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Rationalization of soccer training in terms of health effects of metropolitan smog and activity on the artificial turf

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***Abstract*— The aim of the study was to determine the response of football players to physical exertion taking into account the degree of smog-related air pollution. This response was also assessed in a training environment on an artificial football pitch, where the concentration of particulate air pollutants in the area is higher due to the release of dust from rubber granules found on the grass of artificial football pitches. The study was conducted among 20 male recreational football coaches. The mean age of the participants was 22.8±2.3 years. Continuous research from 2019 to 2021 was conducted during programme football training on an artificial football pitch at a sports facility in Kraków. The body's response (resting and exercise heart rate) was studied in football players under smog and clean air conditions (Samsung AX60R5080WD/EU air pollution meters, Air Visual Pro). The results of the study concluded that the degree of air pollution (smog) influences the body's response (higher HR value). It has also been observed that artificial turf, due to the abrasion of the granules, is characterised by a higher level of air pollution, which, in addition to containing toxic chemical compounds, has a negative impact on the health of the footballer.**

Keywords— healthy training, metropolitan smog, artificial turf

I. INTRODUCTION

Physical activity is one of the integral elements in everyone's life that has a positive impact on health. Well-chosen physical exercise, especially regular participation in such activity, helps develop all systems of the human body. Physical activity is a natural remedy for non-communicable diseases and improves mental health, overall quality of life, and well-being (WHO, 2018). Physical inactivity and a sedentary lifestyle have a negative impact on individuals, families, and society, and can lead to pandemics of obesity and diseases of affluence (Gualdi-Russo et al., 2020; Iurilli et al., 2021).

Also in sports terms, proper or rational training means choosing optimal loads in terms of both volume and intensity, which are responsible for a high level of performance. For health-promoting purposes, it is important that any exercise be performed in good atmospheric conditions, especially in clean air (Duda et al., 2020; Gualdi-Russo et al., 2020). Nowadays, the problem of polluted air in urban areas, or smog, is found almost everywhere, especially in large cities, where air quality deteriorates with the development of urban areas (Hidy, 2018; Ashraf et al., 2019). It has been indicated that inhaling high concentrations of air pollutants can cause more damage to athletes than to residents living in such a polluted environment (Reche et al., 2020).

It has been shown that increased air velocity and volume during physical activity leads to the transport of a significant amount of pollutants deep into the body's airways (Lü et al., 2015). Taking these findings into account in the training of the soccer players who were the participants in our study, it can be assumed that as a result of the physical activity undertaken during training or playing matches under conditions of air pollution, physiological changes may occur in their bodies that may endanger their health. This can manifest as oxidative stress in the respiratory tract, which is a major pathophysiological factor associated with the health effects of air pollution (Zacharko et al., 2021). This creates the risk of ailments that

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adversely affect human health, and can cause dangerous diseases, especially those related to the respiratory and circulatory systems (Kargarfard et al., 2015; Miller, 2020). Too much supply of contaminated air to the body can also contribute to problems related to the heart, immune system, and endocrine or mental disorders (BACCARELLI et al., 2007; Feng et al., 2019). These facts are supported by numerous studies that have found adverse changes in biomarkers of physiological and biochemical functions caused by polluted air (Brook et al., 2010; Wu et al., 2015; Chen et al., 2018).

Children are a group that is particularly vulnerable to air pollution and at risk of developing asthma and allergy symptoms as well as obesity and diabetes as a result of prolonged exposure to polluted air (Mazurek and Badyda, 2018; McGuinn et al., 2019). It has been found that air pollution can lead to damage to virtually all tissues of the human body (Kelishadi and Poursafa, 2010; Gładka and Zatoński, 2016).

Based on information about smog and its negative impact on human health, the authors of the paper attempted to identify the state of the body's response to soccer training in a polluted metropolitan environment, and under the conditions of soccer training on fields with artificial turf. The analysis of studies shows that these places, as a result of physical activity and the abrasiveness of the artificial material, are an area of greater dust and the release of chemical compounds that can be harmful to health (Celeiro et al., 2018; Murphy and Warner, 2022).

Of particular note are polycyclic aromatic hydrocarbons, which can cause cancer (Seidel et al., 2008; Rengarajan et al., 2015). Thus, it seems that addressing these problems will not only rationalize sports training but also indicate the conditions for practicing sports in health-promoting aspects.

