

Article

Perceived Nuisance Caused by Air Pollution on Amateur Endurance Athletes/Exercisers: Development of a Psychometric Scale

George Koskinas ^{1,*}, Ilias Mavroidis ^{1,*}  and Yiannis Giossos ²

¹ School of Science and Technology, Hellenic Open University, 18 Aristotelous Str., 26335 Patras, Greece; koskinasgeorge@yahoo.com

² School of Physical Education and Sports Science, National and Kapodistrian University of Athens, 41 Ethnikis Antistasis Str., Dafni, 17237 Athens, Greece; ygiossos@phed.uoa.gr

* Correspondence: imavr@tee.gr

Abstract: Air pollution is a major health-related environmental challenge that affects many aspects of people's daily lives. For amateur endurance athletes/exercisers, air pollution can cause, apart from the common health issues, reduced performance capacity during training and races. The most significant inconveniences that these amateur athletes/exercisers have to deal with, are related to breathing difficulty, increased heart rate, cough or respiratory problems, and eye or nose discomfort. The aim of this study is to create a psychometric scale that estimates the nuisance/discomfort that amateur endurance athletes/exercisers (triathlon, cycling, running, swimming) feel during their training, under conditions of increased air pollution, and to see how this is linked to demographic characteristics. The main overall purpose is the identification of possible correlation between air pollution and reduced athletic performance, as well as between air pollution and the wellbeing of amateur endurance athletes/exercisers, and to thus enable recommendations on training in a polluted environment. To this aim, a questionnaire was developed, initially through a pilot stage. The fully developed scale was provided to two hundred and ninety-two (292) amateur endurance athletes/exercisers for an exploratory factor analysis to be carried out. The exploratory factor analysis indicated three (3) factors accounting for 37.11% of the overall variance. The first factor "Physical discomfort" included nine (9) questions, the second factor "Lack of discomfort" five (5) questions, and the third factor "No general discomfort" six (6) questions. The degree of reliability was satisfactory, since Cronbach's α coefficient was 0.841 for the first factor, 0.642 for the second, and 0.766 for the third factor. Subsequently, fluctuation analysis (ANOVA), multivariate fluctuation analysis (MANOVA), and Pearson's r coefficient were used to indicate correlations between the independent variables and the three factors identified. Correlation between discomfort due to air pollution and the place of residence, as well as the presence or absence of allergies, was indicated. On the other hand, there were no significant statistical differences between gender, type of sport, the volume of training, the presence or not of respiratory problems, and smoking. Overall, the scale can be considered both valid and reliable.

Keywords: air pollution; nuisance; amateur endurance athletes/exercisers; psychometric scale



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1. Introduction

Air pollution is one of the most important problems in modern society, with a significant impact on human health and the environment. Pollutants in the atmosphere can cause

health problems in relatively large concentrations, but even in smaller concentrations they cause a strong feeling of nuisance to anyone who is exposed to them. By the term nuisance, we mean difficulty breathing, eye or nose discomfort, cough, headache, and other reactions of the human body, as well as psychological pressure, such as decreased appetite, feeling unwell, etc. [1].

While these generally apply to most of the population, in athletes/exercisers, the above symptoms create an additional nuisance by making their activities even more difficult. Whether it is professional athletes, who are looking for the most ideal conditions for even the slightest improvement in their performance, or amateur athletes/exercisers, who train and exercise for their physical and mental health, it is important that they can continue to exercise without the nuisance created by air pollution. Athletes of endurance sports come into contact with polluted air quite often. Such athletes/exercisers include runners, cyclists, triathletes and others, who train frequently on the road—including on roads with increased traffic—and consequently may come into contact with high levels of air pollutants [2].

The instruction to the general population is to avoid roads with increased traffic, whenever possible. The same applies to athletes and exercisers, who are often advised by their coaches to exercise either in stadiums or inside a home or gym, or in remote areas, including sometimes mountains, and generally areas that are distant from traffic arteries [3,4].

The psychological component of the nuisance for amateur athletes and exercisers is extremely important. This may be to a lesser extent for professional athletes, who are bound by contracts and sponsors and who in many cases do not have the option to avoid or overtake a training session or a race. On the other hand, for amateur athletes/exercisers, that train mainly because this is their hobby and because they take pleasure from it, it is important to feel good and enjoy what they do, without feeling stressed or disturbed by external factors such as air pollution [5].

In the literature, there are a number of studies on the nuisance caused by air pollution to the general population [6,7]. However, there is a lack of studies focusing on athletes/exercisers and especially those of endurance sports that take place outdoors and not within a stadium. To this end, the purpose of the present study is the development of a psychometric scale to examine the nuisance caused by air pollution on endurance athletes/exercisers and to examine how the main factors of such a scale are related to independent variables linked to demographic characteristics.

2. Background

2.1. Effect of Air Pollution on Human Health

A number of air pollutants commonly found in the urban environment can cause significant problems for human health. Such pollutants include carbon monoxide (CO, 17–52 ppm), sulphur dioxide (SO₂), nitrogen oxides (NO_x), Volatile Organic Compounds (VOCs, 645–1764 ppm), ozone (O₃) and particulate matter (PM₁₀ and PM_{2.5}, 50.13–96.84 µg/m³) [8–10]. The health effects of human exposure to air pollution can be either long or short-term. Furthermore, different pollutants may have significantly different exposure–response characteristics [11]. According to WHO [12], recommended air quality levels are 4 mg/m³ for CO (24 h), 40 µg/m³ for SO₂ (24 h), 25 µg/m³ for NO₂ (24 h), 100 µg/m³ for O₃ (8 h), 45 µg/m³ for PM₁₀ (24 h), and 15 µg/m³ for PM_{2.5} (24 h).

