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Asthma in cross-country and alpine skiing: Risks and prevention. A review of the literature

Jan Siemianowski[1*], Weronika Kotnis[2], Sandra Prolejko[2], Michalina Doligalska[3], Aleksandra Stremel[4], Błażej Gajęcki[1], Greta Steć[1], Justyna Kopala[5], Agata Brzyska[1], Magdalena Pawlak[1]

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Authors' Affiliation:
[1]Central Clinical Hospital of Medical University of Lodz, Pomorska 251, 92-213 Lodz, Poland
[2]Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland
[3]Medical Hospital in Garwolin, Lubelska 50, 08-400 Garwolin, Poland
[4]Centre of Postgraduate Medical Education, Orłowski Hospital, Czerniakowska 231, 00-416, Warsaw, Poland
[5]University Clinical Hospital No.2 of the Medical University of Lodz, Żeromskiego 113, 90-549 Łódź, Poland

[*]**Corresponding Author**
Central Clinical Hospital of Medical University of Lodz, Pomorska 251, 92-213 Lodz,
Poland
Email: ja.siemianowski@gmail.com

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ABSTRACT

Asthma and exercise-induced bronchoconstriction (EIB) are prevalent among winter athletes, particularly cross-country and alpine skiers. These disciplines involve strenuous exercise in hostile environmental conditions (e.g., cold and dry air), exacerbating respiratory dysfunction. Although much is known about asthma in cross-country skiing, Alpine skiing has been less studied despite similar environmental and physiological risk factors for developing respiratory symptoms. This review collates evidence from consensus statements, systematic reviews, and observational studies to give a renewed perspective on the prevalence, risks, and management strategies of asthma and EIB in these skiing disciplines. The evidence shows that prolonged exposure to sub-zero temperatures, high-intensity training, and poor recovery periods increase the likelihood of airway inflammation and hyperresponsiveness. Preventative measures, such as structured pre-exercise warm-up or using heat-and-moisture-exchanging devices (HMEDs), may help attenuate EIB symptoms, but their usefulness varies. Pharmacological interventions, such as bronchodilators, are essential in controlling EIB when non-pharmacological measures are inadequate. Similarly, asthma management may focus on tailored pharmacological interventions, including inhaled corticosteroids (ICS) and bronchodilators. Non-pharmacological strategies, such as managing environmental factors and implementing structured training programs, can also provide valuable support. This review highlights important gaps in the current research, particularly the need for long-term studies and personalized methods for diagnosis and treatment. Filling these gaps will help promote athlete health and performance while reducing respiratory risk.

Keywords: Asthma, exercise-induced bronchoconstriction, cross-country skiing, Alpine skiing, prevention, respiratory health

1. INTRODUCTION

Asthma and respiratory disorders pose substantial challenges for winter sports athletes, particularly cross-country and Alpine skiing. These activities require persistent physical effort in cold and, quite often, dry environments, which are recognized factors for the induction of airway inflammation and the occurrence of bronchial hyperresponsiveness. Elite cross-country skiers demonstrate a notably increased risk of developing asthma and exercise-induced bronchoconstriction (EIB) compared to athletes participating in other sports or the general population (Mäki-Heikkilä et al., 2020). According to Lennelöv et al., (2019), research has shown that young cross-country skiers have a higher chance of getting asthma and other respiratory issues compared to their peers, mainly due to factors like intense physical activity and cold air exposure.

Despite extensive studies of the effects of cross-country skiing on respiratory health, there is a general lack of information on the incidence of asthma among other winter sports, including Alpine skiing. Winter sports involving similar environmental exposures, including cold air and exercise intensity, have shown increased risks for asthma and bronchial hyperresponsiveness. For instance, respiratory illnesses have been reported among biathlon athletes and Nordic combined skiers, and even in indoor winter sports like figure skating and ice hockey (Carlsen, 2012). Exact data on the prevalence of asthma in Alpine skiing has not been provided, but considering the environment and activity are quite similar, parallel respiratory risks can be extrapolated.

This highlights the need for future research into asthma prevalence and management strategies in Alpine skiing and other less-studied winter sports disciplines. Physiological responses to cold air, including increased parasympathetic activity and heightened bronchial tone, are exacerbated by other risk factors that include repetitive high-intensity exercise and environmental pollution (Carlsen, 2012; Stang et al., 2016). The above factors contribute to the occurrence of bronchial hyperresponsiveness and asthma, mainly in athletes who perform endurance sports. Winter sports training is mostly conducted under vigorous environmental conditions, underscoring the interaction between environmental, physiological, and training factors (Wang et al., 2021).