The aim of the study was to determine the directions of rational sports training, which in its assumptions should optimally promote health. Taking into account the fact that most of the athletes perform physical exercise in metropolitan conditions (a large number of clubs), with a high concentration of pollutants in the ambient air (Rzeszutek and Bogacki, 2016; Watterson, 2017), the study sought to identify the response of the human body to exercise while taking into account the degree of ambient air pollution. Furthermore, the problem was attempted to be identified in the training environment on the artificial turf of a soccer field, where the particulate matter concentration in such areas is higher due to the volatilization of the abraded granular material of the turf.

The aim of the research was to identify methods to control (objective and subjective) the body's physical capacity in systematic sports training.

The following research questions were asked in the study:

1) Does air pollution increase the body's physical strain related to physical exercise?
2) Should atmospheric environmental conditions related to the degree of air pollution be taken into account in planning training loads?
3) Does sports training performed in high air pollution (in smog conditions and on fields with artificial turf) meet health requirements?

Given the main tenets of health training, sports activities in metropolitan areas, and frequent training sessions on artificial soccer fields, the following research hypotheses were proposed:

4) The increase in performance indicators depends not only on regular sports training but also on the quality of the environment (air pollution) in which training takes place.
5) Sports activity under conditions of high pollution (smog), and on soccer fields with artificial surfaces that intensify the dustiness of the training environment as a result of abrasion of the granular material can not only increase physical load but can also have a negative impact on human health.

II. MATERIALS AND METHODS

Participants

The study was conducted among 20 male recreational soccer players. The mean age of the study participants was 22.8±2.3 years. Continuous research was carried out in 2019-2021 during training sessions within a soccer program on the artificial soccer field of a sports facility in Krakow, Poland. The condition of the field was good, and the research was conducted on the so-called "active field" (during the activity of the exercisers).

The study conforms to the code of ethics of the World Medical Association and the standards for research recommendations of the Declaration of Helsinki. The protocol was approved by the local university ethics committee.

Procedures

Each study group performed 180 m walk-and-run exercise during the measurement part of the study consisting of 60 m of fast walking and 120 m of low-intensity running (3.5 [m/s]).

The study groups performed:

- 4 times the above-mentioned physical exercise at an interval of at least 1 week under favorable conditions of air pollution, with average values of PM 1.0 = 21.75 [µg/m3], PM 2.5 = 25.75 [µg/m3], PM 10 = 55 [µg/m3].
  There are different criteria for the division of pollutant particles found in the air. The most commonly analyzed particulate matter criteria (as used in this study) include PM 10 (dust with a particle diameter of less than 10 µm), PM 2.5 (less than 2.5 µm), and PM 1 (less than 1 µm) (Fitch 2015). The smaller the particle, the greater the potential for damage, as it can penetrate deeper into the lungs and body tissues (Lippi, Guidi, Maffulli 2008).
- 4 times the above-mentioned physical exercise at an interval of at least 1 week under unfavorable conditions of air pollution with average values of PM 1.0 = 47.25 [µg/m3], PM 2.5 = 86.5 [µg/m3], PM 10 = 154.75 [µg/m3].
- the values were determined with the Samsung AX60R5080WD/EU, Air Visual Proair air quality monitor under sunny and windless weather conditions at a measurement height of 1.50 m.

The volume and intensity of the tests for the above-mentioned exercise conditions were the same (running distance and speed were measured and exercise duration was recorded).

The following research parameters, which were conducted according to the concept of Duda et al. (2018), Duda et al. 2020), were included:

- resting heart rate (determined for each participant, the value of measurements under favorable and unfavorable conditions of air pollution (measurement in the morning, 5 minutes after getting out of bed, in a standing position),
- heart rate immediately after exercise - measurement using a Polar Pacer-type heart rate monitor in the standing position.

To assess to a greater extent the state of the body's response to physical exercise in the studied individuals, the subjective response (level of perceived exertion following exercise) was assessed on the Borg test (Borg GA, 1992). This test was performed immediately after the exercise test under favorable and unfavorable air quality conditions.

The assessment of perceived exertion based on the Borg scale was recorded for each subject following the exercise. Immediately after the exercise test, the players came to a predetermined place. Each participant reported their perception in private, in order to avoid the effect of other subjects' evaluation. The players were thoroughly familiarized beforehand with the scale and received it for individual review.

The Borg scale is used to assess perceived exertion during exercise (Tab. 1). It consists of 15 digits (the scale starts at 6 points and goes to 20 points), with each digit assigned to a specific level of perceived exertion. According to the literature - this scale is often used to assess subjectively perceived fatigue, objectifying the state of actual fatigue following the exercise (Fanchini et al., 2015; Arslan et al., 2017).