Air pollution (both indoor and ambient) remains responsible for the greatest number of deaths caused by different pollution types, causing 8.1 million deaths in 2021 [13,14]. Lipfert, examined 417 long-term studies of air quality and health and found that 54% of them reported a significant association of health effects with at least one pollutant [15], with cardiovascular and respiratory causes being the most important health effects observed. In 2015 alone in India, about 1 million premature deaths related to respiratory problems were

caused due to outdoor air pollution; in addition, about another 1 million deaths were due to indoor air pollution [16].

The main mechanisms that cause morbidity and mortality in the human population due to air pollution are linked to acute respiratory infections, asthma, chronic obstructive pulmonary diseases, cardiovascular diseases, lung cancer, as well as to aggravation of any pre-existing disease. Air pollution mainly affects those living in large urban areas, where pollutants emitted by vehicles contribute the most to the degradation of air quality, together with pollutants emitted from central heating systems [17]. Pollutants are also emitted by industrial installations, where there is also a danger of industrial accidents. The dispersion of pollutants is determined by many parameters, most notably wind speed and direction and atmospheric stability. Exposure to high air pollution does not occur exclusively outdoors. Indoor pollutants are emitted from heating appliances, such as fireplaces, wood stoves and gas stoves, or even from cooking appliances, such as wood ovens. Li, Zhou and Ding conducted a study in China and observed that a person's long-term exposure to pollutants emitted indoors is associated, *inter alia*, with a greater chance of developing symptoms of depression [18].

2.2. Effect of Air Pollution on Amateur Athletes/Exercisers

The main symptom that air pollution causes for athletes and exercisers is difficulty in breathing, since most pollutants affect the human respiratory system; moreover, athletes and exercisers—especially endurance athletes/exercisers—are frequently undertaking aerobic exercise. Almost all atmospheric pollutants affect athletic performance, although to different extents [19]. Typically, carbon monoxide is destructive to athletic performance and causes significant nuisance, since it prevents the transport of oxygen to the muscles through the blood. On the other hand, sulphur dioxide and nitrogen oxides, although harmful to humans in general, are rarely at a high-enough level to affect athletic performance. However, sulphur dioxide has a greater effect on asthmatic athletes and exercisers [20].

Ground-level ozone has a serious effect on athletic performance as well as on the general health of athletes and exercisers, as it settles in the lungs. The way it works suggests that it can affect athletes and exercisers even when its concentration is low enough. Similarly, suspended particles (PM₁₀) can have an important effect on athletes and exercisers, *inter alia* because they increase the accumulation of lead in the blood as their concentration increases. Many studies highlighted that PM₁₀ and PM_{2.5} were associated with cardiovascular, respiratory, and neurodegenerative diseases [21–23], while the smaller fractions (PM_{2.5}) pose the greatest health risk since they can enter deep into the lungs and some may even enter into the bloodstream. These particles can also accumulate in the atmosphere through a process called 'resuspension', in which particles from the ground, are lifted up due to wind or traffic. High concentrations of particulate matter during resuspended dust episodes are often caused by coarse particles derived from soil and road surfaces [24]. Finally, VOCs have not been studied enough to draw safe conclusions, but the prevailing perception is that they too will negatively affect athletic performance.

How much athletes and exercisers are affected by pollution depends partly on the type of sport they do. Thus, those who exercise outdoors and near roads, such as cyclists or runners, are expected to be more affected than others who exercise indoors, such as basketball players. Also, people who exercise in swimming pools, such as swimmers or divers, often show symptoms of bronchoconstriction caused by their frequent contact with pool chlorine [25]. More specifically, obtained samples of exhaled air were composed of significantly different metabolomics when compared before, during and after exercise training, suggesting that exposition to indoor chlorine causes changes in the airway mucosa [26]. Finally, those who train on ice rinks, such as ice hockey athletes/exercisers, ice skating

rinks, and ice dancers, often experience shortness of breath or bronchoconstriction caused by pollutants produced by machines to preserve ice in solid form [4].

In general, the phenomena of bronchoconstriction and asthma due to exercise are mainly due to the presence of ozone and suspended particles. In addition, ground-level ozone can lead to imbalances in the autonomic nervous system, in the sympathetic medullary axis of the adrenal glands and in the hypothalamus–pituitary–adrenal axis. These systems are of major importance for the overall human nervous system and athletic performance is affected when these systems do not function in the best possible condition [27].

If an athlete/exerciser has allergies and/or respiratory problems, then they are affected to a greater extent by air pollution, both when the person exercises and in his/her daily life. More specifically, in athletes/exercisers who have upper respiratory allergies, a statistically significant decrease in exhalation intensity has been observed under increased levels of nitrogen dioxide and suspended particles. In contrast, in athletes/exercisers who do not have allergies, the decrease in exhalation capacity was not statistically significant [28].

Cruz and his co-workers, analyzed how increased levels of pollution reduce athletic ability [3]. Trained cyclists were assigned a 90 min workout of moderate intensity, in an environment either with vehicle exhaust gases or in clean air. During training, blood samples were taken every half hour, and it was observed that, under the polluted environment, in the first 30 min the metabolic processes of glycine and serine were significantly affected, in the first 60 min those of arginine and proline were significantly affected, while in 90 min the glycolysis process had a significantly reduced performance.

