NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

Journal of Education, Health and Sport. eISSN 2391-8306.

Journal Home Page
https://apcz.umk.pl/JEHS/index

CZAPLA, Natalia, WISOKY, Wiktor, ZIÓŁKOWSKA, Weronika, STRUŻYŃSKA, Ewelina, IGNYŚ, Piotr, ŁOPIŃSKA, Joanna, MAJCHRZYCKA, Marta, GRACZYK, Martyna, GRACZYK, Natalia, and MAJCHRZAK, Mateusz. Physical Activity and Lung Cancer Risk in the Context of Exposure to Air Pollution – A Review of Current Evidence. Journal of Education, Health and Sport. 2026;90:70366. eISSN 2391-8306. https://doi.org/10.12775/JEHS.2026.90.70366

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 29.03.2026. Revised: 30.03.2026. Accepted: 10.04.2026. Published: 15.04.2026.

Physical Activity and Lung Cancer Risk in the Context of Exposure to Air Pollution – A Review of Current Evidence

Natalia Czapla
https://orcid.org/0009-0001-9029-5759
nataliaczaplapoczta@gmail.com
University Clinical Hospital in Poznań
Ul. Przybyszewskiego 49, 60-355 Poznań, Poland

Wiktor Wisoky
https://orcid.org/0009-0009-7226-9133
ww.wiktor.wisoky@gmail.com
University Clinical Hospital in Poznań
Ul. Przybyszewskiego 49, 60-355 Poznań, Poland

Weronika Ziółkowska
https://orcid.org/0009-0003-1896-7877
weronika.ziolkowskaa@gmail.com
University of Zielona Góra
Ul. Zyty 26, 65-046 Zielona Góra, Poland

Ewelina Strużyńska
https://orcid.org/0009-0003-7749-0052
ewelinastruzynskaa@gmail.com
University of Zielona Góra
UL. Licealna 9, 65-417 Zielona Góra, Poland

Piotr Ignyś
https://orcid.org/0009-0009-5938-5412
ignyspiotr88@gmail.com
University of Zielona Góra
Ul. Licealna 9, 65-417 Zielona Góra, Poland

Joanna Łopińska
https://orcid.org/0009-0009-7554-8023
joanna.lopinska96@gmail.com
University Clinical Hospital in Poznań
Ul. Przybyszewskiego 49, 60-355 Poznań, Poland

Marta Majchrzycka
https://orcid.org/0009-0009-1359-1253
marta.majchrzycka@onet.pl
University Clinical Hospital in Poznań
Ul. Przybyszewskiego 49, 60-355 Poznań, Poland

Martyna Graczyk
https://orcid.org/0009-0000-3646-6441
martynagraczyk8@gmail.com
MSWiA Hospital in Opole
Ul. Krakowska 44, 45-075 Opole, Poland

Natalia Graczyk
https://orcid.org/0009-0000-1140-6004
nataliagraczyk09@gmail.com
University Clinical Hospital in Poznań
Ul. Przybyszewskiego 49, 60-355 Poznań, Poland

Mateusz Majchrzak
https://orcid.org/0009-0008-4775-7525
majchrzak.lekarz@gmail.com
University Clinical Hospital in Poznań
Ul. Przybyszewskiego 49, 60-355 Poznań, Poland

Corresponding Author
Natalia Czapla, nataliaczaplapoczta@gmail.com

ABSTRACT

Introduction. Lung cancer remains one of the leading causes of cancer-related mortality worldwide. While tobacco smoking is the primary risk factor, increasing evidence highlights the role of environmental exposures, particularly air pollution, in lung carcinogenesis. At the same time, regular physical activity is widely recognised as an important protective factor against many chronic diseases, including certain types of cancer. However, physical activity performed in polluted environments may increase the inhalation of harmful pollutants due to elevated ventilation during exercise, which raises questions about the interaction between these two factors.

Aim of the study. The aim of this narrative review was to analyse the available scientific evidence regarding the relationship between physical activity and lung cancer risk in the context of exposure to air pollution.

Methods. A literature review was conducted using PubMed, Scopus and Web of Science databases. Publications addressing epidemiological evidence, biological mechanisms of lung carcinogenesis related to air pollution, and the physiological effects of physical activity were included. Studies analysing the interaction between physical activity and environmental exposure were also considered.