Management in asthma treatments, such as inhaled corticosteroids and bronchodilators remains important in minimizing risks and improving exercise capacity (Carlsen, 2012). Therefore, this review assembles the existing evidence from a wide range of studies, including IOC consensus statements, systematic reviews, and individual research articles, aimed toward a more global understanding of asthma in the skiing disciplines. This study identifies significant risk factors and appraises prevention strategies to inform evidence-based practice and identify areas for future research.

2. METHODOLOGY

This review collates information from peer-reviewed literature, systematic reviews, meta-analyses, and consensus statements. A major database search of PubMed and Scopus was performed for the period January 2012 – August 2024. The following terms were used in different combinations: "asthma", "exercise-induced bronchoconstriction", "cross-country skiing", "Alpine skiing", and "respiratory health". Studies were included in which prevalence, risk factors, or prevention strategies in skiing environments were examined. Sources, like the GINA guidelines and IOC consensus statements, gave essential insight.

3. RESULTS AND DISCUSSION

Prevalence of Asthma in Skiers

Asthma and exercise-induced bronchoconstriction (EIB) are particularly common among skiers, with differences shaped by age, gender, and training environments. Research conducted by Näsman et al., (2018) and Eklund et al., (2018) indicates that athletes, especially in endurance disciplines (such as cross-country skiing), exhibit a greater prevalence of asthma and respiratory issues than non-athlete counterparts. Näsman et al., (2018) found that 12% of Swedish recreational endurance athletes self-identified as having self-reported asthma, and among those asthmatics, 23% used daily inhaled corticosteroids (ICS) along with long-acting beta-agonists (LABA), 25% used ISC daily, and 22% reported daily use of LABA/SABA (short-acting beta-agonists).

Similarly, Eklund et al., (2018) discovered that 23% of young cross-country skiers indicated having self-reported asthma, while only 12% of non-athlete controls reported the same, implying that initial exposure to training settings might play a role in the heightened occurrence. Studies on respiratory health related to Alpine skiing are scarce, with only a few specifically examining this group of people. Winter sports athletes typically face diverse environmental factors, like cold air, that may lead to airway hyperresponsiveness and various respiratory issues (Carlsen, 2012). According to Schwellnus et al., (2022), many non-infectious respiratory conditions are common among athletes training in cold environments.

It's important that symptoms can often overlap with those of exercise-induced bronchoconstriction (EIB) or asthma. This suggests that accurate diagnosis is important to ensure patients receive effective treatment. Mäki-Heikkilä et al., (2020) found that in cross-country skiers, the average prevalence of self-reported physician-diagnosed asthma was 21%. The prevalence increased to 28% when self-reported physician-diagnosed asthma was combined with asthma determined by lung function assessments. This is much higher than the generally reported prevalence rate of about 10% in the general population. The research emphasized that respiratory issues, especially during and following strenuous exercise, are worsened by the elevated ventilation rates needed in cold and dry air conditions.

Likewise, Norqvist et al., (2015) discovered that among Swedish teenage athletes aged 15–19 years, 29% of cross-country skiers indicated they had physician-diagnosed asthma, in contrast to 17% of orienteering participants. The use of asthma medications was also more prevalent among skiers (25%) than orienteers (11%), indicating a higher prevalence of asthma among athletes in winter endurance sports. These results reinforce the need for better diagnostic methods and medical attention to respiratory health amongst elite endurance athletes, particularly in cold-climate sports.

Comparative Analysis Between Skiing Disciplines

Although cross-country and Alpine skiing have common environmental factors like cold temperatures and intense physical effort, the physiological and environmental obstacles vary significantly among the fields. Cross-country skiing requires continuous aerobic activity, frequently lasting more than an hour per race, resulting in extended exposure to subzero temperatures and elevated ventilation rates. These circumstances increase the likelihood of airway dryness and inflammation (Kennedy et al., 2019). In contrast, Alpine skiing involves brief episodes of anaerobic effort paired with technical accuracy, highlighting power and stability to handle the pressures and requirements of the sport (Hydren et al., 2013).