TABLE 1. THE RATING OF PERCEIVED EXERTION ON THE BORG SCALE (BORG 1982)

6, 7	No exertion at all or extremely light
8, 9	Very light
10, 11	Light
12, 13	Somewhat hard
14, 15	Hard
16, 17	Very high
18, 19, 20	Extremely hard or maximal exertion

The values of post-exercise heart rate and perceived exertion were obtained as a mean of four results from the efforts under favorable and unfavorable conditions of air quality.

Statistical methods

All statistical analyses were performed using the Statistica ver. 13.1 software package (Dell Inc., Tulsa, OK, USA). Basic statistical computations were used to collect the results as arithmetic means, standard deviations, and Student's t-test used to determine the level of significance of differences. The relationships between measured characteristics were tested using the Pearson correlation coefficient (M et al., 2002). All variables were tested for their conformity with a normal distribution.

III. RESULTS

The study was conducted in a group of men whose resting and exercise heart rates were first compared under favorable and unfavorable air quality conditions. The arithmetic mean for resting HR was 72.65 bpm under clean air conditions and 1.55 bpm higher under air pollution conditions. The results indicated that physical exercise under conditions of air pollution can affect the stress response of the male subjects. However, these parameters did not show significant variation ($p>0.05$) in statistical calculations (Table 2).

TABLE 2. RESTING HR UNDER FAVORABLE AND UNFAVORABLE (SMOG) AIR QUALITY CONDITIONS

Parameters	Resting HR (clean air)	Resting HR (polluted air)
Arithmetic mean	72.65	74.40
Standard deviation	4.15	4.19
Coefficient of variation	5.71	5.63
Significance of differences	0.0964	

Similar tests were performed for HR measurements with assumed physical load, also for clean and polluted air conditions. Data analysis shows that the exercise HR value also changed significantly. These parameters accounted for a significant amount of variation at $p<0.05$ in statistical calculations. This fact suggests that physical exercise under conditions of air pollution affects the stress response in the male athletes studied (Table. 3).

TABLE 3. EXERCISE HR UNDER FAVORABLE AND UNFAVORABLE (SMOG) AIR QUALITY CONDITIONS

Parameters	Exercise HR (clean air)	Exercise HR (polluted air)
Arithmetic mean	109.30	112.15
Standard deviation	5.69	4.85
Coefficient of variation	5.20	4.32
Significance of differences	0.0482*	

*p<0.05

Further measurements were made to confirm these observations. The research aimed to determine the variation in the subjective perception of physical strain (perceived exertion) under clean and polluted air conditions. From the data it can be seen that although the varying air quality did not translate into differences in perceived exertion, a higher parameter of perceived exertion under conditions of higher air pollution was found for mean values. The analysis of the coefficient of variation also indicates that the perception of exertion among the participants may have affected a variable response under conditions of higher air pollution (Table 4).

TABLE. 4. POST-EXERCISE PERCEIVED EXERTION UNDER FAVORABLE AND UNFAVORABLE (SMOG) AIR QUALITY CONDITIONS

Parameters	Perceived exertion on the Borg scale (clean air)	Perceived exertion on the Borg scale (polluted air)
Arithmetic mean	6.69	6.94
Standard deviation	0.48	0.68
Coefficient of variation	7.16	9.80
Significance of differences	0.114	

Confirmation of such results was sought by making further research to analyze the correlation of the results of exercise HR with perceived exertion under clean and polluted air conditions (Tables 5, 6).

It was found that the subjective perception of exertion reflects the state of objective fatigue confirmed by the body's response (positive correlation). This fact seems to be in line with reality, as it has also been confirmed by other studies for such an assessment (Fanchini et al., 2015; Arslan et al., 2017). On the other hand, the higher (statistically significant) correlation found for the objective and subjective responses in participants (Table 6) can largely confirm the body's negative response to physical exertion under conditions of greater air pollution.