It should be noted that regular exercise can, to some extent, protect the health of the athlete/exerciser. Olivo and his co-workers, suggested that aerobic training can strengthen the immune system and the lungs and can delay the presence of inflammations resulting from exhaust gases [29]. However, aerobic training alone is not capable of completely preventing damage to the lungs and other biological processes.

2.3. Nuisance Due to Air Pollution

Air pollution, in addition to its direct effects on humans, can also create the feeling of nuisance, especially after long exposure to it. Human sensory organs are sensitive enough to perceive the presence of non-clean air, while it seems that the threshold of nuisance to humans from air pollution is often lower than the limits established by the institutions. Therefore, even before pollution reaches dangerous levels, the average person will realize it, as they will be annoyed by it [30]. The psychological dimension of nuisance from a polluted atmosphere may be more important than the biosomatic one [31]. This means that how one perceives air quality can have serious effects on one's mental as well as physical health. The effects on mental health usually lead to increased levels of stress in citizens [32].

Stenlund, Liden, Andersson, Garvill, and Nordin concluded that if a person believes that they are in a polluted environment [33], they will be more aware of air pollution than when they believe that they are in a less polluted environment. The authors examined data from a questionnaire before and after the closure of an agglomeration plant in Sweden and observed that even after the closure of the plant, the levels of air pollutants remained high, but the population of the area perceived air pollution to be quite reduced. A similar study in Kenya found that those who lived near an industrial area perceived air pollution much more strongly than those who lived further away from the industrial area [34]. A survey conducted in Spain on pregnant women [35], observed that housewives are much more bothered by air pollution than those who work, while at the same time the authors associated increased nuisance with women living in urban environments, as opposed to those living outside the city.

In general, women, persons with respiratory problems, and those living in urban areas are likely to be more annoyed by air pollution. On the contrary, no correlation was observed between age, educational level, and whether the respondent is a smoker or not [31]. On the other hand, a study by Jacquemin and his co-workers, found a correlation between increased nuisance from air pollution and gender and specific demographic parameters: women, those with respiratory problems, those who lived in urban areas, non-smokers, and those with higher educational attainment were more annoyed by air pollution [36]. Their study also suggested that Northern Europeans are more tolerant of air pollution than Southern Europeans.

Kim, Yi, and Kim in a survey conducted in South Korea found that younger persons, those with higher educational levels, and those with lower incomes (as they mostly live in poorer areas) were more annoyed by air pollution [37]. Forsberg, Stjerjberg, and Wall, in a survey in Sweden, observed that women, those who have respiratory problems or asthma, and those who do not have access to a car, and therefore commute by means of public transport, are likely to experience greater levels of nuisance due to air pollution [38]. Finally, in a survey in three major cities in China, it was found that women, older persons, and those with health problems are more annoyed by air pollution [39].

3. Methodology

3.1. Purpose

The purpose of this study is the construction and development of a psychometric scale, which will recognize and interpret the nuisance/discomfort that amateur endurance athletes/exercisers (triathlon, cycling, running, swimming) feel during their training, under conditions of increased air pollution, and to see how this is linked to demographic characteristics. The main overall purpose is the identification of possible correlation between air pollution and reduced athletic performance as well as between air pollution and the wellbeing of amateur endurance athletes/exercisers, and to thus enable recommendations on training in a polluted environment.

The scale was developed through a robust process involving amateur athletes/exercisers of endurance sports (running, cycling, swimming and triathlon) in various regions in Greece. The main objective of the scale is to enable the correlation between increased air pollution and how athletes/exercisers perceive it, as well as how their performance and appetite for sports are affected. For this purpose, a quantitative scale was developed, and its reliability and validity are studied. A scale is characterized as valid or true when it accurately represents the dimensions of each effect it intends to describe or explain at a theoretical level. Essentially, the validity of a scale expresses the extent to which the scale actually measures what it is supposed to measure. On the other hand, a scale is reliable when it measures in a consistent way, i.e., the scale's reliability is its ability to give the same results if applied repeatedly [40].

3.2. Procedure for Developing and Administering the Questionnaire

The questionnaire consists of questions that refer to factors that can affect an amateur athlete's/exerciser's training or annoy them and are directly related to air pollution. The instructions provided at the beginning of the questionnaire invited participants in the survey to express their own personal opinion. Each question is answered on the basis of the five-point Likert scale from 1 to 5, where number 1 corresponds to "I do not agree at all" and number 5 to "I agree very much".

The experimental process for the development of this psychometric scale involved two main parts: (a) the preparatory pilot stage, in which all the necessary actions were taken for the creation and evaluation of the questionnaire through a credible procedure,

and (b) the main stage, in which the prepared questionnaire was administered to amateur athletes/exercisers through social networks (social media—Facebook, Instagram).

The first, preparatory, stage was divided into 4 distinctive parts. Initially, a bibliographic search regarding the main questions was performed, in order to create an item pool. Then, in the second pilot part, a small sample of amateur athletes/exercisers (6 athletes/exercisers) were interviewed using open-ended questions, with the aim to develop novel, distinct, questions and to further enrich the main questionnaire, increasing its validity. The open questions used were as follows: (1) What bothers you in terms of air pollution/traffic/noise/odors, etc., during your exercise (mainly running and cycling)?; (2) How much and in which way do you think air pollution affects your performance (e.g., increased heart rate, etc.?; (3) Do you have anything else to add related to practicing sports during increased air pollution conditions? Amateur athletes/exercisers answered the questions given above, without being aware that their answers would assist in the creation of the scale. Furthermore, they were requested to be objective, based on their own experience, and not be affected by anything they might have heard.