Intense exercise in cold conditions results in heightened ventilation, boosting respiratory loss of heat and water. This procedure worsens airway hydration and temperature reduction, resulting in situations that may cause exercise-induced bronchoconstriction (EIB) in susceptible athletes. Following exertion, the consequent rise in airway osmolality might additionally trigger respiratory symptoms in individuals training or participating in chilly weather conditions (Carlsen, 2012).

Cross-country skiers benefit from tools like heat-and-moisture-exchanging devices (HMEDs) that enhance air quality to lessen airway dryness and alleviate exercise-triggered bronchoconstriction (EIB) during extended physical activity. Although HMEDs have been firmly established for use in endurance athletes, additional studies are required to investigate their possible advantages for other winter sports activities. Investigating the specific breathing risks for winter athletes, taking into consideration long-term effects on their lungs, will help develop a complete plan for athlete health (Hanstock et al., 2020).

Risk Factors

Environmental Exposures

The influence of environmental exposures on respiratory health cannot be underrated. According to Kennedy et al., (2019), the increases in respiratory volumes in cold conditions induce loss of water from the airways, thereby raising the osmolarity of the airway-surface lining. This results in the contraction of bronchial epithelial cells and causes the release of pro-inflammatory mediators that lead to smooth muscle contraction. High-altitude environments expose the respiratory system to a set of stresses, especially for athletes training in endurance sports. Moreover, prolonged exposure to altitude can often lead to increased ventilation rates.

It has been suggested that the significant trigger of EIB is airway dehydration due to exercise-induced increased ventilatory needs and, therefore, an increase in airway fluid osmolarity (Nair et al., 2017). Athletes in cold-weather sports have unique respiratory challenges related to environmental exposures. Particulate matter (PM) from diesel-powered equipment, truck and auto emissions, and ski waxing fumes at ski resorts has been recognized as a respiratory irritant. These pollutants add to oxidative damage and airway inflammation, which is particularly concerning for athletes with pre-existing respiratory conditions as they can cause exacerbations of asthma and exercise-induced bronchoconstriction (EIB).

The prevalence of EIB, asthma, and decreased resting lung function is much greater in athletes training and competing in high PM emission environments compared to non-athletes and those in low-pollution settings. In addition, these pollutants have a negative effect on both the pulmonary and cardiovascular systems (Rundell, 2012). Hanstock et al., (2020) stated that exercise in cold and dry air can cause airway inflammation and epithelial injury and might be related to an increased prevalence of airway hyperresponsiveness and asthma.

Physiological and Training Demands

Results of a study by Näsman et al., (2018) support that high physical activity is associated with self-reported asthma among competitive recreational athletes. Hence, training volume should be a detailed study of exercise-induced bronchoconstriction in recreational athletes. In Alpine skiers, the periodic nature of their training and competition, added to environmental factors such as sudden changes in altitude, may create unique physiological stresses. The constant changes in altitude can lead to hyperventilation, which may enhance airway hyperresponsiveness due to cold air. The 2024 Global Initiative for Asthma (GINA) guidelines also emphasize the fact that physical activity is a powerful inciting factor for asthma symptoms in many patients, and in most cases, symptoms and bronchoconstriction usually worsen after completion of exercise.

Athletes, particularly those at a high level of competition, have a higher prevalence of several respiratory conditions than non-athletes. They have a higher prevalence of asthma, allergic or non-allergic rhinitis, EIB, inducible laryngeal obstruction, chronic cough, and recurrent respiratory infections. Airway hyperresponsiveness is common in elite athletes, often without reported symptoms. Asthma in elite athletes is characterized by a poorer correlation between symptoms and lung function, increased lung volumes and expiratory flows, reduced eosinophilic airway inflammation, increased difficulty in controlling symptoms, and some reversibility of airway issues following cessation of training (GINA, 2024).

Respiratory Infections

As reported by Ruuskanen et al., (2022), infections of the upper respiratory tract, commonly referred to as the "common cold", are the most prevalent acute illnesses among elite athletes. Infections pose a considerable risk factor for airway malfunction. They assert that among 44 Norwegian cross-country skiers, 48% fell ill during or shortly thereafter following the 10-day Tour de Ski. In the 2018 Winter Olympic Games, 45% of 44 competitors from Team Finland exhibited acute respiratory symptoms, as confirmed by the team physician. Hanstock et al., (2020) noted that athletes who participate in winter sports commonly report respiratory symptoms affecting both the upper and lower airways; up to 80% experience intermittent exercise-related symptoms. It is well known that cold temperatures and low humidity are risk factors for upper respiratory infections in the general population.