TABLE 5. CORRELATION FOR PARAMETERS OF EXERCISE HR AND PERCEIVED EXERTION FOR FAVORABLE AIR QUALITY CONDITIONS

Parameters	**Exercise HR (clean air)**	**Perceived exertion on the Borg scale (clean air)**
Arithmetic mean	109.25	6.69
Standard deviation	5.67	0.48
Coefficient of variation	5.19	7.16
Correlation	0.166	

TABLE 6. CORRELATION FOR PARAMETERS OF EXERCISE HR AND PERCEIVED EXERTION FOR SMOG CONDITIONS

Parameters	**Exercise HR (polluted air)**	**Perceived exertion on the Borg scale (polluted air)**
Arithmetic mean	112.15	6.94
Standard deviation	4.85	0.68
Coefficient of variation	4.32	9.80
Correlation (*p<0.05)	0.444*	

Further research, performed to not only confirm the main hypotheses of the study but also to determine the lack of health-promoting effects of soccer training on fields with artificial turf, was aimed to assess the air quality at sports facilities with artificial surfaces. It was noted in the research that after soccer training on a field with artificial turf filled with granulated product, significant contamination could be found on sports shoes (Fig.1). This inspired further research on the assessment of sports field pollution. In this light, an air analysis was made for clean and polluted air at the artificial turf field. From the analysis of the data contained in Table 7-9 it can be seen that significant differences in their concentrations are observed for particulate matter (PM 1.0, PM 2.5, PM 10), especially under polluted air conditions.

FIGURE 1. CONTAMINATION OF SPORTS FOOTWEAR BY DUST FOUND ON A PITCH WITH ARTIFICIAL TURF AFTER A TRAINING SESSION

Source: author own material.

TABLE 7. SIGNIFICANCE OF DIFFERENCES FOR PM1.0 IN CLEAN AIR AND SMOG CONDITIONS FOR "ACTIVE" AND "INACTIVE" ARTIFICIAL SOCCER FIELD

Parameters	PM1.0 - favorable conditions (clean air)		PM1.0 - unfavorable conditions (polluted air)	
	inactive field	active field	inactive field	active field
Arithmetic mean	20.75	21.75	45.75	47.25
Standard deviation	2.22	1.50	1.26	1.71
Coefficient of variation	10.69	6.90	2.75	3.61
Significance of differences	0.243		0.105	
Significance of differences	0.001***	0.001***	0.001***	0.001***

TABLE 8. SIGNIFICANCE OF DIFFERENCES FOR PM2.5 IN CLEAN AIR AND SMOG CONDITIONS FOR "ACTIVE" AND "INACTIVE" ARTIFICIAL SOCCER FIELD

Parameters	PM2.5 - favorable conditions (clean air)		PM2.5 - unfavorable conditions (polluted air)	
	inactive field	active field	inactive field	active field
Arithmetic mean	23.50	25.75	81.25	86.50
Standard deviation	1.29	0.50	0.96	1.91
Coefficient of variation	5.49	1.94	1.18	2.21
Significance of differences	0.016*		0.003*	
Significance of differences	0.001***	0.001***	0.001***	0.001***

TABLE 9. SIGNIFICANCE OF DIFFERENCES FOR PM10 IN CLEAN AIR AND SMOG CONDITIONS FOR "ACTIVE" AND "INACTIVE" ARTIFICIAL SOCCER FIELD

Parameters	PM10 - favorable conditions (clean air)		PM10 - unfavorable conditions (polluted air)	
	inactive field	active field	inactive field	active field
Arithmetic mean	49.50	55.00	141.75	154.75
Standard deviation	1.29	0.82	2.36	1.50
Coefficient of variation	2.61	1.48	1.67	0.97
Significance of differences	0.001*		0.001*	
Significance of differences	0.001***	0.001***	0.001***	0.001***

Variations in the values of the calculated data were found not only for the "active field" under smog conditions (with floating dust caused by the activity of players) but also for the "inactive field " in clean air conditions (floating dust in the absence of activity apart from the concentration for PM1.0). This finding is worrying, because the increased concentration of artificial turf dust translates into higher contents of various chemicals that can increase the absorption of not only these pollutants into the lungs (PM10 dust) but also into the bloodstream (dust: PM2.5, PM 1.0) (Jędrak et al., 2017; Duda et al., 2020).

IV. DISCUSSION

The aim of the study was to determine the objectives of rational sports training, which should optimally promote health. The study attempted to identify the players' body response to physical exertion in an atmosphere of polluted air and in an environment of high dust concentrations that occurs on fields with artificial turf.

The research process aimed to identify methods to control (objectively and subjectively) the body's physical capacity in systematic sports training. The obtained results confirmed the first research hypothesis which assumed that the indicators of physical capacity depend not only on regular sports training but also on the quality of the environment in which this training is performed. The second research hypothesis that sports activities in an atmosphere of high air pollution, including football fields with artificial turf, can not only increase physical exertion but also negatively affect the health of players, was also confirmed.