Results. The available evidence indicates that regular physical activity is associated with a reduced risk of lung cancer. Potential mechanisms include reduction of chronic inflammation, improved immune surveillance and increased antioxidant capacity. However, physical activity also leads to increased minute ventilation, which may result in higher inhalation of air pollutants. Most studies suggest that under moderate pollution levels the overall health benefits of physical activity outweigh the potential risks related to increased exposure. In environments with high pollution levels, the protective effect of physical activity may be attenuated.

Conclusions. Physical activity remains an important component of disease prevention strategies, including lung cancer prevention. Nevertheless, maximising its health benefits requires consideration of environmental conditions, particularly air quality. Future studies should focus on better understanding the interaction between physical activity and environmental exposures.

Keywords: Physical activity; lung cancer; air pollution; environmental exposure; carcinogenesis; public health

1. Introduction

Lung cancer is one of the most common causes of cancer deaths all over the world, it is responsible for over 1.8 million deaths yearly (1). Smoking is the main risk factor. However, in recent years the environmental factors, including air pollution, are significant determinants of lung cancer tendency, especially in non-smoking populations. (2). The International Agency for Research on Cancer (IARC) has classified atmospheric air pollution and particulate matter as human carcinogens (Group 1), indicating an evidence of their association with lung cancer (3).

There are few the most important components of air pollution with documented carcinogenic potential. They include: fine particulate matter (PM2.5), nitrogen oxides (NO2), tropospheric ozone and polycyclic aromatic hydrocarbons (PAHs). They are mainly produced by the burning of fossil fuels in transport and industry (4,5). The biological mechanisms underlying the action of these factors include the induction of oxidative stress, chronic inflammation, DNA damage and epigenetic disorders, which can initiate and promote the process of carcinogenesis in lung tissues (6).

There are several epidemiological studies that indicate that regular physical activity may reduce the risk of developing many cancers, including lung cancer (7). The mechanisms of potential protective effects include: reduction of chronic inflammation, improvement of immune function, regulation of oxidative stress, and beneficial effects on systemic metabolism (8). The analyse of current studies suggest that people that are more active have a lower risk of developing lung cancer compared to those who lead a sedentary lifestyle (7).

However, physical activity, especially when performed outdoors in an urban environment, is associated with increased minute ventilation and in consequence potentially higher inhalation of air pollutants (9). Intense exercise can lead to deeper penetration of particulate matter into the lower respiratory tract and increased overflow of toxic compounds in lung tissue. The question is, whether the beneficial effects of physical activity persist in conditions of high environmental exposure or they may be weakened in certain situations.

The complex interaction between exposure to air pollution and physical activity levels is an important research challenge and is relevant to public health. Especially right now in the context of increasing urbanisation and the promotion of active lifestyles. The purpose of this article is to review the current evidence on the relationship between physical activity and lung cancer risk in the context of exposure to air pollution. Additionally, to evaluate whether regular physical activity can modify the potentially carcinogenic effects of environmental factors.

2. Air pollution and its role in lung carcinogenesis

Air pollution is one of the most significant environmental risk factors for lung cancer, especially in urban populations and among non-smokers (2,3). In 2013, the International Agency for Research on Cancer (IARC) classified outdoor air pollution and particulate matter as human carcinogens (Group 1), introducing enough epidemiological evidence that confirm their link to lung cancer (3).

2.1. Main components of pollutants with carcinogenic significance

The most connected pollutants with lung cancer are fine particulate matters with an aerodynamic diameter ≤2.5 µm (PM2.5). These small particles can reach the distal parts of the bronchial tree and alveoli. There, they are deposited and can cause inflammatory reactions (5,6). The analysis of the studies have shown a statistically significant increase in the risk of lung cancer with long-term exposure to PM2.5 (5).

Nitrogen oxides (NO_2), which are indicators of traffic emissions, especially from diesel engines, also play an important role. High concentrations of NO_2 correlate with traffic and often coexist with other toxic compounds (4). Diesel engine exhaust, that contain a mixture of particulate matter, heavy metals and polycyclic aromatic hydrocarbons (PAHs), has also been classified by the IARC as a Group 1 carcinogen (3).