This could explain, why there is a higher number of respiratory symptoms reported during winter. However, it's essential to remember that not all symptoms athletes experience are tied to infections. Some of them might be related to physical exertion. For example, among cross-country skiers, a rise in coughing during the competitive season has been associated with the presence of sputum neutrophils and the total annual training undertaken, suggesting a localized influence of immune cell activity within the airways as well as stress resulting from training. Ultimately, the GINA, (2024) guidelines emphasize that elements that can provoke or exacerbate asthma symptoms include viral infections. Research conducted by Palmer et al., (2021) demonstrates that during illness, athletes who show symptoms such as fever or additional symptoms below the neck should be guaranteed sufficient rest and recovery.

Prevention Strategies

Diagnostic Approaches

The 2024 guidelines of the Global Initiative for Asthma (GINA) offer an extensive framework for diagnosing asthma, with specific attention on athletes. Asthma is identified through distinctive symptoms like wheezing, chest constriction, difficulty breathing, and coughing, which change over time and in intensity. These symptoms need to be backed by concrete proof of variable expiratory airflow restriction, usually shown via lung function tests. Spirometry serves as the main diagnostic tool, assessing vital metrics like forced expiratory volume in a single second (FEV1) and forced vital capacity (FVC). An essential diagnostic characteristic is notable bronchodilator reversibility, characterized by a rise in FEV1 of ≥12% and 200 mL from baseline following the administration of a bronchodilator.

When first spirometry findings are unclear, further evaluations like bronchial provocation utilizing methacholine or exercise tests are suggested. These assessments are especially useful for verifying exercise-related bronchoconstriction (EIB) in athletes, as they mimic actual triggers (GINA, 2024). The guidelines highlight the significance of ruling out differential diagnoses that could resemble or occur alongside asthma. Conditions like allergic rhinitis, dysfunctional breathing, inducible laryngeal obstruction, heart irregularities, and the impacts of overtraining need to be taken into account. For athletes subjected to cold or arid settings, specific assessments such as eucapnic voluntary hyperventilation or cold-air tests could offer extra diagnostic insights by simulating environmental stimuli.

As supported by findings from Reier-Nilsen et al., (2023), these methods are valuable in confirming asthma and exercise-induced bronchoconstriction in athletes. An accurate and timely diagnosis is crucial to enable effective management not only in the case of athletes but also in the general population. A complex and patient-focused strategy for asthma management should be provided by the combination of objective assessment, ruling out differential diagnoses, and focusing on environmental and personal elements (GINA, 2024; Reier-Nilsen et al., 2023).

Pharmacological Management

The Global Initiative for Asthma GINA, (2024) highlights a tailored approach to initial asthma management in adults and adolescents aged 12 years and older, framed around the cycle of assessing, adjusting, and reviewing individual patient needs. It includes confirmation of the diagnosis, assessment of symptom control and modifiable risk factors, comorbidity management, checking for proper inhaler technique and adherence, and aligning with patient preferences and goals. Treatment strategies are dynamic and tailored to the severity of symptoms, side effects, lung function, exacerbation history, and patient satisfaction. The two main therapeutic approaches are outlined in the recommendations.

The first and preferred approach involves low-dose inhaled corticosteroid (ICS) plus formoterol for both controller and reliever therapy. Treatment is initiated on an as-needed basis at Steps 1 and 2 and progressed to low-dose maintenance ICS-formoterol (Step 3), medium-dose ICS-formoterol (Step 4), and finally, high-dose ICS-formoterol or add-on therapy (Step 5) in cases labelled as severe. Add-on therapies include long-acting muscarinic antagonists or biological agents, including anti-IgE, anti-IL-5/5R, anti-IL-4Rα, or anti-TSLP, depending on asthma phenotype and severity that requires further evaluation of phenotypes. The guidelines emphasize the need to target modifiable risk factors and comorbidities alongside non-pharmacological interventions such as education and skills training.

