MOUNTADAPT

ELEVATING HEALTHCARE CLIMATE ADAPTATION

Physical Activity Recommendations For Safe and Adaptive Cycling Practices

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1. Introduction

Regular physical activity is widely recognized as a fundamental determinant of health and well-being, playing a key role in the prevention of non-communicable diseases and the improvement of overall quality of life [1], [2]. Active mobility, particularly cycling, contributes not only to increased physical activity but also to more sustainable transportation systems and reduced greenhouse gas emissions associated with urban transport [3] (Woodcock et al., 2010). However, environmental conditions such as air pollution, heat exposure, and solar radiation can affect both the safety and the health benefits of outdoor activities [4] (Tainio et al., 2015).

The PAR project aims to develop evidence-based guidance to help individuals adapt their cycling practices to environmental conditions. Cycling, while beneficial for health, exposes individuals to various environmental stressors. Increased ventilation during physical effort may lead to greater inhalation of pollutants such as particulate matter and nitrogen dioxide [4],[5] (Tainio et al., 2015; Burnett et al., 2017). In parallel, climate change is intensifying heat waves and increasing the frequency of extreme temperature events, amplifying thermal stress during outdoor activity [6],[7] (IPCC, 2023; Jay et al., 2012). Together, these factors can influence cardiovascular strain, hydration status, and overall physiological responses.

This document provides practical, evidence-based recommendations to support safer and healthier cycling practices. It aims to maximize the benefits of active mobility while minimizing environmental health risks, enabling individuals to maintain regular physical activity under varying conditions. Importantly, it addresses potentially contradictory public health messages: while physical activity is strongly encouraged for its health benefits, outdoor activity is sometimes discouraged during periods of high pollution. This document therefore offers balanced guidance to help individuals remain active while limiting environmental risks.

The document targets everyday cyclists rather than competitive athletes, including urban cyclists, recreational cyclists, e-bike users, commuter cyclists, and occasional cyclists. Particular attention is given to vulnerable populations such as older adults and individuals with pre-existing health conditions, for whom adaptation to environmental conditions is especially important.

The recommendations presented here are based on data collected within our research laboratory, Translational Innovation in Medicine and Complexity, as well as on existing scientific literature on environmental health, physical activity, and climate adaptation [2],[8] (World Health Organization, 2020; Lee et al., 2020).

2. Scientific Background

Outdoor physical activity is influenced by a range of environmental factors. While physical activity offers numerous health benefits, certain environmental conditions can increase health risks if not properly managed [2],[9] (World Health Organization, 2020; Lee et al., 2012). Environmental determinants such as air pollution, temperature, and solar radiation can modify both the physiological responses to exercise and the overall health impact of outdoor activities.

Cycling is particularly relevant in this context because it combines physical effort with exposure to environmental stressors. During cycling, ventilation rates increase substantially, which may lead to higher inhalation of airborne pollutants compared to sedentary activities or low-intensity behaviors [4],[10](Tainio et al., 2015; Zuurbier et al., 2010). As a result, cyclists may experience higher exposure to particulate matter and traffic-related air pollutants, especially when cycling in urban environments with high traffic density.

Several environmental factors are particularly important for cyclists, including ambient air pollution, temperature and heat stress, solar radiation, and the intensity of physical effort. These factors interact to influence both physiological responses and environmental exposure during cycling [7], [11](Giles & Koehle, 2014; Jay et al., 2012).

The PAR project collected field data using instrumented bicycles to better understand these interactions between environmental conditions and cycling practices. Instrumented bicycles have been increasingly used in environmental exposure research to assess real-world conditions experienced by cyclists [12] (Int Panis et al., 2010).

These bicycles were equipped with sensors capable of measuring environmental and physiological variables during cycling activities. The collected data include measurements of air pollution levels, cycling speed and effort, and physiological responses of participants.

Mobile monitoring approaches such as these provide valuable insights into real-world exposure patterns during active mobility and allow researchers to better characterize the environmental determinants of cycling-related health outcomes [12],[13] (Kaur et al., 2007; Int Panis et al., 2010).

