

Impact of Pollution on Health

Author
Valérie Bougault[a]

[a]Université Côte d'Azur, UPR 6312 LAMHESS, EUR HEALTHY, Nice, France

Introduction

The practice of regular and consistent physical activity has long been recognised as an essential factor for good health and aging well [1]. Sportswomen and sportsmen are often considered in our society as a model of good health. For example, Olympic athletes and Tour de France cyclists have a longer life expectancy than the general population [2,3]. However, practicing a physical activity or a sport in unfavourable environmental conditions may not be without danger, even in apparently healthy people [4–6]. For example, many incidents and discomforts occurred during the 2019 athletics championships in Qatar, and isolated health concerns regularly occur during local sporting events, especially when the temperature is hot. During the 2021 Tokyo Olympics, medical teams were prepared and were able to take care of athletes whose core temperatures had sometimes risen to 42°C, potentially fatal for a non-trained person. Scientific research has accelerated in recent years on the effects of heat on the human body of elite athletes, the role and methods of acclimatization to avoid heat stroke (*https://pubmed.ncbi.nlm.nih.gov/?term=athletes+heat*). The place, dates and times of competitions may be affected by the weather in the future, as was already the case of the Tokyo marathon during the Olympic Games 2021 which was moved to the North of Japan to avoid the too intense heat.

Global warming, due to its obvious risks and effects on the health of the athletes, often masks the effects of atmospheric pollutants to the population, and yet it will be accompanied inexorably by a degradation of the quality of the air [7–10]. Air pollutants, with a few exceptions, are often odourless and colourless and unless they have an external indication (governmental association or individual sensor or World Health Organization, etc.) of their concentration in the atmosphere, few people know that they are exposed to them. However, they have a significant impact on health, causing premature deaths and an increase in emergency room admissions with each pollution episode and with years of exposure [11,12]. Megafires, for example, have been heralded as the future, with the accompanying considerable degradation of air quality, potentially deadly [13,14]. In 2019, Wildfires occurred in Australia during the Australian Open Tennis Tournament, and many players were unable to play due to coughs, nausea, and other various symptoms (*https://www.bbc.com/news/world-australia-50497492*). Some countries have dramatic concentrations of air pollutants, and sporting events continue to be organised, despite a lack of data on the future consequences on health (*https://edition.cnn.com/2019/10/18/asia/delhi-marathon-pollution-*

intl-hnk-scli/index.html). In 2019, the Iron man in Nice (France), for example, occurred during a heat wave accompanied by an ozone pollution alert. Without resources to know what to do, the organisers reduced the distances randomly without scientific rational to avoid a cancellation (https://france3-regions.francetvinfo.fr/provence-alpes-cote-d-azur/alpes-maritimes/nice/canicule-parcours-ironman-france-nice-2019-raccourcis-1692562.html). Only during the Olympic Games, since at least those of Los Angeles in 1984, are preventative measures taken to reduce local production of pollutants during the event [15], such as reduced traffic [16], but this is not the case for athletes in other events or during the year and we cannot act on the acute pollution linked to natural events like mega fires, or volcanoes. The population of sportsmen and women, who represent a model of health, is too little studied, but is nevertheless a privileged target, because (1) they represent the model of good health in our societies, (2) they have capacities of adaptation and acclimatization often out of the ordinary and sometimes absent or failing in sick or sedentary people, (3) if the practice of a sport in a polluted environment becomes deleterious on their health, this would have dramatic consequences for the future of humanity, which would have the choice between becoming ill while practicing intense sport in an overly polluted environment or not doing so and being exposed to all the chronic diseases linked to sedentary life and pollution. Thus, some current epidemiological data indicate that the health benefits of physical activity (active transport in general) remain greater than the harms of air pollution [17], for example in European societies for healthy subjects. However, in countries where pollution is significant, there are no further benefice of exercise (at a mean ventilation of 63 l/min corresponding to 65% of maximum oxygen uptake) after 15 min (tipping point) and the air pollution health risks surpassed the exercise benefits after 75 min (break-even point) [6]. It should be noted that these studies are far from taking into account the duration and the intensity of the efforts of the sportsmen/women, in particular of endurance, and that often concerns particulate matter (PM) only. Children may also be more at risk of air pollution exposure even at levels slightly below air quality standards [18] and in polluted cities, especially with high level of ambient ozone [19], the most active children have an increased risk of developing respiratory problems, such as asthma compared to less active ones [20].