Thus, the guidelines seek to improve the management of their symptoms while reducing the likelihood of future exacerbations tailored to the individual patient and his situation. Recent work by Koya et al., (2020) gives an overview of exercise-induced bronchoconstriction (EIB) management in athletes. The authors underline that pharmacological management is directed toward either the prevention or treatment of symptoms. To prevent symptoms, SABA is used 5–20 minutes before exercise. In cases where SABAs alone are inadequate, other treatments may be added, such as anticholinergics or mast cell stabilizing agents (MCSA). In cases requiring frequent use of SABAs (daily or more often), controller therapies such as daily inhaled corticosteroids (ICS), potentially combined with LABA or leukotriene receptor antagonist (LTRA), are recommended.

Antihistamines may also be considered in allergic individuals. In individuals with asthma experiencing EIB, it often indicates inadequate asthma control, necessitating an intensification of treatment. Therapeutic modifications are executed following corresponding guidelines, and the most frequently utilized are those of the Global Initiative for Asthma (GINA). Koya et al., (2020) further add that incorporating individualized dietary intervention strategies, including omega-3 fatty acid supplementation, holds promise for regulating inflammation associated with respiratory diseases.

Mäki-Heikkilä et al., (2020) suggest that occasional use of bronchodilators in therapeutic doses does not improve exercise performance; however, it is important in preventing bronchoconstriction in asthmatic skiers. In contrast, two studies reported that high oral doses of salbutamol or a combination of inhaled β2-agonists improved sprinting capacity or maximum strength, both acutely and longitudinal. Further research is needed to clarify whether such strength improvements would be beneficial to healthy cross-country skiers, especially concerning their final sprint performance.

Environmental and Training Modifications

Exercising in cold, dry air is recognized to lead to airway inflammation and epithelial damage, which may increase the likelihood of airway hyper-responsiveness and asthma (Hanstock et al., 2020). GINA, (2024) recommends that strategies to prevent significant exposure to air pollutants and allergens, especially during training sessions, should be communicated to the athletes. They ought to steer clear of exercising in severe cold or pollution. Training and adequate warm-up decrease the frequency and intensity of EIB. Stickland et al., (2012) demonstrate that a suitable warm-up approach, featuring at least some activity near peak oxygen uptake or maximum heart rate, can serve as a brief non-pharmacological option for alleviating EIB.

Heat-and-moisture-exchanging devices (HMEDs) are potentially useful solutions to environmental management concerning the reduction of the impact of cold and dry air by the conditioning of inspired air. Often in the form of masks to cover the nose and mouth, these devices are designed to conserve heat and moisture from exhaled air and pass it to the inhaled air, maintaining hydration and temperature stability in the airways. This might help to prevent the drying and cooling effects of cold air on the lining of the airways, a common trigger for airway irritation and bronchoconstriction (Hanstock et al., 2020). Exercise in cold, dry air is known to cause airway inflammation and epithelial damage, which may contribute to an increased incidence of airway hyper-responsiveness and asthma.

Heat and moisture exchangers (HMEDs) have the potential to mitigate exercise-induced bronchoconstriction, but evidence regarding their effectiveness under different environmental conditions is inconsistent. In athletes with asthma, the use of HMEDs in cold or dry conditions may provide important airway protection (Hanstock et al., 2020). Jong et al., (2023) also reported a number of pragmatic problems with the use of HMEDs: Enhanced breathing resistance, saliva within masks, and ice-obstructing filters that can compromise venting in adverse conditions. Table 1 provides an overview of prevention strategies for asthma symptoms and exercise-induced bronchoconstriction in cross-country and alpine skiers.

Table 1 Summary of prevention strategies for asthma symptoms and exercise induced bronchoconstriction in cross-country and alpine skiers.

Category	**Strategies**
Environmental Management	Avoid severe cold, pollution; use heat-and-moisture-exchanging devices (HMEDs)
Training Modifications	Structured warm-ups
Pharmacological	Use of ICS, bronchodilators (SABA, LABA); tailored treatment based on individual severity

Anti-Doping Regulations and Therapeutic Use Exemptions (TUEs)

The World Anti-Doping Agency (WADA) offers protocols to maintain fairness and safeguard athlete health while permitting essential treatment for issues such as asthma and exercise-induced bronchoconstriction (EIB). These conditions are common among athletes, especially in endurance sports, and frequently necessitate the use of medications that could be considered banned substances. In these situations, to use these medications within the allowed boundaries, athletes need to secure a Therapeutic Use Exemption (TUE) (WADA, 2024). As per WADA guidelines, inhaled beta-2 agonists like salbutamol, formoterol, and salmeterol are permitted in certain therapeutic dosages.