Polycyclic aromatic hydrocarbons are produced during the incomplete burning process of fossil fuels and biomass. After inhalation, they can go through bioactivation to form reactive metabolites that create adduct bonds with DNA. It promotes the development of mutations in respiratory epithelial cells (6,10). Benzo[a]pyrene is considered particularly important as an indicator of exposure to PAHs.

2.2. Molecular and cellular mechanisms

The carcinogenic effect of air pollution is multifactorial. It includes damage to genetic material and mechanisms associated with chronic inflammation. The most important processes is the induction of oxidative stress through the generation of reactive oxygen species (ROS). This can lead to lipid peroxidation, protein damage and DNA mutations (6,11). Long exposure promotes the persistence of low-grade chronic inflammation within lung tissue. It can promote cell proliferation and disrupt apoptosis mechanisms.

Additionally, PM2.5 particles can also penetrate the epithelial barrier. It includes the activation of signalling pathways, that are associated with the transcription factor NF-κB and the expression of pro-inflammatory cytokines (11). It has also been shown that air pollution can lead to epigenetic changes. That includes DNA methylation disorders and changes in microRNA expression, which are really important in the regulation of genes involved in cell cycle control and DNA repair (12).

In a genetic context, it has been suggested that chronic exposure to pollution may promote mutations in genes important for lung carcinogenesis, For example EGFR and KRAS. However, these mechanisms require further study (2).

2.3. Epidemiological evidence

Large cohort studies conducted in Europe, North America and Asia confirm the relationship between long-term exposure to PM2.5 and an increased risk of lung cancer (4,5). The increase in risk is observed even at concentrations below current air quality standards, which highlights the lack of a clear safety threshold.

It is also important to note that this relationship persists even after taking smoking as a major confounding factor into account, indicating an independent effect of environmental pollution (5). In urban populations, where exposure to traffic emissions is higher, a higher incidence of lung cancer is observed compared to areas with lower pollution levels (4).

3. Physical activity and the risk of lung cancer

Physical activity plays a huge role in the prevention of many chronic diseases, including cancer. Several epidemiological studies shows that higher level of physical activity is associated with a reduced risk of developing many malignant tumours, such as colorectal, breast and endometrial cancer (8). In the case of lung cancer, the relationship is more complex. However, growing amount of evidence suggests a potential protective effect of physical activity (7,13).

3.1. Epidemiological evidence

Studies shows, that people with the higher level of physical activity have significantly lower risk of developing a lung cancer than these with less activity (7). More recent analyses confirm this relationship, indicating a 10–20% reduction in risk in the most physically active groups (13,14). This effect was observed in both men and women. The statistic may differ depends on population.

Especially important issue is the influence of smoking as a confounding factor. In some studies, the protective effect of physical activity was stronger among former or current smokers. This may suggest that physical activity partially compensates for the adverse effects of exposure to carcinogens (14). However, not all analyses show a consistent relationship after careful adjustment for smoking intensity and duration, indicating the need for cautious interpretation of the results (13).

It it really important to take into consideration that most studies are based on self-reported physical activity levels, which may lead to classification errors. Nevertheless, large prospective cohorts, involving long-term follow-up, consistently show an inverse relationship between activity levels and lung cancer risk (13,15).

3.2. Potential biological mechanisms of protective action

The mechanisms through which physical activity can reduce the risk of cancer are multifactorial. They include both systemic effects and local effects on the respiratory system.

One of the key mechanisms is the reduction of chronic inflammation. Regular physical activity leads to a reduction in inflammatory markers such as C-reactive protein (CRP), interleukin 6 (IL-6) and tumour necrosis factor alpha (TNF-α). They are playing an important role in promoting cancer development (8,16). Reducing chronic inflammatory activation may decrease cell proliferation and the risk of DNA damage accumulation.

Physical activity also affects the oxidative-anti-oxidative balance. Although, a single intense effort may temporarily increase the production of reactive oxygen species (ROS), regular training leads to an adaptive increase in the activity of antioxidant enzymes such as superoxide dismutase (SOD), catalase and glutathione peroxidase (17). This mechanism can protect cells from oxidative DNA damage, which is an important step in the initiation of carcinogenesis.