Few studies have directly addressed the impact of air quality on the activity of soccer players. Evaluation of the impact of PM10 air pollution in German stadiums found that player performance decreased under conditions of poor air quality (Lichter et al., 2017). In a study with an extended range of measured parameters, it was discovered that reduced levels of air quality during a match negatively affected the total distance covered and the level of very high-intensity exercise (Zacharko et al., 2021). It was shown that during increased physical activity, athletes inhale up to 20 times more air than when walking, and a large amount of toxic substances enter their bodies (Duda et al., 2020).

From the analysis of the data obtained, it was concluded that the state of air pollution (metropolitan smog) had a negative impact on the functional state of the athlete's bodies. There was a significant change in the body's response to stress under smog conditions (increased HR and perceived exertion on the Borg scale). The findings are in line with those reported by previous researchers, who have found that metropolitan smog and any associated chemical pollutants have harmful effects on human health and can even result in premature deaths (Jędrak et al., 2017; Maher et al., 2017; Ontawong et al., 2020). This includes both short-term and long-term exposure to such a polluted environment, which can result in irritation in the trachea but also cause genetic changes or lung cancer (Stafoggia et al., 2008; Valavanidis et al., 2013). Previous studies have found that smog is a risk factor for respiratory tract infections, carrying microorganisms and deteriorating the body's immunity, making it more susceptible to pathogens (Cai et al., 2007) .

The current state of research was a reason to seek further consideration in aspects of additional dust pollution that is observed on soccer fields with artificial turf. Such facilities contain rubber granules that have been found to contain toxic and carcinogenic chemical compounds, such as polycyclic aromatic hydrocarbons and metal compounds (Llompart et al., 2013; Brandsma et al., 2019; Schneider et al., 2020). The objective of these investigations was not accidental, as it was noted in the public opinion not only in Poland but also in Western European countries that after physical activity on soccer fields with artificial surfaces, children and adolescents had numerous cases of allergic reactions (Cohen, 2008; Kirkland and Adams, 2008). Consequently, the problem started to be examined in specialized research by the European Chemicals Agency (ECHA), which, although it concluded that physical activity on soccer fields with artificial turf does not pose too much of a risk, hygiene precautions (including washing body surfaces) are advised (Valeriani et al., 2019).

Studies by previous researchers have consistently found the transfer of compounds of heavy metals such as Cd, Cr, and Pb into the air and rainwater in close proximity to artificial playing fields. The environmental risk was also demonstrated, posed by burning rubber tire crumbs, showing a significant increase in both the number and concentration of hazardous chemicals (Celeiro et al., 2018; Armada et al., 2022).

There is currently much discussion about the risks of the use of artificial playing fields to human health and the environment. The problem lies in the presence of harmful chemicals in the artificial turf fibers and their filling with rubber crumbs. A Yale University study found that there are at least 306 different chemicals in the crumb rubber filling, as many as 197 of which have been shown to have carcinogenic properties (Perkins et al., 2019).

In the Netherlands, the problem has grown into significant decisions in closing artificial fields that do not meet standards for sanitary approvals. In 2018, The Dutch National Institute for Public Health and the Environment (RIVM) proposed lowering concentration limits for eight polycyclic aromatic hydrocarbons detected in rubber granules and non-woven fabrics used on playing fields, other sports facilities, and playgrounds (Commission regulation (EU) 2021).

In our study, exact chemical composition determinations were not made, but it was found that after each training session, there was significant dust on the sports shoes, and the measuring apparatus showed higher particulate air concentrations of PM 2.5 and PM 10. These values showed significant variation in training conditions on fields with artificial turf. This raises the rhetorical question: what was the chemical composition of the air inhaled by the athletes? Based on the assumption that it was within acceptable standards, however, the increased air pollution negatively affected not only the state of the respiratory system but also had an impact on the cardiovascular response and increased perceived exertion.

The information we received in our research is worrying as the increased concentration of dust on fields with artificial turf translated into higher content of various chemicals inhaled by the athletes. Undoubtedly, this should contribute to the consideration of whether physical activity on fields with artificial turf (especially of low quality) meets the requirements of health-promoting training.

V. CONCLUSIONS

1) Smog and chemical pollutants in the air increase physical stress on the body caused by physical activity
2) Rational recreational and sports training requires not only

monitoring in terms of volume and intensity of loads but also control of external conditions (smog, dusty environment)

3) Playing fields with artificial turf require not only the inspection of approved cushioning products (high-quality rubber granulated product) but also the regular replacement of used products.
4) Temporary protection against excessive dustiness in the areas of worn-out artificial turf on playing fields requires regular water spraying.
5) In periods of high pollution to the environment (smog, toxic air), it is required to reduce the volume and intensity of exercise loads and use anti-smog masks during training sessions.