In the third part of the first stage, the answers to the above questions were evaluated to develop distinct closed questions, while the questions already created through the bibliographic search were also evaluated. Some questions were excluded because they duplicated other questions that would achieve the same result or because they did not fit the style and expected results of the scale. Following the information above, the final compilation of the questions to be included in the questionnaire was made.

In the fourth, final, part of the first stage, the questionnaire was administered on a pilot scale to a small sample of amateur athletes/exercisers (25 athletes/exercisers) to confirm adequate variation in the answers and to showcase any issues related to the questionnaire that had not been observed before. For this pilot stage, a convenient sample of amateur athletes/exercisers was used, coming from the local cycling team and the local running team in Corfu, Greece. Participants were asked to answer the questionnaire and note if there are any possible challenges in responding to it and if they would like to add any questions that had probably been overlooked. The results of the preliminary pilot stage were considered satisfactory: the variation in responses was satisfactory and no new questions were added. Twenty-five (25) questions were recommended overall in this first stage.

During the second, main, stage of the research, the questionnaire was administered to the main sample of amateur athletes/exercisers—mainly amateur runners, cyclists, swimmers and triathletes—through social networks (Facebook and Instagram groups). Taking into account that the population of the study consists of active athletes/exercisers and that the questions asked do not contain sensitive content, choosing social networks is not expected to affect the representativeness of the population and of the responses. The questionnaire consisted of (a) demographic questions (gender, age, place of residence, type and hours of exercise, etc.) to define the independent variables of the survey, and (b) the twenty-five (25) questions recommended in the first stage. It is estimated that its completion by participants took about 5–7 min. Table 1 below shows the 25 questions of the questionnaire, in the order in which they were administered to the participants.

Table 1. The final questions of the scale as administered to participants.

How Much Do You Agree with the Following Suggestions?
1. I am bothered by vehicle exhaust pollution when I train.
2. I am bothered by pollution due to chimneys (fireplaces, etc.) when I train.
3. I feel it is dangerous for my health to train in the midst of high air pollution.
4. I feel more tired when I train on days when I feel increased air pollution.

Table 1. *Cont.*

How Much Do You Agree with the Following Suggestions?
5. I don't mind the noise when I'm training.
6. I feel like I'm having more difficulty in high-intensity workouts on days when I feel increased air pollution.
7. I feel like I struggle more in low-intensity workouts on days when I feel high air pollution.
8. I don't feel like I have a drop in my performance (e.g., running pace, etc.) on days when I feel increased air pollution.
9. I don't mind air pollution when I train at night.
10. I feel stinging in the eyes, nose, etc. when I train on days when I feel increased air pollution.
11. I don't feel like I have reduced recovery (increased leg pains, etc.) after training on days when I feel increased air pollution.
12. I am bothered by air pollution when I train indoors.
13. I am bothered by odors (from garbage, etc.) when I train.
14. I am bothered by air pollution, so I adjust my training hours to avoid high levels of pollution.
15. I feel like I have worse sleep quality on days when I feel increased air pollution.
16. I am bothered by air pollution, so I train indoors.
17. I don't mind the pollution from heating/cooling appliances when I train indoors.
18. I feel that for the same training intensity, I have higher heart rate on days when I feel increased air pollution.
19. I feel pains in the muscles, chest, etc. when I train on days when I feel increased air pollution.
20. I am bothered by dust/pollen pollution when I train.
21. I don't feel like air pollution makes it difficult for me to train.
22. I feel headache, nausea, etc. when I train on days when I feel increased air pollution.
23. I am bothered by air pollution and that's why I choose to train on a mountain.
24. I do not feel a decreased appetite for training on days when I feel increased air pollution.
25. I feel short of breath while exercising on days when I feel increased air pollution.

3.3. *Methods of Statistical Analysis*

3.3.1. Preliminary Checks of Factorial Analysis

To check the structural validity of the questionnaire, the following tests were used regarding the suitability of the scale and the adequacy of the sample used for factorial analysis: (a) Bartlett's test of sphericity to test the independence of the variables from each other, and (b) the KMO criterion to test the adequacy and suitability of the sample (Kaiser–Meyer–Olkin).

3.3.2. Structural Validity of the Measurement Instruments/Scales

The principal component analysis method was chosen in order to examine the factorial structure, and, in general, the structural validity of the questionnaires. The statistical program Statistical Package for Social Science (SPSS; Version 13.0) was used. To determine the number of factors in the questionnaire, both the analysis of the main components and factorial analysis with lateral rotation of the axes were used.

The main component method is the method that interprets both the common and the unique variance that occurs in each factorial structure. In addition, the method of the main components determines the number of factors that should be extracted from the analysis; for this reason, different methods of rotation of the axes are chosen. Since the only variance may be due to error variance [41], the main component method was chosen to further investigate the structural validity of the questionnaires.