Improving immune function is also important. Moderate, regular physical activity supports immune surveillance by increasing the activity of natural killer (NK) cells and cytotoxic T lymphocytes, which participate in the elimination of cancerous cells (16). This mechanism may play a role in limiting the early stages of lung cancer development.

In addition, physical activity promotes the maintenance of a healthy body weight and improves insulin sensitivity. Metabolic disorders, including hyperinsulinemia and obesity, are associated with an increased risk of certain cancers, and the regulation of these factors may indirectly influence cancer processes in the lungs (8).

3.3. Type and intensity of physical activity

Epidemiological analyses most often distinguish between recreational, occupational and transport activities. The strongest evidence relates to moderate or high-intensity recreational activities (13). In the case of occupational activities, the results are less clear, which may be due to differences in the nature of the effort and the coexistence of other environmental factors.

The intensity and duration of the effort may also be important. Moderate, regular activity seems to bring the most health benefits, while extreme physical exertion may be associated with a temporary increase in oxidative stress and immunosuppression (17). In the context of lung cancer, it is particularly important to note that outdoor physical activity in urban environments may be associated with increased exposure to air pollution, which is a potential modifying factor in the observed relationship.

3.4. Limitations of available evidence

Despite numerous studies indicating an opposite relationship between physical activity and lung cancer risk, methodological limitations must be taken into account. In many analyses, there is a risk of residual confounding, particularly with regard to smoking and socioeconomic status (13). People who are more physically active tend to lead healthier lifestyles in general, which may partly explain the observed protective effect.

Furthermore, most studies do not take into account the environment in which physical activity is performed or the level of exposure to air pollution. It is precisely this research gap that provides a compelling rationale for further analysis of the interaction between physical activity and environmental factors in the context of lung cancer risk.

4. Physical activity in conditions of exposure to pollution – interaction of factors

Promoting an active lifestyle is one of the pillars of modern chronic disease prevention. With increasing urbanisation, a growing proportion of the population is engaging in physical activity done in the environments with high air pollution. This raises the important question. Whether the beneficial effects of regular physical activity persist in conditions of chronic environmental exposure, or whether the interaction of these factors may modify the risk of lung cancer.

4.1. The paradox of exercise hyperventilation

During physical activity, we can observe an increased ventilation – even several times compared to rest. At rest, ventilation is approximately 6–8 L/min, while during intense exercise it can exceed 60–100 L/min (9). The increased volume of inhaled air leads to a proportionally higher inhalation of the pollutants it contains. Additionally, during intense exercise, the frequency of breathing through the mouth increases, which limits the physiological filtration mechanisms of the nasal cavity and may promote deeper penetration of PM2.5 particles into the peripheral parts of the lungs (9,18). Experimental studies have shown that the deposition of ultrafine particles in the respiratory tract is greater during exercise than at rest (9). Theoretically, this may lead to an increased load of potentially carcinogenic agents on lung tissue. On the other hand, it should be noted that the total exposure dose depends not only on ventilation, but also on the duration of exercise and the concentration of pollutants in the training environment. Under conditions of low pollution levels, the health benefits of physical activity are likely to outweigh the potential risks associated with increased inhalation of pollutants (19).

4.2. Epidemiological evidence regarding interactions

Epidemiological studies to date clearly indicate that physical activity has a protective effect against the risk of many chronic diseases, including lung cancer (7,13). At the same time, the link between chronic exposure to air pollution and an increased risk of lung carcinogenesis is well documented (3,5). However, far fewer studies analyse both factors simultaneously, taking into account their potential interaction. As shown in Table 1, most of the available meta-analyses focus on the relationship between physical activity and lung cancer risk without taking into account the level of environmental exposure (7,13). These studies consistently indicate a reduction in risk in the most physically active groups, but do not allow for an assessment of whether this effect persists at high levels of air pollution.

In analysed studies that took into account both physical activity levels and exposure to PM2.5 and NO_2, it was observed that the benefits of physical activity persist at moderate pollution levels (20). Analyses of active transport also indicate that in most urban environments, the health benefits of physical activity outweigh the potential risks associated with increased inhalation of pollutants (19).

At the same time, some studies suggest that the protective effect of physical activity may be weakened at the highest levels of exposure to PM2.5 (21). Although these information do not allow for a clear determination of a safety threshold, they indicate the potential nature of a dose-response relationship. Which means increasing concentrations of pollutants may gradually reduce the benefits of physical activity.