VI. REFERENCES

Armada, D., Llompart, M., Celeiro, M., Garcia-Castro, P., Ratola, N., Dagnac, T., et al. (2022). Global evaluation of the chemical hazard of recycled tire crumb rubber employed on worldwide synthetic turf football pitches. *Sci. Total Environ.* 812, 152542. doi: 10.1016/j.scitotenv.2021.152542.

Arslan, E., Alemdaroglu, U., Koklu, Y., Hazir, T., Muniroglu, S., and Karakoc, B. (2017). Effects of Passive and Active Rest on Physiological Responses and Time Motion Characteristics in Different Small Sided Soccer Games. *J. Hum. Kinet.* 60, 123–132. doi: 10.1515/hukin-2017-0095.

Ashraf, A., Butt, A., Khalid, I., Alam, R. U., and Ahmad, S. R. (2019). Smog analysis and its effect on reported ocular surface diseases: A case study of 2016 smog event of Lahore. *Atmos. Environ.* 198, 257–264. doi: 10.1016/j.atmosenv.2018.10.029.

Baccarelli, A., Zanobetti, A., Martinelli, I., Grillo, P., Hou, L., Giacomini, S., et al. (2007). Effects of exposure to air pollution on blood coagulation. *J. Thromb. Haemost.* 5, 252–260. doi: 10.1111/j.1538-7836.2007.02300.x.

Borg GA (1992). Psychophysical bases of perceived exertion. *Med Sci Sport. Exerc* 14, 377–381.

Brandsma, S. H., Brits, M., Groenewoud, Q. R., van Velzen, M. J. M., Leonards, P. E. G., and de Boer, J. (2019). Chlorinated Paraffins in Car Tires Recycled to Rubber Granulates and Playground Tiles. *Environ. Sci. Technol.* 53, 7595–7603. doi: 10.1021/acs.est.9b01835.

Brook, R. D., Rajagopalan, S., Pope, C. A., Brook, J. R., Bhatnagar, A., Diez-Roux, A. V., et al. (2010). Particulate Matter Air Pollution and Cardiovascular Disease. *Circulation* 121, 2331–2378. doi: 10.1161/CIR.0b013e3181dbece1.

Cai, Q.-C., Lu, J., Xu, Q.-F., Guo, Q., Xu, D.-Z., Sun, Q.-W., et al. (2007). Influence of meteorological factors and air pollution on the outbreak of severe acute respiratory syndrome. *Public Health* 121, 258–265. doi: 10.1016/j.puhe.2006.09.023.

Celeiro, M., Dagnac, T., and Llompart, M. (2018). Determination of priority and other hazardous substances in football fields of synthetic turf by gas chromatography-mass spectrometry: A health and environmental concern. *Chemosphere* 195, 201–211. doi: 10.1016/j.chemosphere.2017.12.063.

Chen, R., Li, H., Cai, J., Wang, C., Lin, Z., Liu, C., et al. (2018). Fine Particulate Air Pollution and the Expression of microRNAs and Circulating Cytokines Relevant to Inflammation, Coagulation, and Vasoconstriction. *Environ. Health Perspect.* 126, 017007. doi: 10.1289/EHP1447.

Cohen, P. R. (2008). The skin in the gym: a comprehensive review of the cutaneous manifestations of community-acquired methicillin-resistant Staphylococcus aureus infection in athletes. *Clin. Dermatol.* 26, 16–26. doi: 10.1016/j.clindermatol.2007.10.006.

Duda, H., Rydzik, Ł., Czarny, W., Błach, W., Görner, K., and Ambroży, T. (2020). Reaction of the Organisms of Young Football Players to City Smog in the Sports Training. *Int. J. Environ. Res. Public Health* 17, 5510. doi: 10.3390/ijerph17155510.

Fanchini, M., Ghielmetti, R., Coutts, A. J., Schena, F., and Impellizzeri, F. M. (2015). Effect of Training-Session Intensity Distribution on Session Rating of Perceived Exertion in Soccer Players. *Int. J. Sports Physiol. Perform.* 10, 426–430. doi: 10.1123/ijspp.2014-0244.

Feng, B., Song, X., Dan, M., Yu, J., Wang, Q., Shu, M., et al. (2019). High level of source-specific particulate matter air pollution associated with cardiac arrhythmias. *Sci. Total Environ.* 657, 1285–1293. doi: 10.1016/j.scitotenv.2018.12.178.