These data contribute to a better understanding of how environmental conditions influence cycling practices and health outcomes. Such knowledge is essential for developing adaptive recommendations that help cyclists balance the health benefits of physical activity with potential environmental risks [4] (Tainio et al., 2015).

The development of the recommendations followed a structured methodological approach. The recommendations are based on a combination of a review of the scientific literature on physical activity, environmental exposure, and health outcomes, analysis of field data collected within the PAR project, and expert interpretation of the available evidence.

The strength of each recommendation was graded (A, B, C) according to the quality of the scientific evidence and the consistency of the findings. For situations where the available scientific evidence did not allow a consensus to be established, it would be relevant to reassess and reformulate the recommendations using a Delphi-type method in order to reach expert consensus.

This approach ensures that the proposed recommendations are transparent, evidence-based, and applicable to real-world conditions.

3. Target Population

The recommendations provided in this document are designed for a wide range of cyclists engaged in active mobility or recreational cycling.

Target groups include:

- Urban cyclists
- Recreational cyclists
- E-bike users
- Commuter cyclists
- Occasional cyclists

Special consideration should be given to individuals who may be more sensitive to environmental stressors, including:

- Older adults
- Individuals with respiratory conditions
- Individuals with cardiovascular diseases
- Children and adolescents
- Individuals with low physical fitness

For these groups, careful adaptation of cycling practices to environmental conditions is particularly important.

4. Environmental Factors Affecting Cycling

4.1 Air Pollution

Air pollution is a major environmental health concern in urban environments. Key pollutants that may affect cyclists include:

- PM2.5 (fine particulate matter)
- PM10 (coarse particulate matter)
- Nitrogen dioxide (NO_2)
- Ozone (O_3)

all of which have been associated with adverse health outcomes [5], [14](World Health Organization, 2021; Burnett et al., 2017).

During physical activity, increased breathing rates can lead to higher inhalation of pollutants. Long-term exposure to air pollution has been associated with respiratory diseases, cardiovascular diseases, and reduced lung function. [5],[14]

Cyclists may experience particularly high exposure levels when cycling near busy roads or during peak traffic hours, as demonstrated in exposure studies comparing different transport modes [10],[12] However, research also shows that the health benefits of regular physical activity often outweigh the risks associated with pollution exposure, provided that exposure is managed appropriately [4].

4.2 Heat and Thermal Stress

Climate change is increasing the frequency and intensity of heat waves in many regions [6]. High temperatures can significantly affect physical performance and increase physiological stress during exercise [7].

Heat exposure during cycling can lead to dehydration, increased cardiovascular strain, reduced performance, heat exhaustion, and heat stroke [7],[15] (Casa et al., 2015; Jay et al., 2012).

Thermal stress is influenced by several factors, including ambient temperature, solar radiation, humidity, wind speed, and exercise intensity, all of which contribute to the body's heat balance during physical activity [7],[16] (Jay et al., 2012; Cheung et al., 2016).

Adapting cycling practices to thermal conditions is essential to prevent heat-related health risks.

4.3 Physical Effort and Individual Capacity

The intensity of physical effort strongly influences physiological responses during cycling, including cardiovascular strain, ventilation rate, and thermoregulation [17] (ACSM, 2021).

Individuals with different fitness levels may experience the same environmental conditions differently, as physiological responses to exercise are influenced by aerobic capacity, training status, and health condition [18] (Bassett & Howley, 2000).

Factors influencing effort tolerance include age, physical fitness, health status, cycling experience, and the use of electric assistance, which can significantly reduce physiological load during cycling [19] (Castro et al., 2019).

Adjusting effort intensity according to both environmental conditions and personal capacity is essential for safe cycling and for minimizing health risks associated with environmental stressors [17] (ACSM, 2021).

5. Physical Activity Recommendations

This section provides practical recommendations for adapting cycling practices to environmental conditions.