This statistical method has an advantage over factorial analysis, because it examines the common variation within the factorial structure of the specific questionnaire. It is considered the appropriate method when there are no previous research results on the factorial structure of a measuring instrument. Also, both rectangular rotation (varimax rotation) and oblimin rotation ($\delta = 0$) of the axes were conducted to determine the interrelationships of the factors and the degree of correlation [42].

The following five criteria were used to select the number of factors: (1) the scree plot test, (2) the eigenvalue-greater-than-one rule, (3) the percentage of the interpreted variance of each factor, (4) the percentage of the total interpreted variance from the extracted factors, and (5) the number of factors that can be conceptually interpreted [43]. The following criteria were used to make the factorial structure of the questionnaire acceptable: (1) the query load on the agent is above 0.40 [44], and (2) the community of variance (communality; h^2) of each query is above 0.30 [41].

3.3.3. Internal Consistency and Reliability of the Scales

To measure the internal consistency and reliability of the questionnaires, which concerns the homogeneity of the answers to the measurement instruments' questions, three methods were used: (a) Cronbach's α , (b) the control of the correlations between the inter-item correlation, and (c) the control of the corrected correlations of each question with the total value of the scale (corrected item-total correlations), for the estimation of the contribution of each question to the scale.

4. Results and Discussion

4.1. Study Participants

The survey involved two hundred and ninety-two ($N = 292$) amateur endurance athletes/exercisers (triathlon, cycling, long-distance swimming, distance running), of which two hundred and twenty-five ($n_1 = 225$, or 77%) were men and sixty-seven ($n_2 = 67$, or 23%) women (Figure 1a). A sample of approximately 300 is considered very good, a sample of more than 200 is considered as the lower threshold for Exploratory Factor Analysis, while according to [45], 150 samples are sufficient; according to Mundfrom, Shaw, and Ke, even samples smaller than 100 are sufficient for factor analysis when the population is high enough and the factors are represented by many items [46]. Therefore, the sample of this research ($n = 292$) is considered sufficient.

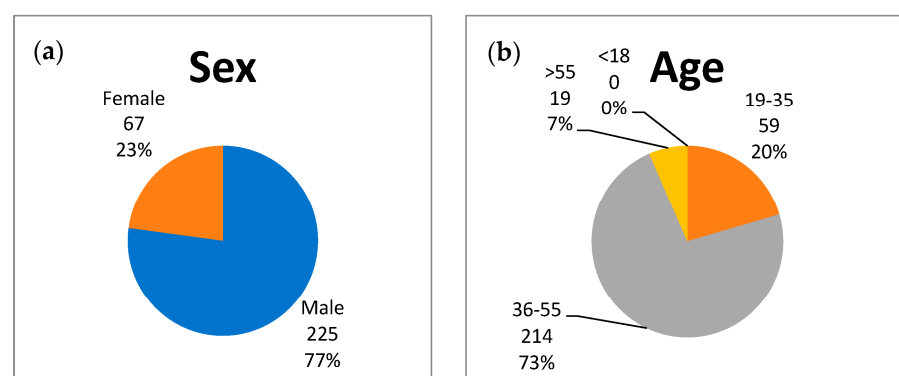


Figure 1. (a) Sex and (b) age diagrams for study participants.

Besson and his co-workers [5], noted that the average ratio of male to female participants per article in relation to endurance running was approximately 65:35 (male:female), which is close to the number observed in this study. Part of this difference has been attributed to gender differences in willingness to participate in certain types of research [5].

Regarding the age of the survey participants, fifty-nine ($n = 59$, or 20.2%) amateur athletes/exercisers were between 19 and 35 years old, two hundred and fourteen ($n = 214$, or 73.3%) were between 35 and 55 years old and nineteen ($n = 19$, or 6.5%) were 56 years old and above (Figure 1b). Of the participants, one hundred and eighty-four ($n = 184$, or 63%) are mainly engaged in running, fifty ($n = 50$, or 17.1%) in cycling, four ($n = 4$, or 1.5%) in swimming, and fifty-four ($n = 54$, or 18.4%) in triathlons.

As regards the place of residence of the participants, one hundred and twenty-five ($n = 125$, or 42.8%) live in a city center, one hundred and thirty ($n = 130$, or 44.5%) in peri-urban areas or city suburbs, eleven ($n = 11$, or 3.8%) in rural areas, and twenty-six ($n = 26$, or 8.9%) live in a village or settlement (Figure 2a). The participants' average training hours were $M = 7.36$ h/week, with $SD = 3.95$ and variation from 1 h/week to 25 h/week (Figure 2b).

