The Journal of Open Source Software

healthiar: An R package to quantify and monetize health impacts attributable to (environmental) exposure

Alberto Castro [1,2*], **Axel Luyten** [1,2*], **Arno Pauwels** [3], **Liliana Vázquez Fernández** [4], **Gianni Ardielli** [1,2], **Iracy Pimenta** [5], **Susanne Breitner** [6], **Carl Baravelli** [4], **Vanessa Gorasso** [3], **Maria Lepnurm** [7], **Andreia Novais** [5], **María José Rueda-López** [8], **Pham Minh Nhat** [4], **Ana Barbosa** [5], **João Vasco Santos** [5], **and Anette Kocbach Bølling** [4]

1 Swiss Tropical and Public Health Institute, Switzerland **2** University of Basel, Switzerland **3** Sciensano, Belgium **4** Norwegian Institute of Public Health, Norway **5** University of Porto, Portugal **6** LMU Munich, Germany **7** Tervise Arengu Instituut, Estonia **8** Centre Scientifique et Technique du Batiment, France * These authors contributed equally.

DOI: 10.21105/joss.10599

Software

- Review
- Repository
- Archive

Editor: Frederick Boehm

Reviewers:

- @welch16
- @MikeLydeamore
- @Ruslan-Kurmashev

Submitted: 20 February 2026
Published: 29 July 2026

Summary

Health impacts attributable to exposures, such as ambient air pollution or noise, can be quantified (and monetized). However, such assessments can be time-consuming in terms of programming and often lack transparency in methodology. The open-source R package `healthiar` contributes to solving these challenges by providing functions to quantify (and monetize) attributable health impacts. It offers multiple calculation pathways and options, including iteration across multiple geographical units and stratification by subgroups. Epidemiologists and public health professionals can benefit from using `healthiar` for health impact quantifications.

Statement of need

Environmental exposures, e.g., ambient air pollution, are major contributors to disease and mortality worldwide (GBD 2023 Disease and Injury and Risk Factor Collaborators, 2025). Epidemiologists and public health researchers or practitioners quantify the (negative or positive) health impacts that are attributable to (no) changes in exposure to inform policy making.

The general methodology for quantifying health impacts has been documented in the literature (Lehtomäki et al., 2025). However, studies of specific assessments are not always transparent or complete about the specific methods used and the assumptions made, hindering reproducibility and plausibility checks. Additionally, the calculation can become tedious and error-prone, also when programming, e.g., in R (R Core Team, 2023).

The open-source R package `healthiar` quantifies (and monetizes) health impacts attributable to exposure. `healthiar` contributes to the comparability and transparency of results by using established methodology approved by international experts and making it publicly available. The package is available on the Comprehensive R Archive Network (CRAN), with a development version accessible via a public GitHub repository. Online documentation is provided on the package website.

`healthiar` enables multiple calculation pathways and options. Health impacts can be quantified using a) relative or absolute risk, b) single or sex- and age-specific baseline health data, c)

fixed-shape (e.g. linear, log-linear…) or user-defined exposure-response functions, d) population-weighted mean or categorical exposure. Additionally, `healthiar` offers the option to specify disability weight, cutoff and confidence interval, stratify by socio-economic group, iterate assessments across geographical units, compare scenarios, summarize uncertainty using Monte Carlo simulation, monetize health impacts or consider social inequalities in exposures. While `healthiar` focuses on ambient air pollution and noise exposure, it can potentially be used for other environmental or non-environmental exposures (e.g., green spaces, chemicals or physical activity).

State of the field

Existing R packages and tools for quantifying health impacts do not fully meet the needs of `healthiar` due to fundamental differences in scope and design:

- The World Health Organization (WHO) tool AirQ+ (Amini et al., 2024) focuses on ambient air pollution, but is offline and not an R package, limiting integration with programming workflows. While it partly overlaps with `healthiar` (and was used to validate some `healthiar` results), it lacks applicability for other exposures.
- The R package `rhap` (Sampedro et al., 2025) targets household air pollution using predefined scenarios from the Global Change Analysis Model, lacking applicability for ambient exposures and custom scenarios offered by `healthiar`.
- The R package `ithimr` (Abbas et al., 2023), based on ITHIM (Integrated Transport and Health Impact Modelling tool), and the online WHO tool HEAT (Health-Economic Assessment Tool for walking and cycling) (Götschi et al., 2020) use walking and cycling data to quantify health impacts (from physical activity, air pollution, and traffic crashes). Instead, `healthiar` derives health impacts directly from environmental exposures, enabling broader applications beyond transportation. Additionally, HEAT (like AirQ+) lacks an R package counterpart, limiting integration in programming workflows.

Extending these R packages and tools was impractical because it would have required major architectural changes, distorting their original purpose and complicating usage. Thus, `healthiar` was developed as a standalone R package to provide flexibility, modularity, and programming integration.