5.1 Adaptation of Cycling Practice in Air Pollution Situations: Public Health Message

5.1.1 Maintain cycling while adapting exposure conditions to limit pollution-related risks (Grade A)

Maintaining cycling is justified by the overall benefits of physical activity, which generally outweigh the risks associated with exposure to pollutants in most situations. However, this practice should be adapted to reduce exposure.

References :

- 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.
- Mueller N, Rojas-Rueda D, Cole-Hunter T, et al. Health impact assessment of active transportation: a systematic review. *Prev Med.* 2015;76:103–14.
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- Ramel-Delobel M, Heydari S, de Nazelle A, Praud D, Salizzoni P, Fervers B, et al. Air pollution exposure in active versus passive travel modes across five continents: a Bayesian random-effects meta-analysis. *Environ Res.* 2024;261:119666.
- Bo et al. (2021) — Effects of Air Pollution and Habitual Exercise on the Risk of Death (CMAJ, DOI: 10.1503/cmaj.202729)

5.1.1.1 Maintain regular active travel to increase cardiovascular resilience (Grade A)

Regular cycling significantly reduces the risk of cardiovascular diseases and mortality. It is recommended to maintain this activity in daily travel, gradually increasing the intensity and frequency of trips to optimize health benefits while respecting individual capacity.

Reference:

- Garcia L, Pearce M, Abbas A, Mok A, Strain T, Ali S, Crippa A, Dempsey PC, Golubic R, Kelly P, Laird Y, McNamara E, Moore S, de Sa TH, Smith AD, Wijndaele K, Woodcock J, Brage S. Non-occupational physical activity and risk of cardiovascular disease, cancer and mortality outcomes: a dose-response meta-analysis of large prospective studies. Br J Sports Med. 2023 Aug;57(15):979-989. doi: 10.1136/bjsports-2022-105669. Epub 2023 Feb 28. PMID: 36854652; PMCID: PMC10423495.

5.1.1.2 Balance physical activity and pollution exposure to preserve health benefits (Grade A)

It is recommended to maintain regular cycling, including during periods of pollution, while considering its physiological effects. Air pollution induces oxidative stress involved in cardiovascular damage, whereas physical activity—despite transient increases in reactive oxygen species (ROS)—enhances antioxidant defenses in the long term. Therefore, cycling practice should be adapted (moderate intensity, favorable conditions) to limit exposure while preserving health benefits.

References:

- Bo YC, Yu T, Guo C, Lin CC, Yang HT, Chang LYY, et al. Cardiovascular mortality, habitual exercise, and particulate matter 2.5 exposure: a longitudinal cohort study. Am J Prev Med. 2023;64(2):250–258.
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- Jin X, et al. Exercise-mediated protection against air pollution-induced immune damage. Biology (Basel). 2024;13(4):247. doi:10.3390/biology13040247
- Wang Y, et al. Physical exercise in the context of air pollution: an emerging research topic. Front Physiol. 2022;13:784705. doi:10.3389/fphys.2022.784705.

5.1.1.3 Develop regular cycling to prepare the body for hot conditions (Grade A)

Heat acclimatization relies on progressive and repeated exposure to exercise in hot conditions, improving physiological tolerance to effort. It is associated with adaptations such as reduced heart rate and core temperature, increased sweating, and improved cardiovascular stability. These adaptations help reduce thermal stress, maintain performance, and limit heat-related risks during physical activity.

Reference :

- Rahimi GRM, Albanaqi AL, Van der Touw T, Smart NA. Physiological responses to heat acclimation: a systematic review and meta-analysis of randomized controlled trials. J Sports Sci Med. 2019;18(2):316.
- Racinais S, Alonso JM, Coutts AJ, Flouris AD, Girard O, González-Alonso J, Hausswirth C, Jay O, Lee JK, Mitchell N, Nassis GP, Nybo L, Pluim BM, Roelands B, Sawka MN, Wingo J, Périard JD. Consensus recommendations on training and competing in the heat. Sports Med. 2015;45(7):925–38. doi:10.1007/s40279-015-0343-6.