Gładka, A., and Zatoński, T. (2016). Wpływ zanieczyszczenia powietrza na choroby układu oddechowego. *Kosm. Probl. Nauk Biol.* 65, 573–582.

Gualdi-Russo, E., Rinaldo, N., Toselli, S., and Zaccagni, L. (2020). Associations of Physical Activity and Sedentary Behaviour Assessed by Accelerometer with Body Composition among Children and Adolescents: A Scoping Review. *Sustainability* 13, 335. doi: 10.3390/su13010335.

Hidy, G. M. (2018). An historical experiment: Los Angeles smog evolution observed by blimp. *J. Air Waste Manage. Assoc.* 68, 643–655. doi: 10.1080/10962247.2018.1433251.

Iurilli, M. L., Zhou, B., Bennett, J. E., Carrillo-Larco, R. M., Sophiea, M. K., Rodriguez-Martinez, A., et al. (2021). Heterogeneous contributions of change in population distribution of body mass index to change in obesity and underweight. *Elife* 10. doi: 10.7554/eLife.60060.

Jędrak, J., Konduracka, E., Badyda, A. ., and Dąbrowiecki, P. (2017). “Wpływ zanieczyszczeń powietrza na zdrowie,” in *Polskie Towarzystwo Medycyny Środowiskowej;Wojskowy Instytut Medyczny* (Polska Federacja Stowarzyszeń Chorych na Astmę, Alergię i POChP).

Kargarfard, M., Shariat, A., Shaw, B. S., Shaw, I., Lam, E. T. C., Kheiri, A., et al. (2015). Effects of Polluted Air on Cardiovascular and Hematological Parameters After Progressive Maximal Aerobic Exercise. *Lung* 193, 275–281. doi: 10.1007/s00408-014-9679-1.

Kelishadi, R., and Poursafa, P. (2010). Air pollution and non-respiratory health hazards for children. *Arch. Med. Sci.* 4, 483–495. doi: 10.5114/aoms.2010.14458.

Kirkland, E. B., and Adams, B. B. (2008). Methicillin-resistant Staphylococcus aureus and athletes. *J. Am. Acad. Dermatol.* 59, 494–502. doi: 10.1016/j.jaad.2008.04.016.

Lichter, A., Pestel, N., and Sommer, E. (2017). Productivity effects of air pollution: Evidence from professional soccer. *Labour Econ.* 48, 54–66. doi: 10.1016/j.labeco.2017.06.002.

Llompart, M., Sanchez-Prado, L., Pablo Lamas, J., Garcia-Jares, C., Roca, E., and Dagnac, T. (2013). Hazardous organic chemicals in rubber recycled tire playgrounds and pavers. *Chemosphere* 90, 423–431. doi: 10.1016/j.chemosphere.2012.07.053.

Lü, J., Liang, L., Feng, Y., Li, R., and Liu, Y. (2015). Air Pollution Exposure and Physical Activity in China: Current Knowledge, Public Health Implications, and Future Research Needs. *Int. J. Environ. Res. Public Health* 12, 14887–14897. doi: 10.3390/ijerph121114887.

Marska-Kotlińska, M., Bartz, J., and Wieliński, D. (2002). *Wybrane zagadnienia statystyki dla studiujących wychowanie fizyczne*. AWF.

Maher, A., Abdel Rahman, M. F., and Gad, M. Z. (2017). “The Role of Nitric Oxide from Neurological Disease to Cancer,” in, 71–88. doi: 10.1007/978-3-319-60733-7_5.

Mazurek, H., and Badyda, A. (2018). *Smog- Konsekwencje zdrowotne zanieczyszczeń powietrza*. Państwowy Zakład Wydawnictw Lekarskich.

McGuinn, L. A., Schneider, A., McGarrah, R. W., Ward-Caviness, C., Neas, L. M., Di, Q., et al. (2019). Association of long-term PM2.5 exposure with traditional and novel lipid measures related to cardiovascular disease risk. *Environ. Int.* 122, 193–200. doi: 10.1016/j.envint.2018.11.001.

Miller, M. R. (2020). Oxidative stress and the cardiovascular effects of air pollution. *Free Radic. Biol. Med.* 151, 69–87. doi: 10.1016/j.freeradbiomed.2020.01.004.

Murphy, M., and Warner, G. R. (2022). Health impacts of artificial turf: Toxicity studies, challenges, and future directions. *Environ. Pollut.* 310, 119841. doi: 10.1016/j.envpol.2022.119841.