Software design

The functions included in `healthiar` enable a modular workflow (Figure 1). Functions for additional analyses, such as modification of existing scenarios, scenario comparisons, or multi-exposure assessments, use `healthiar` outputs as input data. In other cases, for instance, for monetization and social inequalities, the health impact can be entered either using `healthiar` outputs or directly from user input. Furthermore, smaller helper functions covering preparatory steps or single calculation steps are available.

The Journal of Open Source Software

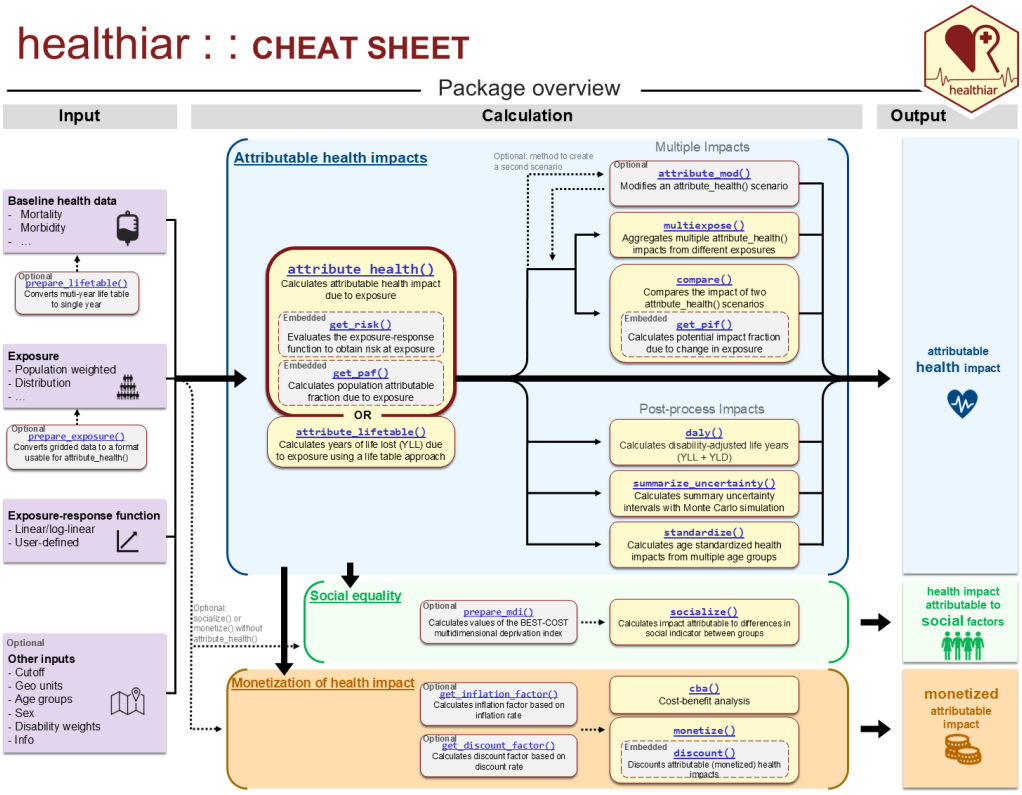

Figure 1: Overview of the `healthiar` functions (June 2026 snapshot; latest version on the `healthiar` website).

We refrained from providing default or background input data (e.g., exposure data, exposure-response functions, or baseline health data), as they a) would be incomplete given the many different exposures and health outcomes and b) would become quickly outdated, and updates would be time-consuming. Nevertheless, the R package includes example datasets that allow users to explore the functions.

Input data for `healthiar` functions are entered as separate arguments using vectors instead of within a data set/frame. This has two objectives: a) to facilitate simple assessment without creating a table, and b) to explicitly identify input data, avoiding mismatches.

The use of tidy data (Wickham, 2014) is supported and encouraged by `healthiar`. Thus, each row in the user data set corresponds to a unique stratification level (geographical unit, social group…), and each column to a function argument.

Methodological decisions have been taken together with experts from the European project BEST-COST (European Commission, 2025a). Currently, more than 350 internal tests check the correct behavior of `healthiar`, including the correctness of its results.

Research Impact Statement

Still as a non-public prototype, `healthiar` was firstly presented in 2024 at the scientific conferences European Public Health Conference (Luyten et al., 2024) and Urban Transitions (Castro, 2024). In September and October 2025, shortly after the public release on GitHub, two international online workshops introduced `healthiar` to around 110 participants. `healthiar` was published in CRAN on 11 November 2025 and, eight months later, had been downloaded over 2,000 times (Csárdi, 2026).