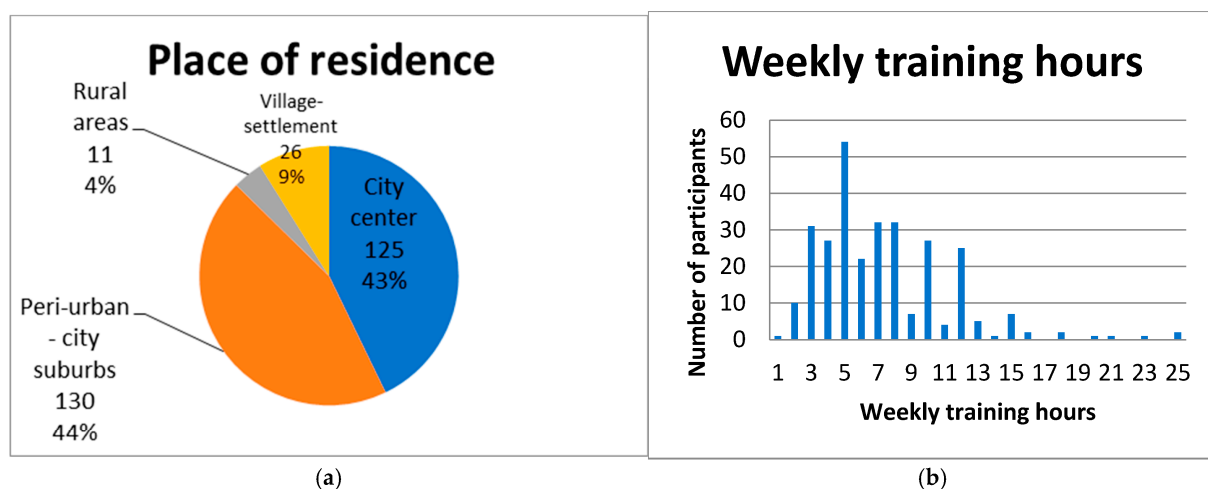


Figure 2. (a) Place of residence and (b) weekly training hours for the study participants.

4.2. Validity of the Questionnaire—Exploratory Factorial Analysis

The results of Bartlett's sphericity test (2284.721, $df = 300$, $p < 0.00001$) lead to the rejection of the null hypothesis [44] that the variables are independent of each other, while the value of the KMO criterion = 0.882 is at a perfectly satisfactory level [47]. The analysis of the main components, according to the criteria for selecting factors (diagram of eigenvalues, eigenvalue factor above 1, percentage of interpreted variance per factor, total interpreted variance, conceptual interpretation of factors) [43,44], supported the existence of three (3) factors that explain 36.27% of the total variance. Query loads and query variance communities ranged from 0.358 to 0.821 for the first factor, from 0.375 to 0.611 for the second, and from 0.376 to 0.765 for the third. The results of the analysis showed the existence of problems in some questions of the questionnaire: based on statistical criteria, such as loads and communities of variation in questions, but also conceptual criteria, five (5) questions were excluded from further analyses of the survey. The excluded questions were Question 4, Question 11, Question 12, Question 17, and Question 25.

Based on the results of the first analysis of the main components, the remaining twenty (20) questions were rechecked regarding their factorial structure. The significant results from Bartlett's sphericity test (1636.864, $df = 190$, $p < 0.00001$) lead to the rejection of the null hypothesis that the variables are independent of each other, while the value of criterion KMO = 0.872 is at a perfectly satisfactory level. According to the analysis of the main components, three (3) factors were selected which explain 37.11% of the total interpreted variance. The results of the two-factor selection as well as the loads and variation communities of the factor questions are presented in Table 2.

Table 2. Loadings and communalities of the questionnaire questions (the table shows the loads of queries over 0.30).

Questions	Factor 1: Physical Discomfort	Factor 2: Absence of Discomfort	Factor 3: No General Discomfort	h^2
22	0.806			0.597
19	0.757			0.467
18	0.648			0.431
15	−0.601			0.524
16	−0.479			0.240
10	−0.475			0.409
14	−0.439			0.366
23	0.427			0.284
20	0.363			0.315
8		0.595		0.365
21		0.565		0.334
9		0.495		0.270
24		0.455		0.209
5		0.431		0.206
1			−0.792	0.567
3			−0.606	0.401
2			−0.578	0.370
6			−0.551	0.566
13			−0.383	0.215
7			−0.332	0.287
Eigenvalues	5.232	1.173	1.017	
% interpreted variance	26.158	5.865	5.087	

4.3. Reliability of the Questionnaire

After the final selection of the questions based on the analysis of the main components, the degree of reliability of the factors of the questionnaire administered to the amateur athletes/exercisers was checked. The results of the check of the reliability of the questionnaire are presented in Table 3 below. The indicators are at a satisfactory level, while at the same time, the value of Cronbach's α , as the main indicator of the internal consistency of the questionnaire, fluctuated at a satisfactory level for each of the three factors [43,48]. The correlations of the questions with the scale, as well as the correlations of the questions of each factor with each other, also fluctuated at a very satisfactory level.

Multivariate variance analysis (MANOVA) was used to examine possible cross-gender differences in the values of the questionnaires (Table 4). No statistically significant gender differences were observed for the following factors: (1) physical discomfort ($F_{1,290} = 0.585$, $p = 0.445$), (2) absence of discomfort ($F_{1,290} = 0.485$, $p = 0.487$), and (3) no general discomfort ($F_{1,290} = 0.002$, $p = 0.965$). Therefore, there is no cross-gender effect on the values of these factors. This contradicts previous literature studies, which state that women in general are more sensitive to air pollution conditions [31,35,36,38]. This difference may be due to the fact that the sample of amateur athletes/exercisers who participated in the survey was not

equally distributed between men and women, while it may also be related to the evolutions in gender perceptions during the last years.

Table 3. Questionnaire reliability indicators for the 3 factors.

	Inter-Item Correlations Mean (Min–Max)	Item-Total Correlations Mean (Min–Max)	Cronbach's α
Physical discomfort	0.374 (0.201–0.558)	0.628 (0.333–0.933)	0.841
Absence of discomfort	0.266 (0.157–0.376)	0.452 (0.282–0.593)	0.642
No general discomfort	0.364 (0.191–0.498)	0.429 (0.218–0.752)	0.766

Table 4. MANOVA results regarding gender differences.