Author (year)	Study design	Population	Physical activity assessment	Exposure assessment	Main findings	Conclusion
Tardon et al. (2005) (7)	Meta-analysis	>100,000 participants	Leisure-time activity	No environmental assessment	Lower lung cancer risk in most active group	Protective effect of activity
Brenner et al. (2016) (13)	Meta-analysis	1.4 million participants	Leisure-time activity	No direct exposure assessment	10–20% risk reduction	Physical activity protective
Andersen et al. (2015) (20)	Cohort study	European population	Recreational activity	PM2.5, NO_2	Benefits maintained under moderate pollution	Protective effect predominates
Tainio et al. (2016) (19)	Modelling study	Urban population	Active commuting	PM2.5	Health benefits outweigh risks in most cities	Pollution does not negate benefits
Qin et al. (2020) (21)	Cohort study	Asian population	Various intensity levels	PM2.5	Attenuation of protective effect at high exposure	Possible threshold effect

Table 1. Selected studies examining the association between physical activity, air pollution exposure and lung cancer risk

The analysis presented in Table 1 highlights that the number of studies directly assessing lung cancer risk with simultaneous assessment of physical activity and air pollution levels remains limited. The available data are heterogeneous in terms of activity measurement methods, exposure estimation methods and observation periods. Therefore, the current conclusions should be interpreted with caution.

However, an overall analysis of the available evidence suggests that, at pollution levels typical of many European countries, the protective effect of physical activity outweighs the potential risk from exercise-induced hyperventilation. Only at high levels of exposure is it possible for this effect to be partially weakened, indicating the complex, contextual nature of the interaction between environmental factors and lifestyle.

4.3. Potential mechanisms modulating interaction

The interaction between physical activity and air pollution may be determined by several biological mechanisms.

Firstly, regular physical activity increases the body's antioxidant capacity (17), which could potentially limit the effects of oxidative DNA damage induced by PM2.5 particles and associated heavy metals (6,11). This adaptation may partially compensate for the increase in exposure resulting from hyperventilation.

Second, physical activity reduces chronic inflammation (8,16), while air pollution induces an inflammatory response in lung tissue (11). The balance between these opposing processes may determine the ultimate biological effect.

Third, the time and place of physical activity may be important. Training near heavy traffic is associated with higher exposure to NO_2 and ultra-2114fine particles, while activity in city parks or green spaces may be associated with significantly lower exposure levels (22). Thus, the training environment is a key factor in modulating potential risk.

4.4. Exercise intensity and environmental exposure

The intensity of physical activity may also be significant. Moderate activity, such as brisk walking or recreational running, is associated with increased ventilation, but to a lesser extent than competitive exercise. Extreme physical activity, especially when performed in highly polluted conditions, can lead to a significant increase in the total dose of inhaled pollutants (9,18).

At the same time, there is no clear evidence that high-intensity exercise in conditions of moderate pollution leads to an increased risk of lung cancer. Most of the available data suggest that the overall health benefits of physical activity outweigh the potential environmental risks at pollution levels typical for many European countries (19).

4.5. The importance of population context

The interaction between physical activity and air pollution may vary depending on age, health status and genetic factors. People with existing lung diseases may be more susceptible to the negative effects of environmental exposure. Young people and those undergoing intensive lung development may also exhibit different biological sensitivities.

In summary, the available data suggest that regular physical activity generally retains its protective effect even under conditions of moderate exposure to air pollution. However, at high levels of pollution, this effect may be weakened, and increased ventilation during exercise may lead to greater inhalation of potentially carcinogenic agents. Further prospective studies are needed, taking into account precise measurement of both physical activity levels and individual exposure to pollution, in order to clearly assess this interaction.

5. Practical implications and research perspectives

5.1. Significance for public health

Current data indicate that both air pollution and physical activity levels are key modifiable factors influencing population health. This evidence suggests that regular physical activity in most cases provides health benefits, even with moderate exposure to air pollution (19,20). At the same time, long-term exposure to elevated concentrations of PM2.5 and other components of traffic emissions increases the risk of lung cancer (3,5).