5.2. Adaptation of Route Choice and Exposure Environment in Air Pollution Conditions

5.2.1 Prefer routes away from major emission sources (Grade A)

Proximity to road traffic is a major determinant of exposure to air pollutants. Choosing routes that avoid high-traffic roads, main roads, tunnels, or highly emissive areas can significantly reduce inhaled concentrations, even if these routes are slightly longer.

References :

- Ramel-Delobel M, Heydari S, de Nazelle A, Praud D, Salizzoni P, Fervers B, et al. Air pollution exposure in active versus passive travel modes across five continents: a Bayesian random-effects meta-analysis. *Environ Res.* 2024;261:119666.
- Bigazzi AY, Rouleau M. Can traffic management strategies improve urban air quality? A review of the evidence. *Environ Health.* 2017;16(1):1–13.
- Pant P, Harrison RM. Estimation of the contribution of road traffic emissions to particulate matter concentrations. Atmos Environ. 2013;77:78–97.
- Aix ML. Air pollution, mobility and health in the Grenoble area [thèse]. Grenoble: Université Grenoble Alpes; 2023

5.2.2 Use dedicated and separated cycling infrastructure (Grade B)

Using cycling infrastructure separated from road traffic increases distance from emission sources and helps limit exposure to pollutants. It also improves the quality of air inhaled by cyclists.

References :

- Ramel-Delobel M, Heydari S, de Nazelle A, Praud D, Salizzoni P, Fervers B, et al. Air pollution exposure in active versus passive travel modes across five continents: a Bayesian random-effects meta-analysis. *Environ Res.* 2024;261:119666.
- Kumar P, Patton AP, Durant JL, Frey HC. A review of factors impacting exposure to PM2.5, ultrafine particles and black carbon in urban microenvironments. *Atmos Environ.* 2018;187:301–16.

5.2.3 Avoid narrow and confined streets (“street canyons”) (Grade B)

Narrow streets bordered by tall buildings limit pollutant dispersion and promote accumulation. Using more open routes allows better air ventilation and reduces exposure.

References :

- Ozgen S, Ripamonti G, Signorini S, et al. Evaluation of street canyon air quality using CFD modelling. *Atmos Environ.* 2016;139:97–106.
- Betancourt RM, Galvis B, Balachandran S, et al. Exposure to fine particulate matter in urban environments: effect of street canyon morphology. *Environ Pollut.* 2017;220:1078–85.

5.2.4 Prefer routes in green areas (Grade B)

Green spaces (parks, greenways) generally have lower pollution levels. Including them in routes helps reduce exposure while improving comfort.

References :

- Nieuwenhuijsen MJ, Khreis H. Car free cities: Pathway to healthy urban living. *Lancet.* 2016;388(10062):2573–4.
- Ramel-Delobel M, Heydari S, de Nazelle A, Praud D, Salizzoni P, Fervers B, et al. Air pollution exposure in active versus passive travel modes across five continents: a Bayesian random-effects meta-analysis. *Environ Res.* 2024;261:119666

5.3. Adaptation of Timing and Practice Conditions

5.3.1 Avoid peak traffic hours (Grade A)

Periods of heavy traffic are associated with increased pollutant concentrations. Shifting travel times outside these periods helps reduce exposure.

References :

- de Nazelle A, Bode O, Orjuela JP. Comparison of air pollution exposures in active vs. passive travel modes in European cities. *Environ Health Perspect.* 2013;121(7):807–12.
- Dons E, Int Panis L, Van Poppel M, Theunis J, Wets G. Personal exposure to black carbon in transport microenvironments. *Atmos Environ.* 2012;55:392–8.

5.3.2 Adapt practice to weather conditions (Grade A)

Pollution episodes, meteorological conditions (temperature, wind, heatwaves), and specific situations such as winter influence pollutant dispersion and tolerance to effort. Adaptation may include reducing intensity or duration, adjusting schedules, choosing less exposed routes, increasing breaks and hydration. Postponing activity may be considered, especially for sensitive populations.