Air pollution is a generic term, but the chemical compositions and types of pollutants are extremely varied, and it seems that the mechanisms of action of each are different. While some are irritants to the airways, others may be carcinogenic. Air pollutants may be gas (Ozone (O3), nitric oxide (NO), sulfur oxide (SOx), carbon monoxide (CO)) or particulate matter. They may be of primary source, from human or natural origin, or secondary, formed by a photochemical reaction, such as O3 formed through the reaction of sunlight, NO, especially dioxide (NO2) and volatile organic compounds [21]. Particulate matter is a very large category of molecules characterized by the size of the PM, their composition, mass, shape and electrical charge. Generally, they are characterized by their size, PM10 and PM2.5, being generally measured in the atmospheres of the cities worldwide, and with PM1 and ultra-fine particles (PM0.1) being the most studied in health studies. As the inhaled dose, whatever the pollutant, depends on its concentration, the ventilation of the subject, and the duration of exposure, people exercising are particularly exposed to the deleterious effect of pollutants. Indeed, sport and physical activity, through an increase in the person's breathing, may increase the risk of penetration of pollutants in the airways, lungs, blood, and organs [22,23]. The ventilation a rest is around 6 l/min, it may increase

to around 50 l/min in healthy people exercising at light to moderate intensity and 100 l/min in young physically active people at high intensities, but may be sustained for a few hours well above 100 l/min and more than 200 l/min over a few minutes in young elite endurance athletes. There is an insufficient number of studies that can allow us to conclude on the short- or long-term risks of exposure to different pollutants in athletes of different sports, the regulations to be adopted, to identify healthy people at risk, and also the management and prevention plans to be adopted (nutrition, medication…) [23–25]. The international sports federations have tried to regulate, for many years, the conduct of competitions in cold or hot temperatures, taking into account the WBGT [26–28] (*https://www.ccsam.ca/competitive-skiing/event-information/event-cancellation-policy-2/*) . In case of a health threat, they have the possibility to cancel or postpone competitions, and these policies are currently well applied. In case of high pollution level, there is no rule at all, and we don't know what to do.

Several scientific publications have very recently underlined the lack of studies on the effects of the different pollutants on the respiratory health of healthy people performing an exercise. Only ozone has been studied, especially by Californian teams in the 80s, and shows an obvious impact on pulmonary function and respiratory difficulties. In view of the Los Angeles Olympic Games in 1984, research was carried out, in particular because of the recurrent high ozone concentrations in this region [29,30]. Ozone is the pollutant that usually accompanies heat waves and is of particular concern for the future. Worryingly, it may be locally more difficult to reduce ozone concentrations than those of PM for example (by reducing traffic for example). After the COVID-19 lockdown period, PM and NO2 emissions (mainly related to reduced traffic), were drastically reduced in Europe and China [31]. On the other hand, ozone increased in the same cities studied [31]. In healthy non asthmatic non allergic adults, it may provoke severe falls in lung volumes, sometimes around 50% during light to moderate exercise, and even more in asthmatics [23–25,32]. As a consequence, rare studies showed that up to 40% of a group of healthy well-trained athletes may stop exercise when performed in the presence of ozone concentrations similar to episodes of pollution observed in Europe, due to a severe respiratory discomfort [32–34]. Some rare studies of concern suggest that regular inhaled corticosteroid treatments may have no effect on airway response to ozone [35–37], and may even worsen symptoms and fall in lung function when exposed to ozone in people with respiratory pathologies[38,39]. This is of particular concern because inhaled corticosteroid therapy is the preferred treatment for inflammation in many lung or airway diseases (asthma, chronic obstructive pulmonary disease), but also for athletes having exercise-induced bronchoconstriction ("exercise induced asthma") [40]. It is now well-known that endurance sport may favor the development of such diseases due to the high-level of ventilation but also inhalation of pollutants [41]. In a disturbing way too, only a few studies exist but report the complete inefficiency of inhaled Beta2-agonist (Salbutamol, albuterol) to reverse the fall in lung function due to ozone when exercising in elite non-asthmatic cyclists [42,43]. This medication is the rescue medication or taken as a preventive measure by many asthmatics, whether or not they are athletes, and particularly before exercise to avoid an attack of exercise-induced asthma. The mechanisms of the fall in lung function due to ozone and of asthma crisis may be different and it may explain why inhaled medication is less effective during ozone peaks and why asthmatics lose control of their disease, leading to emergency room visits and death for some.