For example, inhaled salbutamol is allowed up to a maximum of 1,600 micrograms in a 24-hour span, with a limit of 600 micrograms in any eight-hour timeframe. Inhaled formoterol is similarly allowed up to 54 micrograms within 24 hours, and doses do not exceed 36 micrograms over 12 hours starting from any dose, whereas salmeterol can be administered at doses reaching 200 micrograms over 24 hours. Surpassing these thresholds without a TUE may result in an adverse analytical finding (AAF). A controlled pharmacokinetic study might be necessary to demonstrate therapeutic use when limits are surpassed. Inhaled corticosteroids (ICS), essential for asthma treatment, are allowed at regular therapeutic levels and do not need a TUE when used correctly (WADA, 2024). Leukotriene receptor antagonists and anticholinergic agents can be used as described in the GINA guidelines (GINA, 2024).

Usage of glucocorticoids in oral, rectal, or any injectable routes of administration is prohibited in-competition and will need a TUE. In severe asthma instances, biologic treatments such as omalizumab and mepolizumab are not explicitly listed as prohibited on the International Standard Prohibited List by WADA for 2025. The process for TUE applications requires thorough medical records, such as an extensive history of the issue, spirometry results, and proof of airway hyperresponsiveness verified by bronchial provocation tests if needed (WADA, 2024). Athletes are required to provide a statement from a licensed physician detailing the need for the prescribed medication. The TUE Committee evaluates applications to confirm adherence to WADA's anti-doping guidelines while focusing on athlete health (WADA, 2024). More information about Anti-Doping Regulations and TUEs are available online at www.wada-ama.org.

Gaps in Research

Despite substantial progress, research gaps persist. More longitudinal studies are needed to evaluate the long-term impact of preventative measures. Additionally, personalized strategies considering genetic and environmental variances remain underexplored. The lack of research focused on Alpine skiing highlights the need for this specific research to fill the gap in the literature and, consequently, to develop comprehensive management strategies for competitors in all winter disciplines.

4. CONCLUSION

Asthma and exercise-induced bronchoconstriction (EIB) are significant challenges for athletes participating in winter sports, particularly cross-country and Alpine skiing. This review underscores the heightened prevalence of these conditions among skiers, driven by a combination of environmental exposures, physiological demands, and training regimens unique to these disciplines. Cross-country skiing, characterized by sustained high-intensity aerobic exertion in cold and dry environments, presents well-documented risks of airway dehydration, inflammation, and bronchial hyperresponsiveness. Although research on Alpine skiing remains limited, similar environmental and physiological stressors suggest comparable risks for respiratory dysfunction.

Effective management of asthma and EIB in skiers necessitates a multifaceted approach, integrating both pharmacological and non-pharmacological strategies. Personalized pharmacological treatments, such as inhaled corticosteroids (ICS) and bronchodilators, remain the cornerstone of asthma care, while non-pharmacological measures, including pre-exercise warm-ups and heat-and-moisture-exchanging devices (HMEDs), offer additional support in mitigating symptoms. However, the variability in response to these interventions highlights the need for individualized approaches tailored to the athlete's specific needs and environmental contexts.

This review identifies research gaps, including the need for longitudinal studies assessing the long-term efficacy of preventive strategies and a more thorough investigation of the prevalence and management of asthma in Alpine skiing. Filling these research gaps will help improve our understanding of respiratory health in winter sports and set evidence-based guidelines to optimise athlete health and performance. Ultimately, asthma and EIB management require a holistic and individual approach that protects the respiratory health of the athletes while enabling them to achieve their full potential in winter sports.

Authors' Contribution

Jan Siemianowski: Conceptualization, writing- rough preparation, investigation
Aleksandra Stremel: Formal analysis, supervision
Weronika Kotnis: Visualization, supervision
Michalina Doligalska: Conceptualization, project administration
Sandra Prolejko: Methodology, data curation
Błażej Gajęcki: Conceptualization, methodology
Greta Steć: Resources, writing- rough preparation
Justyna Kopala: Conceptualization, writing- rough preparation
Agata Brzyska: Resources, data curation
Magdalena Pawlak: Writing - Review and editing, supervision
All authors have read and agreed to the published version of the manuscript.

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Informed consent

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Data and materials availability
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