References :

- Aix ML. Air pollution, mobility and health in the Grenoble area [thèse]. Grenoble: Université Grenoble Alpes; 2023
- 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
- World Health Organization. WHO global air quality guidelines. Geneva: WHO; 2021
- Agence nationale de sécurité sanitaire (ANSES). Pollution de l'air et activité physique. Maisons-Alfort: ANSES; 2019
- Qiu Z, Song J, Xu X, et al. The influence of meteorological factors on air pollution. *Sci Total Environ.* 2019;651:1139–47

5.4. Adaptation of Behavior in Traffic

5.4.1 Avoid direct proximity to vehicle exhaust plumes (Grade B)

Vehicle exhaust plumes are a direct source of pollutant exposure. Maintaining sufficient lateral or longitudinal distance helps reduce exposure.

References :

- Ramos CA, Reis JF, Almeida T, et al. Estimating the inhaled dose of pollutants during commuting by bicycle. *Environ Int.* 2016;92–93:352–63.
- Ramel-Delobel M, Heydari S, de Nazelle A, Praud D, Salizzoni P, Fervers B, et al. Air pollution exposure in active versus passive travel modes across five continents: a Bayesian random-effects meta-analysis. *Environ Res.* 2024;261:119666.

5.4.2 Position yourself away from intersections and traffic lights (Grade B)

Intersections and traffic lights are associated with pollution peaks due to vehicle stopping and restarting. Staying slightly back reduces exposure to these high concentrations.

References :

- Goel A, Kumar P. Characterisation of nanoparticle emissions and exposure at traffic intersections. *Atmos Environ.* 2015;102:169–79.
- Dons E, Int Panis L, Van Poppel M, Theunis J, Wets G. Personal exposure to black carbon in transport microenvironments. *Atmos Environ.* 2012;55:392–8.

5.4.3 Maintain a steady and smooth pace by anticipating slowdowns (Grade C)

Adopting a stable speed and avoiding frequent stops reduces time spent in highly polluted areas, particularly at intersections, and helps lower overall exposure.

References :

- Dons E, Int Panis L, Van Poppel M, Theunis J, Wets G. Personal exposure to black carbon in transport microenvironments. *Atmos Environ.* 2012;55:392–8.
- Bigazzi, A. Y., & Figliozzi, M. A. (2014). Review of Urban Bicyclists' Intake and Uptake of Traffic-Related Air Pollution. Transport Reviews, 34(2), 221–245. https://doi-org.sid2nomade-2.grenet.fr/10.1080/01441647.2014.897772

5.5. Adaptation of Exercise Intensity

5.5.1 Adjust exercise intensity according to the environment (Grade A)

Exercise intensity directly influences ventilation and thus the amount of pollutants inhaled. In polluted environments, moderate intensity is recommended to limit total inhaled dose.

References :

- de Nazelle A, Bode O, Orjuela JP. Comparison of air pollution exposures in active vs. passive travel modes in European cities. *Environ Health Perspect.* 2013;121(7):807–12.
- Ramel-Delobel M, Heydari S, de Nazelle A, Praud D, Salizzoni P, Fervers B, et al. Air pollution exposure in active versus passive travel modes across five continents: a Bayesian random-effects meta-analysis. *Environ Res.* 2024;261:119666.
- Bigazzi AY, Figliozzi MA. Review of urban bicyclists' intake and uptake of traffic-related air pollution. Transp Rev (Oxf). 2014;34(2):221–245. doi:10.1080/01441647.2014.897772.

5.5.2 Avoid intense efforts in highly polluted areas (Grade A)

Intense efforts greatly increase breathing rate and pollutant penetration into the respiratory tract. Such efforts should therefore be reserved for less polluted environments.

References :

- 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.

5.6. Hydration and Nutrition

5.6.1 Maintain good hydration, especially in hot conditions (Grade C)

Staying properly hydrated before and during exercise helps maintain blood pressure, sweating rate, thermoregulation, and cardiovascular stability, thereby reducing heat-related risks and supporting physical performance.