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial ETA Squared
Physical discomfort	0.422	1	0.422	0.585	0.445	0.002
Absence of discomfort	0.339	1	0.339	0.485	0.487	0.002
No general discomfort	0.001	1	0.001	0.002	0.965	0.000

In addition, Pearson's r coefficient was used to examine possible correlations between the training hours of each athlete/exerciser and the parameters of the questionnaires. There was no strong correlation observed for any of the factors, namely (1) physical discomfort ($r = 0.005$, $p = 0.937$), (2) absence of discomfort ($r = -0.109$, $p = 0.062$), and (3) no general discomfort ($r = -0.023$, $p = 0.692$). In all three cases, $p > 0.05$ while the coefficient r is less than 0.20, so there is no correlation between the training hours and the values of the questionnaire parameters.

A variance analysis test (ANOVA) was performed to examine differences in the values of the questionnaire in relation to the main sport of each amateur athlete/exerciser. There was no statistically significant difference in the sport for any of the factors: (1) physical discomfort ($F_{3,288} = 0.034$, $p = 0.991$), (2) absence of discomfort ($F_{3,288} = 0.459$, $p = 0.711$), and (3) no general discomfort ($F_{3,288} = 0.331$, $p = 0.803$). Therefore, there is no influence of the sport on the values of the factors. Rundell and his co-workers, suggested that athletes who exercise under dry air conditions, such as in ice rinks or swimming pools, are more sensitive to the occurrence of asthma due to exercise [4]. On the other hand, the literature does not show a difference between athletes/exercisers of different endurance sports, depending on the place of exercise or the air quality.

Another variance analysis test (ANOVA) was carried out in order to examine differences in the values of the questionnaire in relation to the place of residence of each amateur athlete/exerciser. Here, a statistically significant difference was observed between amateur athletes/exercisers residing in the city/urban area, in peri-urban or city suburbs, in rural areas, or in villages/settlements.

The ANOVA showed that for the first factor (physical discomfort) ($F_{3,288} = 3.245$, $p = 0.022$), in-town residents recorded the lowest values ($M = 2.9054$), while peri-urban residents ($M = 3.0359$) and especially village/settlement residents ($M = 3.3590$) and rural residents scored the highest values ($M = 3.4747$). For the second factor (absence of

discomfort) ($F_{3,288} = 3.225$, $p = 0.023$), in-town residents ($M = 2.7376$) and residents of peri-urban areas ($M = 2.7246$) recorded similar values, residents of villages/settlements recorded the highest values ($M = 3.1846$) and residents of rural areas recorded the lowest values ($M = 2.3636$). Finally, for the third factor (no general discomfort) ($F_{3,288} = 2.673$, $p = 0.048$), in-town residents recorded the lowest values ($M = 3.8493$) together with residents of peri-urban areas ($M = 3.9000$), while residents of rural areas ($M = 4.1603$) and especially villagers/settlements ($M = 4.3788$) recorded the highest values. The ANOVA showed statistically significant differences in perceived air pollution between people living within cities and people living outside urban areas for all three factors, since $p < 0.05$ in all three cases.

The existing literature examining the general population suggests that residents within the city perceive air pollution to a greater extent in their daily lives than those who do not reside in urban areas [31,36,38]. This difference may be related to the fact that people living outside of urban areas have less tolerance to air pollution when they take the train, and therefore are more affected by adverse air-quality conditions. At the same time, city residents are accustomed to a certain extent to air pollution in their daily lives, and this also influences how they perceive increased pollution during their training. Figure 3 shows the variation in the responses, depending on the respondents' region of residence.

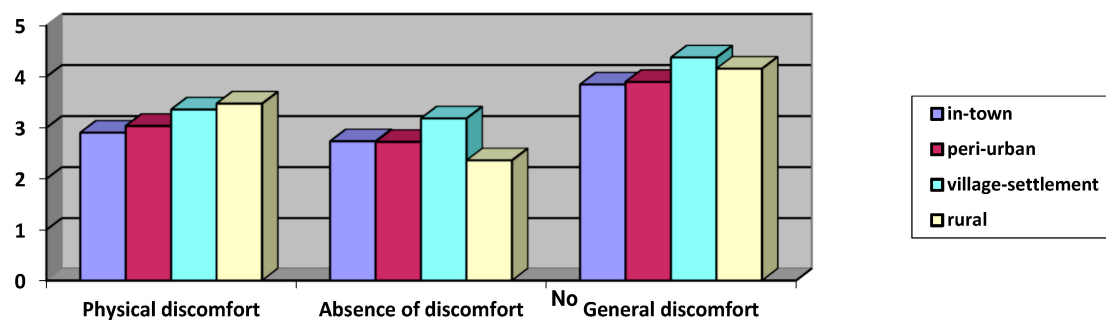


Figure 3. Average variation in responses, depending on the region of residence.

Another fluctuation analysis test (ANOVA) was conducted to examine differences in the responses in relation to whether the respondents have allergies. The results show a statistically significant difference in the first factor, physical discomfort. The results of the test ($F_{1,290} = 4.989$, $p = 0.026$) are statistically significant and show that amateur athletes/exercisers who have allergies ($M = 3.3525$) feel greater physical discomfort compared to those who do not have allergies ($M = 2.9839$). Regarding the other two factors, there was no statistically significant difference between respondents who have allergies and those who do not. More specifically, for the second factor (absence of discomfort) the values are $F_{1,290} = 2.271$, $p = 0.133$, while for the third factor (no general discomfort) they are $F_{1,290} = 0.768$, $p = 0.382$.