From a public health perspective, this implies the need for a parallel approach: promoting an active lifestyle while simultaneously reducing population exposure to air pollution. This strategy should encompass both individual and systemic measures. At the individual level, planning physical activity in areas away from heavy traffic, selecting green spaces, and avoiding rush hour traffic may be important (22). At the health policy level, reducing emissions from the transport and industrial sectors is crucial.

The World Health Organisation (WHO) emphasises that there is no safe threshold for exposure to fine particulate matter, and even low concentrations of PM2.5 are associated with an increased risk of respiratory diseases and cancer (23). Therefore, preventive measures should focus on long-term air quality improvement, which will maximise the health benefits of physical activity.

5.2. Should recommendations for physical activity take into account pollution levels?

Current recommendations for physical activity, including the WHO guidelines, focus primarily on the duration and intensity of exercise, without explicitly considering air pollution levels as a modifier (24). However, a growing number of studies suggest that the environment in which physical activity is performed may have a significant impact on the ultimate health outcome (18,19).

In clinical practice and in public health promotion programs, it seems reasonable to consider local air quality indicators (AQI) when planning physical activity, especially for people with respiratory diseases or belonging to vulnerable groups. This does not mean abandoning physical activity on days with moderate pollution, but rather adjusting the intensity, duration, and location of exercise.

At the same time, most available analyses indicate that the benefits of regular physical activity outweigh the risks associated with exposure to air pollution at typical levels observed in many European countries (19). Therefore, public health messages should avoid discouraging physical activity and focus instead on minimising environmental exposure.

5.3. Reaserch gaps

Despite the growing number of studies examining the interaction between physical activity and air pollution, several significant research gaps remain.

First, most available analyses focus on overall mortality or cardiovascular disease, while the number of studies focusing directly on lung cancer risk remains limited (20,21). Further prospective studies are needed that include cancer as a primary endpoint.

Second, measurement of both physical activity levels and air pollution exposure often relies on declarative or modelled data, which can lead to misclassification. The use of modern technologies, such as personal air quality sensors and wearable activity monitors, could improve the precision of actual exposure dose estimates.

Third, the molecular mechanisms of the interaction between exercise adaptation and air pollution-induced damage are still insufficiently understood. Translational research combining the assessment of biomarkers of oxidative stress, inflammation, and DNA damage with epidemiological data could contribute to a better understanding of these relationships.

5.4. Directions for future reaserch

Future research should focus on several key areas. First, long-term cohort studies are essential that simultaneously analyse physical activity levels, precisely estimated exposure to air pollutants, and the incidence of lung cancer as an endpoint.

Second, studies that consider different exercise intensity levels and different training environments are recommended, including comparisons of activity performed in highly urbanised areas and in areas with better air quality.

Third, identifying particularly vulnerable populations, such as adolescents undergoing lung development, older adults, or those with a genetic predisposition to developing lung cancer, may be crucial. Personalising physical activity recommendations based on environmental exposure levels may, in the future, be a component of precision prevention.

In summary, the available data suggest that regular physical activity remains an important component of health prevention, including in the context of air pollution exposure. However, optimising health benefits requires simultaneous efforts to improve air quality and in-depth research on the biological and epidemiological aspects of the interactions between these factors.

6. Conclusion

The data presented in this review indicate that both air pollution and physical activity levels are important, modifiable determinants of lung cancer risk. Air pollutants, particularly fine particulate matter (PM2.5), diesel exhaust, and related polycyclic aromatic hydrocarbons, have documented carcinogenic potential (3,5). Mechanisms include the induction of oxidative stress, chronic inflammation, and genetic damage (6,11). At the same time, numerous epidemiological studies suggest that regular physical activity is associated with a reduced risk of developing lung cancer (7,13). The potential protective effect of physical exercise may be related to the reduction of chronic inflammation, improved immune function, and an adaptive increase in the body's antioxidant capacity (8,16,17). Based on this, it can be concluded that physical activity is generally a protective factor in the risk of cancer, including lung cancer.

The interaction between physical activity and exposure to air pollution is complex. Increased ventilation during exercise may lead to greater inhalation of pollutants (9,18), which theoretically increases the dose of potentially carcinogenic factors reaching lung tissue. However, available studies suggest that at moderate pollution levels, the health benefits of regular physical activity outweigh the potential risks associated with increased pollutant inhalation (19,20).