References

- Racinais S, Alonso JM, Coutts AJ, Flouris AD, Girard O, González-Alonso J, Hausswirth C, Jay O, Lee JK, Mitchell N, Nassis GP, Nybo L, Pluim BM, Roelands B, Sawka MN, Wingo J, Périard JD. Consensus recommendations on training and competing in the heat. Sports Med. 2015;45(7):925–38. doi:10.1007/s40279-015-0343-6.

5.6.2 Maintain a balanced diet rich in antioxidants (Grade C)

A balanced diet rich in antioxidants helps reduce inflammation related to pollution. Oxidative stress is a key mechanism in pollution-related health effects. A comprehensive diet contributes to anti-inflammatory processes, epigenetic modulation, and gut microbiota support.

References :

- Tashakkor AY, Chow KS, Carlsten C. Modification by antioxidant supplementation of changes in human lung function associated with air pollutant exposure: a systematic review. BMC Public Health. 2011 Jul 5;11:532. doi: 10.1186/1471-2458-11-532.

- Barthelemy J, Sanchez K, Miller MR, Khreis H. New Opportunities to Mitigate the Burden of Disease Caused by Traffic Related Air Pollution: Antioxidant-Rich Diets and Supplements. Int J Environ Res Public Health. 2020 Jan 18;17(2):630. doi: 10.3390/ijerph17020630
- Rocha-Velasco, O.A.; Morales-Suárez-Varela, M.; Llopis-González, A. Dietary Flavonoids: Mitigating Air Pollution's Cardiovascular Risks. Nutrients 2024, 16, 2647. https://doi.org/10.3390/nu16162647

6. Implementation in Demonstration Sites

The recommendations developed within the MOUNTADAPT project will be implemented and evaluated in several demonstration sites.

Implementation activities include:

- Dissemination of recommendations to participants
- Communication through local mobility networks
- Integration with cycling promotion programs
- Awareness campaigns targeting active mobility users

Local stakeholders will play a key role in promoting the adoption of these recommendations.

7. Monitoring and Evaluation

To evaluate the effectiveness of the recommendations, the PAR project includes a monitoring process based on participant feedback.

Evaluation tools include:

- AQAP (Self-administered Physical Activity Questionnaire)
- Pre-implementation surveys assessing cycling practices
- Post-implementation surveys assessing behavioral changes

These surveys will help determine whether the recommendations influence cycling behavior and improve awareness of environmental risks.

The results will contribute to the continuous improvement of the guidelines.

8. Limitations

Although the recommendations are based on scientific evidence and field data, several limitations should be considered.

Environmental conditions vary widely across locations and seasons, and individual responses to environmental stressors may differ.

Future research may provide additional insights into the interactions between environmental exposure and physical activity.

9. Conclusion

Cycling offers significant benefits for both individual health and environmental sustainability. However, environmental conditions such as air pollution, heat, can influence the safety and comfort of cycling activities.

The recommendations developed within the MOUNTADAPT project aim to support cyclists in adapting their physical activity practices to changing environmental conditions. By adjusting effort levels, choosing appropriate routes and timing, and adopting protective measures, cyclists can maximize the benefits of active mobility while minimizing environmental health risks.

These recommendations contribute to broader strategies promoting climate adaptation, sustainable mobility, and public health.

10. bibliographie

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6. Intergovernmental Panel on Climate Change. Climate change 2023: Sixth assessment report. Geneva: IPCC; 2023.
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8. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, et al. Effect of physical inactivity on major non-communicable diseases worldwide. Lancet. 2012;380(9838):219–29.
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14. World Health Organization. WHO global air quality guidelines. Geneva: WHO; 2021.
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MOUNTADAPT is a Horizon Europe project aiming to boost the community-driven resilience of the health system in European mountain areas, mitigating the impact of climate change on public health. Leveraging the expertise of 27 partners, including healthcare facilities, public authorities, innovators, and researchers, MOUNTADAPT aims to develop solutions and strategies to enhance healthcare climate adaptation and safeguard the health and well-being of communities living in mountain regions

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