The results of this test are in agreement with previous studies [28,31,38], that consider that people with allergies are likely to perceive pollution to a greater extent. The test confirmed the above consideration for the first factor (physical discomfort), but not for the other two. Allergies generally burden the human immune system, and in combination with exercise, they can weaken it even more. Thus, the presence of allergies in amateur athletes/exercisers is associated with increased nuisance and increased physical discomfort.

Another fluctuation analysis test (ANOVA) was performed to examine possible differences in relation to whether the amateur athletes/exercisers have respiratory problems. In this test, no statistically significant differences were observed between respondents with respiratory problems and those without. For the first factor (physical discomfort), the results were $F_{1,290} = 3.440$, $p = 0.065$, for the second factor (absence of discomfort) the results were $F_{1,290} = 0.644$, $p = 0.423$, and for the third factor (no general discomfort) $F_{1,290} = 0.031$,

$p = 0.859$. While for the general population the literature [31,36,38] considers that persons who have respiratory problems will perceive air pollution to a greater extent, in the present case, which is focused on amateur endurance athletes/exercisers, no differences emerged between those who have respiratory problems and those who do not. This finding may be related to the suggestion of Olivo et al. [29], who indicated that aerobic exercise could prevent lung damage in the short term, but not in the long term. Another possible explanation could be related to the relatively small number of participants in the study that have respiratory problems.

Finally, a variance analysis test (ANOVA) was performed to examine differences in relation to whether the respondents are smokers or not. In this test, no statistically significant differences were observed between the two groups, which is in agreement with Rotko et al. [31]. For the first factor (physical discomfort), the values are $F_{1,292} = 0.042$, $p = 0.838$, for the second factor (absence of discomfort) the values are $F_{1,295} = 0.016$, $p = 0.901$, and for the third factor (no general discomfort) the values are $F_{1,292} = 2.906$, $p = 0.089$.

5. Conclusions

The aim of this study was to develop a psychometric scale that will measure the perceived nuisance caused by air pollution in endurance athletes/exercisers. The main research questions of the study were as follows: (a) what are the questions that an instrument for assessing perceived nuisance due to air pollution by athletes/exercisers should contain, (b) what is the reliability of the specific instrument, and (c) what is its validity, while the relationship was also examined between the answers given by the participants on the three factors identified and the independent variables used in the questionnaire.

Regarding the structure of the scale, the results from Bartlett's sphericity test led to the rejection of the zero hypothesis that the variables are independent of each other, while the value of the KMO criterion was at a perfectly satisfactory level. According to the analysis of the main components, three (3) factors were selected which explain 37.11% of the total interpreted variance.

The reliability indicators of the scale were at a satisfactory level, while Cronbach's α coefficient, a key indicator of the internal consistency of a questionnaire, was at a satisfactory level for each of the three factors. The correlations of the questions with the scale, as well as the correlations of the questions of each factor with each other, also fluctuated at a very satisfactory level.

The results of the tests of MANOVA, ANOVA, and Pearson's r correlation coefficient showed that there were no differences in the perception of air pollution between genders. In addition, there were no differences in perceived nuisances in relation to the hours of exercise, to the type of the main sport they perform, to smoking or not, and to the presence or not of respiratory problems.

On the other hand, there was a difference in the perception of pollution between respondents residing within a city or peri-urban areas and those living outside urban areas, i.e., in villages, settlements and rural areas. Amateur athletes/exercisers living in the city showed lower levels of nuisance than those living outside urban areas. Also, there was a difference in the scores of the questionnaire between respondents who have allergies and those who do not. The above results are generally in line with those of previous studies examining the general population, which confirms that the scale is satisfactorily defined. The differences that have been identified indicate the different nature of endurance athletes/exercisers to the general population in relation to some of the specific aspects examined. Overall, the results show that this scale is well defined and weighted for the data of amateur endurance athletes/exercisers using a sample of respondents from Greece. Similarly, this scale can possibly be used for any other countries or for similar

endurance sports conducted outdoors (e.g., rowing). It should be noted that in such a case, climatic conditions can also be of influence and, therefore, considered as a significant factor in influencing respondents' discomfort. Also, air temperature, humidity, atmospheric pressure, and weather conditions can significantly change the composition of the air and therefore affect the concentration (increase/decrease) of pollutants.

Another suggestion could be to incorporate statistical models that account for variables such as gender, age, location, and use such parameters as confounding factors in relation to responses received by administering the questionnaire developed in the present study to different samples. It should be noted that, to be able to safely use a scale to examine levels of nuisance during other sports which are not endurance sports or are not conducted outdoors, further research is needed, along with the possible development of another scale that is not based on the same data as this one. For further research, it would be interesting to also examine the level of education of respondents, as well as the subject of their under-graduate or post-graduate degrees (for those respondents who have one), so that this information can then be correlated to the levels of perceived air pollution, as well as touching upon other possible routes of exposure, such as visual and tactile (to the skin). Finally, one suggestion for future research would be to examine the correlation between the perceived air pollution experienced by athletes, using the current scale, with actual air quality measurements from air quality monitoring stations or personal samplers. This would allow for an in-depth investigation, providing valuable insights into whether the discomfort perceived by athletes, which they believe affects their athletic performance, is linked to actual air pollution levels or it is related to psychological factors.

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