LAMHESS's (Université Côte d'Azur, France) associate colleagues, who work for the World Athletics Medical Commission, have continuously measured pollution in athletics stadiums around the world since 2019 and aim to see the effects on the health and performance of athletes, but also to plan the schedules and dates of sports events accordingly. Our laboratory (LAMHESS) is also represented regularly in international working groups on sport, health and pollution, including the International Olympic Committee (IOC) medical commission. LAMHESS aspires to bring together researchers from around the world working on pollution, health and performance to accelerate the production of knowledge in regular athletes, elite or not. This network is nascent but will allow the standardization of studies between countries because the multidisciplinary nature of studies requires toxicologists, atmospheric chemists, epidemiologists, sports science specialists, physiologists, specialized doctors, nutritionists, international sports federations, etc. Our studies will relate on the one hand to field measurements, with measurement of the pollutants and physiological variables in situations of exercise by practitioners, and on the other hand will relate to exposure in inhalation chambers to better understand the mechanisms of each pollutant. We will look at a wide range of parameters such as the mechanisms of action of various pollutants, including various types (gas, particulate, etc.), and composition, why some subjects are sensitive and others not, what is the recommendation threshold for air pollutants according to their properties for postponing or cancelling a mass or elite sporting event, what are the management and prevention plans, etc. The risk of not accelerating the pace of these studies is to find ourselves without a solution to save people sensitive to pollutants (the current medication being insufficient for some pollutants) and to see an increase in the number of deaths or respiratory or other diseases among athletes during events, training or in recreation courses. For now, when an acute air pollution episode is announced in Europe (in general level 2 or 3), sensitive people (adults and children) with asthma or chronic disorders are currently told not to do physical activity in order to avoid emergencies and death. With the air pollution accompanying global warming, it is likely to affect more and more people and finally what will we do? Force everyone to stop doing sports, knowing the harmful impact of physical inactivity ?

References

1. *Physical activity. https://www.who.int/news-room/fact-sheets/detail/physical-activity (accessed 12 Sep 2022).*
2. *Antero-Jacquemin J, Rey G, Marc A, et al. Mortality in female and male French Olympians: a 1948-2013 cohort study. Am J Sports Med 2015;43:1505–12. doi:10.1177/0363546515574691*
3. *Marijon E, Tafflet M, Antero-Jacquemin J, et al. Mortality of French participants in the Tour de France (1947-2012). Eur Heart J 2013;34:3145–50. doi:10.1093/eurheartj/eht347*
4. *Coleman CJ, Yeager RA, Pond ZA, et al. Mortality risk associated with greenness, air pollution, and physical activity in a representative U.S. cohort. Sci Total Environ 2022;824:153848. doi:10.1016/j.scitotenv.2022.153848*
5. *Münzel T, Hahad O, Daiber A. Running in polluted air is a two-edged sword - physical exercise in low air pollution areas is cardioprotective but detrimental for the heart in high air pollution areas. Eur Heart J 2021;42:2498–500. doi:10.1093/eurheartj/ehab227*