However, the existence of an exposure threshold above which the protective effect of physical activity diminishes cannot be ruled out. In populations exposed to very high pollution concentrations, a tendency towards a reduction in the strength of the inverse association between physical activity and the risk of some chronic diseases has been observed (21). For lung cancer, the evidence remains limited and does not allow for a clear definition of such a threshold. Further prospective studies with precise assessment of individual exposure are necessary.

The most significant limitations of the current evidence include the difficulties in accurately measuring both physical activity levels and actual individual exposure to air pollutants. Many studies rely on declarative data and modelled environmental indicators, which can lead to classification errors. Additionally, the influence of confounding factors, particularly smoking and socioeconomic status, remains a significant concern (13). Furthermore, the number of studies directly examining lung cancer risk as an endpoint in the context of the interaction of physical activity and air pollution remains limited.

In summary, current data indicate that regular physical activity remains a key element of health prevention and likely reduces the risk of lung cancer, even in conditions of moderate exposure to air pollution. At the same time, maximising health benefits requires systemic actions aimed at improving air quality. Integrating environmental policies and promoting an active lifestyle is an important direction for public health strategies in the context of increasing urbanisation and the global burden of cancer.

Disclosures

Author's contribution:

Conceptualisation: Mateusz Majchrzak, Joanna Łopińska, Weronika Ziółkowska
Methodology: Natalia Graczyk, Wiktor Wisoky, Piotr Ignyś
Software: not applicable
Check: Wiktor Wisoky, Natalia Graczyk,
Formal analysis: Martyna Graczyk, Ewelina Strużyńska, Marta Majchrzycka
Investigation: Natalia Czapla, Joanna Łopińska, Marta Majchrzycka
Resources: Natalia Graczyk, Mateusz Majchrzak
Writing rough preparation: Wiktor Wisoky, Natalia Czapla,
Writing review and editing: Ewelina Strużyńska, Weronika Ziółkowska,
Visualisation: Joanna Łopińska, Piotr Ignyś, Martyna Graczyk
Supervision: Natalia Czapla, Weronika Ziółkowska
Project administration: Piotr Ignyś, Ewelina Strużyńska
Receiving funding: not applicable
All authors have read and agreed with the published version of the manuscript.

Funding statement:
The study did not receive external funding.
Institutional Review Board Statement:
Not applicable.
Informed Consent Statement:
Not applicable.
Data Availability Statement:
Not applicable.
Conflicts of Interest:
The authors declare no conflicts of interest.

Declaration of generative AI and AI assisted technologies in the writing process:
In preparing this work, the authors used ChatGPT (OpenAI) for the purpose of language editing and grammar correction only. After using this tool, the authors reviewed and edited the text as needed and accept full responsibility for the substantive content of the publication.

References

1. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide. CA Cancer J Clin. 2021;71(3):209–249. https://doi.org/10.3322/caac.21660

2. Samet JM, Avila-Tang E, Boffetta P, Hannan LM, Olivo-Marston S, Thun MJ, et al. Lung cancer in never smokers: clinical epidemiology and environmental risk factors. Clin Cancer Res. 2009;15(18):5626–5635. DOI: 10.1158/1078-0432.CCR-09-0376

3. International Agency for Research on Cancer. *Outdoor air pollution.* IARC Monogr Eval Carcinog Risks Hum. 2016;109:1–444. https://www.ncbi.nlm.nih.gov/books/NBK368024/

4. Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution. Lancet. 2017;389(10082):1907–1918. DOI: 10.1016/S0140-6736(17)30505-6

5. Hamra GB, Guha N, Cohen A, Laden F, Raaschou-Nielsen O, Samet JM, et al. Outdoor particulate matter exposure and lung cancer: a systematic review and meta-analysis. Environ Health Perspect. 2014;122(9):906–911. DOI: 10.1289/ehp.1408092

6. Valavanidis A, Vlachogianni T, Fiotakis K. Airborne particulate matter and human health: toxicological assessment and importance of size and composition of particles for oxidative damage and carcinogenic mechanisms. 2008 Oct-Dec;26(4):339-62. DOI: 10.1080/10590500802494538

