to the harmful effect of particles discharged in to the air from power plants "A" and "B" in Kosovo). It can be concluded that irritation of the airways and the initiation of respiratory tract inflammatory reactions was expressed more in the smokers than in the non-smokers.

An extremely important aspect in studying the effects of air pollution on human health is to analyze the other factors that favor, increase, or aggravate the harmful effects of air pollution. In this context, there is no doubt that a very important factor in relation to the respiratory tract is smoking. The notorious effects of tobacco on the respiratory tractare known globally, but here we were interested in the summative effect of air pollution and smoking. As can be expected, smoking significantly increased the effect of air pollution on respiratory disorders. This was confirmed by our research in which we measured a highly significant difference ($p = 0.0003$) of SRaw values between smokers and the control group (healthy students). Our conclusion regarding the aggravating effect of tobacco on the effects of air pollution on respiration is supported by previous research[18]. When the experimental group was compared with the control group, there was a high, $p = 0.0003$, significance between the smoking group and the control group. This significant difference shows conclusively that air pollution and smoking have a combined negative effect on the health of residents living near the power plants in Kastriot. Since our research was examining bronchial reactivity, we analyzed this phenomenon through body plethysmography. It would be useful to compare our results with those of other authors who have applied the same methodology because the plethysmography parameters, SRaw and SGaw, are gold standards for assessing and testing the degree of bronchial hyperreactivity. To date, very little such research has been done not only in our country but also worldwide. Therefore, our research is one of the first to apply this sophisticated and sensitive technique in assessing the effect of air pollution on bronchial reaction in a population that has been exposed for a long time to high concentrations of air pollution. The Kastriot region is among the most polluted regions in Kosovo in terms of air quality. Based on measurements made by the Kosovo Environmental Protection Agency, the largest environmental polluter in Kosovo, the Kosovo Energy Corporation, has recently increased the level of air pollution excessively. Again, according to data from this agency, the "Kosovo A" power plant leads in dust particle discharge, with up to 14 times the permitted level, while the "Kosovo B" power plant has up to 3 times this level. Based on the anamnestic data available from the hospitals in the country, patients coming from this area of Kosovo have a high prevalence of respiratory problems and cardiopulmonary morbidities. It is this information regarding the air pollution and the complaints of inhabitants of this region, including through the media that provided the main impetus for this study. For these reasons, our experimental research group was made up of permanent residents from the city of Kastriot.

5. Author Contributions

AH and PI conducted the literature search and determined studies for exclusion and inclusion. LM, AD and AB extracted data from the studies included, performed the meta-analysis, and drafted the manuscript. HI conceived the idea for the study, designed the study, and critically revised the manuscript for content. All authors contributed to the data analysis, drafting and revising the article, and gave their final approval to the version to be published, and agreed to be accountable for all aspects of the work.

6. Disclosure

The authors report no conflicts of interest in this work.

7. Summary

The effect of air pollution on bronchial reactivity is very evident and this effect is a function of the duration of exposure and concentration of air pollutants. The correlation between bronchial hyper-reactivity and level of pollution was confirmed in all groups and subgroups analyzed ($p < 0.01$). The entire experimental group and the smoking subgroup indicated extremely significant changes in the specific resistance of their airways (SRaw) ($p < 0.01$), which was much higher than that of the control group ($p > 0.1$). The difference between the two experimental subgroups proved the impact of smoking in aggravating the negative respiratory effects of air pollution.

In conclusion, the results obtained demonstrate that bronchial hyper-reactivity can be used as a pathophysiological parameter in assessing the harmful effects of air pollution on human health. This study demonstrates the need for continuous macro and micro climatic monitoring to verify the concentration level of harmful particles in order to detect the reactions of organisms in the event of increased and unexpected emission of particles for whatever reason. These conclusions suggest that the realities of the situation for this population with its level of exposure to air pollution are very serious. Based on this situation, further exposure of this population to the existing level of air pollution poses a high risk to their health in general, and especially to their respiratory health.

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