Ontawong, A., Saokaew, S., Jamroendararasame, B., and Duangjai, A. (2020). Impact of long-term exposure wildfire smog on respiratory health outcomes. *Expert Rev. Respir. Med.* 14, 527–531. doi: 10.1080/17476348.2020.1740089.

Perkins, A. N., Inayat-Hussain, S. H., Deziel, N. C., Johnson, C. H., Ferguson, S. S., Garcia-Milian, R., et al. (2019). Evaluation of potential carcinogenicity of organic chemicals in synthetic turf crumb rubber. *Environ. Res.* 169, 163–172. doi: 10.1016/j.envres.2018.10.018.

Reche, C., Viana, M., van Drooge, B. L., Fernández, F. J., Escribano, M., Castaño-Vinyals, G., et al. (2020). Athletes' exposure to air pollution during World Athletics Relays: A pilot study. *Sci. Total Environ.* 717, 137161. doi: 10.1016/j.scitotenv.2020.137161.

Rengarajan, T., Rajendran, P., Nandakumar, N., Lokeshkumar, B., Rajendran, P., and Nishigaki, I. (2015). Exposure to polycyclic aromatic hydrocarbons with special focus on cancer. *Asian Pac. J. Trop. Biomed.* 5, 182–189. doi: 10.1016/S2221-1691(15)30003-4.

Rzeszutek, M., and Bogacki, M. (2016). Ocena modelu dyspersji zanieczyszczeń powietrza OSPM: studium przypadku. *Annu. Set Environ. Prot.* 18, 351–362.

Schneider, K., de Hoogd, M., Madsen, M. P., Haxaire, P., Bierwisch, A., and Kaiser, E. (2020). ERASSTRI - European Risk Assessment Study on Synthetic Turf Rubber Infill – Part 1: Analysis of infill samples. *Sci. Total Environ.* 718, 137174. doi: 10.1016/j.scitotenv.2020.137174.

Seidel, A., Spickenheuer, A., Straif, K., Rihs, H.-P., Marczynski, B., Scherenberg, M., et al. (2008). New Biomarkers of Occupational Exposure to Polycyclic Aromatic Hydrocarbons. *J. Toxicol. Environ. Heal. Part A* 71, 734–745. doi: 10.1080/15287390801985265.

Stafoggia, M., Schwartz, J., Forastiere, F., and Perucci, C. A. (2008). Does Temperature Modify the Association between Air Pollution and Mortality? A Multicity Case-Crossover Analysis in Italy. *Am. J. Epidemiol.* 167, 1476–1485. doi: 10.1093/aje/kwn074.

Valavanidis, A., Vlachogianni, T., Fiotakis, K., and Loridas, S. (2013). Pulmonary Oxidative Stress, Inflammation and Cancer: Respirable Particulate Matter, Fibrous Dusts and Ozone as Major Causes of Lung Carcinogenesis through Reactive Oxygen Species Mechanisms. *Int. J. Environ. Res. Public Health* 10, 3886–3907. doi: 10.3390/ijerph10093886.

Valeriani, F., Margarucci, L. M., Gianfranceschi, G., Ciccarelli, A., Tajani, F., Mucci, N., et al. (2019). Artificial-turf surfaces for sport and recreational activities: microbiota analysis and 16S sequencing signature of synthetic vs natural soccer fields. *Heliyon* 5, e02334. doi: 10.1016/j.heliyon.2019.e02334.

Watterson, A. (2017). Artificial Turf: Contested Terrains for Precautionary Public Health with Particular Reference to Europe? *Int. J. Environ. Res. Public Health* 14, 1050. doi: 10.3390/ijerph14091050.

WHO. (2018). *Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World*. Geneva, Switzerland: World Health Organization.

Wu, S., Yang, D., Wei, H., Wang, B., Huang, J., Li, H., et al. (2015). Association of chemical constituents and pollution sources of ambient fine particulate air pollution and biomarkers of oxidative stress associated with atherosclerosis: A panel study among young adults in Beijing, China. *Chemosphere* 135, 347–353. doi: 10.1016/j.chemosphere.2015.04.096.

Zacharko, M., Cichowicz, R., Andrzejewski, M., Chmura, P., Kowalczuk, E., Chmura, J., et al. (2021). Air Pollutants Reduce the Physical Activity of Professional Soccer Players. *Int. J. Environ. Res. Public Health* 18, 12928. doi: 10.3390/ijerph182412928.