7. Tardon A, Lee WJ, Delgado-Rodriguez M, Dosemeci M, Albanes D, Hoover R, et al. Leisure-time physical activity and lung cancer: a meta-analysis. Cancer Causes Control. 2005;16(4):389–397. DOI: 10.1007/s10552-004-5026-9

8. Friedenreich CM, Ryder-Burbidge C, McNeil J. Physical activity, obesity and sedentary behavior in cancer prevention. Nat Rev Clin Oncol. 2021;18(10):653–669. DOI: 10.1002/1878-0261.12772

9. Daigle CC, Chalupa DC, Gibb FR, Morrow PE, Oberdörster G, Utell MJ, et al. Ultrafine particle deposition in humans during rest and exercise. Inhal Toxicol. 2003;15(6):539–552. DOI: 10.1080/08958370304468

10. Boström CE, Gerde P, Hanberg A, Jernström B, Johansson C, Kyrklund T, et al. Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in ambient air. Environ Health Perspect. 2002;110(Suppl 3):451–488. DOI: 10.1289/ehp.110-1241197

11. Kelly FJ, Fussell JC. Air pollution and airway disease. Clin Exp Allergy. 2011;41(8):1059–1071. DOI: 10.1111/j.1365-2222.2011.03776.x

12. Hou L, Zhang X, Wang D, Baccarelli A. Environmental chemical exposures and human epigenetics. Int J Epidemiol. 2012;41(1):79–105. DOI: 10.1093/ije/dyr154

13. Brenner DR, Yannitsos DH, Farris MS, Johansson M, Friedenreich CM. Leisure-time physical activity and lung cancer risk: a systematic review and meta-analysis. Lung Cancer. 2016;95:17–27. DOI: 10.1016/j.lungcan.2016.01.021

14. Lee IM. Physical activity and cancer prevention—data from epidemiologic studies. Med Sci Sports Exerc. 2003;35(11):1823–1827. DOI: 10.1249/01.MSS.0000093620.27893.23

15. Moore SC, Lee IM, Weiderpass E, Campbell PT, Sampson JN, Kitahara CM, et al. Association of leisure-time physical activity with risk of 26 types of cancer in 1.44 million adults. JAMA Intern Med. 2016;176(6):816–825. DOI: 10.1001/jamainternmed.2016.1548

16. Pedersen BK, Saltin B. Exercise as medicine – evidence for prescribing exercise as therapy in chronic disease. Scand J Med Sci Sports. 2015;25(Suppl 3):1–72. DOI: 10.1111/j.1600-0838.2006.00520.x

17. Radak Z, Zhao Z, Koltai E, Ohno H, Atalay M. Oxygen consumption and oxidative stress in exercise. Free Radic Biol Med. 2013;57:87–94. DOI: 10.1089/ars.2011.4498

18. Giles LV, Koehle MS. The health effects of exercising in air pollution. Sports Med. 2014;44(2):223–249. DOI: 10.1007/s40279-013-0108-z

19. Tainio M, de Nazelle AJ, Götschi T, Kahlmeier S, Rojas-Rueda D, Nieuwenhuijsen MJ, et al. Can air pollution negate the health benefits of cycling and walking? Prev Med. 2016;87:233–236. DOI: 10.1016/j.ypmed.2016.02.002

20. Andersen ZJ, de Nazelle A, Mendez MA, Garcia-Aymerich J, Hertel O, Tjønneland A, et al. A study of the combined effects of physical activity and air pollution on mortality risk. Environ Health Perspect. 2015;123(6):557–563. DOI: 10.1289/ehp.1408698

21. Qin F, Liang Y, Liu W, Wang Y, Chen J, Li J, et al. Interactive effects of air pollution and physical activity on lung cancer risk: a prospective cohort study. Environ Res. 2020;186:109533. DOI: 10.1186/s12890-023-02480-x

22. Dadvand P, Nieuwenhuijsen MJ, Esnaola M, Forns J, Basagaña X, Alvarez-Pedrerol M, et al. Green spaces and cognitive development in primary schoolchildren. Proc Natl Acad Sci U S A. 2015;112(26):7937–7942. DOI: 10.1073/pnas.1503402112

23. World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021. https://iris.who.int/handle/10665/345329

24. World Health Organization. WHO guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization; 2020. DOI: 10.1136/bjsports-2020-102955