Within the European research project BEST-COST (where `healthiar` was developed), the package was adopted to quantify health impacts attributable to air pollution and noise in case studies (publications in preparation). External adoption of `healthiar` (beyond BEST-COST) further demonstrates its significance as a research tool:

- The European research project UBD-Policy (European Commission, 2025b) also adopted `healthiar` for case studies on air pollution, e.g. in Barcelona (Cussotto et al., 2025).
- Other researchers deployed `healthiar` to quantify health impacts attributable to noise in Europe (Engelmann et al., 2026) and Germany [walsch2026].

Additionally, new international research projects and existing exposure assessment tools have expressed interest in adopting `healthiar` to quantify health impacts.

AI usage disclosure

We only used artificial intelligence (AI) in a few cases for code optimization and debugging, rather than extensively. The whole code was internally reviewed by the two main developers.

Acknowledgements

`healthiar` has been developed under the framework of European project BEST-COST, which has been funded by the European Union's Horizon Europe program under Grant Agreement No.101095408. We also appreciate the feedback provided by all the test users.

Author contributions

AC and AL are the main authors of `healthiar` and this manuscript. AC, as creator, led code development and AL was code co-developer.

The rest of the JOSS manuscript authors are contributors to `healthiar` (methodological advice and systematic testing) and provided feedback on the manuscript. AP, CB and VG are also co-authors of helper functions.

References

Abbas, A., Schroeder, A., Gil, D., Tatah, L., Khreis, H., & Johnson, R. (2023). *Ithimr: Integrated transport and health impact model*. https://doi.org/10.5281/zenodo.14712046

Amini, H., Yousefian, F., Faridi, S., & others. (2024). Two decades of air pollution health risk assessment: Insights from the use of WHO's AirQ and AirQ+ tools. *Public Health Rev*, *45*, 1606969. https://doi.org/10.3389/phrs.2024.1606969

Castro, A. (2024). *Healthiar: R package to quantify and monetize the burden of disease attributable to air pollution and noise*.

Csárdi, G. (2026). *Cranlogs: Download logs from the 'RStudio' 'CRAN' mirror*. https://doi.org/10.32614/CRAN.package.cranlogs

Cussotto, F., Khomenko, S., Basagaña, X., & others. (2025). The barcelona low emission zone: A post-implementation health impact assessment from 2020 to 2022. *Eur J Public Health*, *35*(Supplement_4), ckaf161.1338. https://doi.org/10.1093/eurpub/ckaf161.1338

Engelmann, N., Vienneau, D., Jiang, X., & Röösli, M. (2026). Transportation noise in relation to depression and dementia: A burden of disease study for europe. *Environmental Research*. https://doi.org/10.1016/j.envres.2026.125005

European Commission. (2025a). *Burden of disease based methods for estimating the socio-economic cost of environmental stressors*. CORDIS. https://doi.org/10.3030/101095408

European Commission. (2025b). *The urban burden of disease estimation for policy making (project 101094639)*. CORDIS. https://doi.org/10.3030/101094639

GBD 2023 Disease and Injury and Risk Factor Collaborators. (2025). Burden of 375 diseases and injuries, risk-attributable burden of 88 risk factors, and healthy life expectancy in 204 countries and territories, including 660 subnational locations, 1990–2023: A systematic analysis for the global burden of disease study 2023. *The Lancet*, *406*(10513), 1873–1922. https://doi.org/10.1016/S0140-6736(25)01637-X

Götschi, T., Kahlmeier, S., Castro, A., & others. (2020). Integrated impact assessment of active travel: Expanding the scope of the health economic assessment tool (HEAT) for walking and cycling. *Int J Environ Res Public Health*, *17*(20), 7361. https://doi.org/10.3390/ijerph17207361

Lehtomäki, H., Aasvang, G. M., Sulo, G., & others. (2025). Burden of disease attributable to PM2.5 at low exposure levels: Impact of methodological choices. *Environ Health*, *25*(1), 4. https://doi.org/10.1186/s12940-025-01250-y

Luyten, A., Breitner, S., Barbosa, A., Kocbach Bølling, A., Lepnurm, M., Pauwels, A., Rueda-López, M. J., & Castro, A. (2024). Novel R package to quantify and monetize burden of disease attributable to air pollution and noise. *European Journal of Public Health*, *34*(Supplement 3), ckae144.1559. https://doi.org/10.1093/eurpub/ckae144.1559

R Core Team. (2023). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://doi.org/10.32614/R.manuals

Sampedro, J., Rodés-Bachs, C., Smith, S., Tomas, M., Urrutia, I., & Van de Ven, D. J. (2025). Rhap: A tool to analyze health impacts attributable to household air pollution. *Journal of Open Source Software*, *10*(114), 8091. https://doi.org/10.21105/joss.08091

Wickham, H. (2014). Tidy data. *Journal of Statistical Software*, *59*(10). https://doi.org/10.18637/jss.v059.i10