6. *Pasqua LA, Damasceno MV, Cruz R, et al. Exercising in Air Pollution: The Cleanest versus Dirtiest Cities Challenge. Int J Environ Res Public Health 2018;15. doi:10.3390/ijerph15071502*
7. *Orru H, Ebi KL, Forsberg B. The Interplay of Climate Change and Air Pollution on Health. Curr Environ Health Rep 2017;4:504–13. doi:10.1007/s40572-017-0168-6*
8. *Liang D, Lee W-C, Liao J, et al. Estimating climate change-related impacts on outdoor air pollution infiltration. Environ Res 2021;196:110923. doi:10.1016/j.envres.2021.110923*
9. *De Sario M, Katsouyanni K, Michelozzi P. Climate change, extreme weather events, air pollution and respiratory health in Europe. Eur Respir J 2013;42:826–43. doi:10.1183/09031936.00074712*
10. *Doherty RM, Heal MR, O'Connor FM. Climate change impacts on human health over Europe through its effect on air quality. Environ Health 2017;16:118. doi:10.1186/s12940-017-0325-2*
11. *Kampa M, Castanas E. Human health effects of air pollution. Environ Pollut 2008;151:362–7. doi:10.1016/j.envpol.2007.06.012*
12. *Yang D, Yang X, Deng F, et al. Ambient Air Pollution and Biomarkers of Health Effect. Adv Exp Med Biol 2017;1017:59–102. doi:10.1007/978-981-10-5657-4_4*
13. *Canadell JG, Meyer CPM, Cook GD, et al. Multi-decadal increase of forest burned area in Australia is linked to climate change. Nat Commun 2021;12:6921. doi:10.1038/s41467-021-27225-4*
14. *Graham AM, Pringle KJ, Pope RJ, et al. Impact of the 2019/2020 Australian Megafires on Air Quality and Health. Geohealth 2021;5:e2021GH000454. doi:10.1029/2021GH000454*
15. *Fitch K. Air pollution, athletic health and performance at the Olympic Games. J Sports Med Phys Fitness 2016;56:922–32.*
16. *Schleicher N, Norra S, Dietze V, et al. The effect of mitigation measures on size distributed mass concentrations of atmospheric particles and black carbon concentrations during the Olympic Summer Games 2008 in Beijing. Sci Total Environ 2011;412–413:185–93. doi:10.1016/j.scitotenv.2011.09.084*
17. *Tainio M, de Nazelle AJ, Götschi T, et al. Can air pollution negate the health benefits of cycling and walking? Prev Med 2016;87:233–6. doi:10.1016/j.ypmed.2016.02.002*
18. *Nickmilder M, de Burbure C, Carbonnelle S, et al. Increase of exhaled nitric oxide in children exposed to low levels of ambient ozone. J Toxicol Environ Health A 2007;70:270–4. doi:10.1080/15287390600884834*
19. *Romieu I, Meneses F, Sienra-Monge JJ, et al. Effects of urban air pollutants on emergency visits for childhood asthma in Mexico City. Am J Epidemiol 1995;141:546–53. doi:10.1093/oxfordjournals.aje.a117470*
20. *McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. Lancet 2002;359:386–91. doi:10.1016/S0140-6736(02)07597-9*
21. *World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization 2021. https://apps.who.int/iris/handle/10665/345329 (accessed 18 Jan 2022).*

22. *Oravisjärvi K, Pietikäinen M, Ruuskanen J, et al. Effects of physical activity on the deposition of traffic-related particles into the human lungs in silico. Sci Total Environ 2011;409:4511–8. doi:10.1016/j.scitotenv.2011.07.020*
23. *Rundell KW, Smoliga JM, Bougault V. Exercise-Induced Bronchoconstriction and the Air We Breathe. Immunol Allergy Clin North Am 2018;38:183–204. doi:10.1016/j.iac.2018.01.009*
24. *Hung A, Nelson H, Koehle MS. The Acute Effects of Exercising in Air Pollution: A Systematic Review of Randomized Controlled Trials. Sports Med 2022;52:139–64. doi:10.1007/s40279-021-01544-4*
25. *Bougault V, Adami PE, Sewry N, et al. Environmental factors associated with non-infective acute respiratory illness in athletes: A systematic review by a subgroup of the IOC consensus group on "acute respiratory illness in the athlete." J Sci Med Sport 2022;25:466–73. doi:10.1016/j.jsams.2022.03.003*
26. *Nielsen B. Olympics in Atlanta: a fight against physics. Med Sci Sports Exerc 1996;28:665–8. doi:10.1097/00005768-199606000-00004*
27. *Grundstein AJ, Scarneo-Miller SE, Adams WM, et al. From theory to practice: operationalizing a climate vulnerability for sport organizations framework for heat hazards among US High schools. J Sci Med Sport 2021;24:718–22. doi:10.1016/j.jsams.2020.11.009*
28. *Chalmers S, Jay O. Australian community sport extreme heat policies: Limitations and opportunities for improvement. Journal of Science and Medicine in Sport 2018;21:544–8. doi:10.1016/j.jsams.2018.01.003*
29. *Aris R, Christian D, Sheppard D, et al. The effects of sequential exposure to acidic fog and ozone on pulmonary function in exercising subjects. Am Rev Respir Dis 1991;143:85–91. doi:10.1164/ajrccm/143.1.85*
30. *Samet JM. Ozone and Respiratory Health. The Story Continues. Am J Respir Crit Care Med 2015;192:272–3. doi:10.1164/rccm.201505-1021ED*
31. *Sicard P, De Marco A, Agathokleous E, et al. Amplified ozone pollution in cities during the COVID-19 lockdown. Sci Total Environ 2020;735:139542. doi:10.1016/j.scitotenv.2020.139542*
32. *Adams WC. Effects of ozone exposure at ambient air pollution episode levels on exercise performance. Sports Med 1987;4:395–424. doi:10.2165/00007256-198704060-00002*
33. *Adams WC, Schelegle ES. Ozone and high ventilation effects on pulmonary function and endurance performance. J Appl Physiol Respir Environ Exerc Physiol 1983;55:805–12. doi:10.1152/jappl.1983.55.3.805*
34. *Gong H, Bradley PW, Simmons MS, et al. Impaired exercise performance and pulmonary function in elite cyclists during low-level ozone exposure in a hot environment. Am Rev Respir Dis 1986;134:726–33. doi:10.1164/arrd.1986.134.4.726*
35. *Nightingale JA, Rogers DF, Chung KF, et al. No effect of inhaled budesonide on the response to inhaled ozone in normal subjects. Am J Respir Crit Care Med 2000;161:479–86. doi:10.1164/ajrccm.161.2.9905031*
36. *Vagaggini B, Taccola M, Conti I, et al. Budesonide reduces neutrophilic but not functional airway response to ozone in mild asthmatics. Am J Respir Crit Care Med 2001;164:2172–6. doi:10.1164/ajrccm.164.12.2009090*

37. *Vagaggini B, Bartoli MLE, Cianchetti S, et al. Increase in markers of airway inflammation after ozone exposure can be observed also in stable treated asthmatics with minimal functional response to ozone. Respir Res 2010;11:5. doi:10.1186/1465-9921-11-5*
38. *Ierodiakonou D, Zanobetti A, Coull BA, et al. Ambient air pollution, lung function, and airway responsiveness in asthmatic children. J Allergy Clin Immunol 2016;137:390–9. doi:10.1016/j.jaci.2015.05.028*
39. *Rider CF, Carlsten C. Air pollution and resistance to inhaled glucocorticoids: Evidence, mechanisms and gaps to fill. Pharmacol Ther 2019;194:1–21. doi:10.1016/j.pharmthera.2018.08.005*
40. *Schwellnus M, Adami PE, Bougault V, et al. International Olympic Committee (IOC) consensus statement on acute respiratory illness in athletes part 2: non-infective acute respiratory illness. Br J Sports Med 2022;:bjsports-2022-105567. doi:10.1136/bjsports-2022-105567*
41. *Price OJ, Sewry N, Schwellnus M, et al. Prevalence of lower airway dysfunction in athletes: a systematic review and meta-analysis by a subgroup of the IOC consensus group on "acute respiratory illness in the athlete." Br J Sports Med 2021;:bjsports-2021-104601. doi:10.1136/bjsports-2021-104601*
42. *McKenzie DC, Stirling DR, Fadl S, et al. The effects of salbutamol on pulmonary function in cyclists exposed to ozone: a pilot study. Can J Sport Sci 1987;12:46–8.*
43. *Gong H, Bedi JF, Horvath SM. Inhaled albuterol does not protect against ozone toxicity in nonasthmatic athletes. Arch Environ Health 1988;43:46–53. doi:10.1080/00039896.1988.9934373*