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# Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project), study protocol.

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**Title**

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# Abstract

**Introduction:** The European Environment Agency estimates that 75% of the European population lives in cities. Despite the many advantages of city life, the risks and challenges to health arising from urbanization need to be addressed to tackle the growing burden of disease and health inequalities in the cities. This study, *Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain* (DAS-EP project), aims to investigate the complex association between the urban environmental exposures (UrbEE) and health.

**Methods and analysis:** DAS-EP is a Spanish multiregional cross-sectional project that combines Population Health Surveys (PHS) and Geographical Information System (GIS) allowing to collect rich individual level data from 17,000 adult citizens participating in the PHS conducted in the autonomous communities of the Basque Country, Andalusia, and the Valencian Community, and the city of Barcelona in years 2021-2023. This study focuses on the population living in cities or metropolitan areas with more than 100,000 inhabitants. UrbEE are described by objective estimates at participants' home addresses by GIS and subjective indicators present in PHS. The health outcomes included in the PHS and selected for this study are self-perceived health (general and mental), prevalence of chronic mental disorders, health-related quality of life, consumption of medication for common mental disorders, and sleep quality. We aim to further understand the direct and indirect effect between UrbEE and health as well as to estimate the impact at the population level taking respondents' socio-demographic and socio-economic characteristics, and lifestyle into account.

**Ethics and dissemination:**

The study was approved by the regional Research Ethics Committee of the Basque Country (CEIm-E; PI2022138), Andalusia (CEIM GRANADA; 2078-N-22), Barcelona (CEIC-PSMar; 2022/10667), and Valencian Community (CEIC DGSP/CSISP; 20221125/04). The results will be

communicated to the general population, health professionals and institutions through conferences, reports, and scientific articles.

**Strengths and limitations of this study**

- The linkage of four independent population health surveys (PHS) will provide a large volume of information and a large sample size of the study.
- The method is novel for the inclusion of objective & subjective UrbEE as well as the combination of PHS from different study areas and GIS estimates.
- Despite the cross-sectional nature of the study, the results will ultimately help identify urban indicators, increasing the capacity to detect and intervene in community health, improving the routine surveillance and monitoring of the cities' health information systems.

## 1. Introduction

According to World Health Organization, modifiable environmental factors are responsible for 23% and 22% of global mortality and morbidity respectively (1). As reported by the European Environment Agency, in 2021, 75% of the European population lived in urban areas including cities but also smaller urban settlements and suburban areas, developed for residential, industrial or recreational purposes (2). The conditions and quality of the local urban environment influences people's health by determining their level of urban environmental exposures (UrbEE) (3,4). The UrbEE include the totality of the surrounding natural (e.g.., green and blue spaces), built (e.g., walkability, urbanisation level, traffic,) and social (e.g.., security, public services) environments within which people live, move, and interact, as well as environmental stressors like air pollution and noise. Increasing evidence shows that UrbEE such as lack of greenness, air pollution and noise can impact population's mental and physical health and quality of life (5–9). The health implications of the environmental exposures become even more important in the contemporary demographic setting, given that they are perhaps starker in urban areas (10–14). Moreover, in many regions, environmental exposures are not evenly distributed across socioeconomic status and socio-economically vulnerable populations are also affected by poorer environmental quality (10,11). In fact, this double jeopardy may make individuals from poorer socioeconomic backgrounds more significantly affected by environmental exposures (3,15).

The UrbEE, including environmental stressors, traffic-infrastructure, natural spaces, and the built environment, have all been studied in relation health. Widespread evidence in the literature shows that air pollution, noise and lack of green space are related to a range of chronic physical diseases (16–21). Recently, it has been suggested that air pollution is associated with a range of mental disorders and poorer sleep quality (16,22–25). Other recent studies observed that environmental noise has negative effects on mental health, well-being, and sleep quality (25–28), while evidence on its impact on prescriptions and consumption of medication for common mental disorders has yet to be scientifically confirmed (29). Otherwise, current scientific evidence indicates that residential greenness is positively associated with mental health and quality of life (28,30,31), and lower consumption of anxiolytics, antidepressants, and sleeping pills (25,32). Blue spaces (aquatic environments such as rivers, lake, and the coast) are expected to have similar health effects to those described here, however, evidence on this subject is limited (32,33). As for the built environment, walkability or accessibility have also been related to reduced obesity and better cardiovascular health (34), improved mental health (35,36) and well-being (37). To date, the main mechanisms proposed to explain these associations are the mitigation of exposure to environmental pollutants, the promotion of physical activity, and the strengthening of social cohesion (30,31,34,38–40). However, these mechanisms are probably synergistic (41). The correlations between several UrbEE and their relationship with behavioural exposures like physical activity, and social cohesion makes the assessment of these associations and pathways highly challenging (42–46). Hence, noise and air pollution could act both as exposures, mediators, or potential confounders. Overall, results of previous studies are quite mixed and the associations as well as the underlying mechanisms between UrbEE and mental health outcomes need more robust scientific evidence (8,45,47–49).

This knowledge gap can be partly explained by the heterogeneity and limitations of exposure and outcome metrics used in the studies (20,49,50). Moreover, there is a lack of studies addressing the impact of UrbEE on health integrating objective and perceived accounts of such exposures (51). Therefore, it is evident that more research is needed to determine which UrbEE are associated with health, the potential mechanisms involved, and the role of social aspects in those associations. Beyond this, researchers are increasingly called to provide information that can guide the selection of the best and most feasible interventions to improve public health in cities. In this respect, experts in the field have claimed the vital role that the health impact assessment tool plays in integrating the evidence in the decision-making process (52,53).

*Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain* (DAS-EP project) is a 3-year project (2023-2025) aimed at further investigating the associations and underlying mechanisms, including direct and indirect effects, between UrbEE and health with a health equity perspective. Five main objectives have been established for this project:

1. To estimate, describe and compare the objective and subjective levels of UrbEE in the study areas.
2. To describe urban environmental inequalities according to socio-demographic and socio-economic variables as well as the study area.
3. To estimate the association between UrbEE and self-perceived general and mental health, health-related quality of life, chronic mental disorders, consumption of medication for common mental disorders and sleep quality (Figure 1).
4. To estimate the population impact of UrbEE on the health outcomes under evaluation and conduct a health impact assessment.
5. To assess the mediating role of physical activity, social cohesion, and environmental stressors on the association between UrbEE and the health outcomes under evaluation (Figure 1).

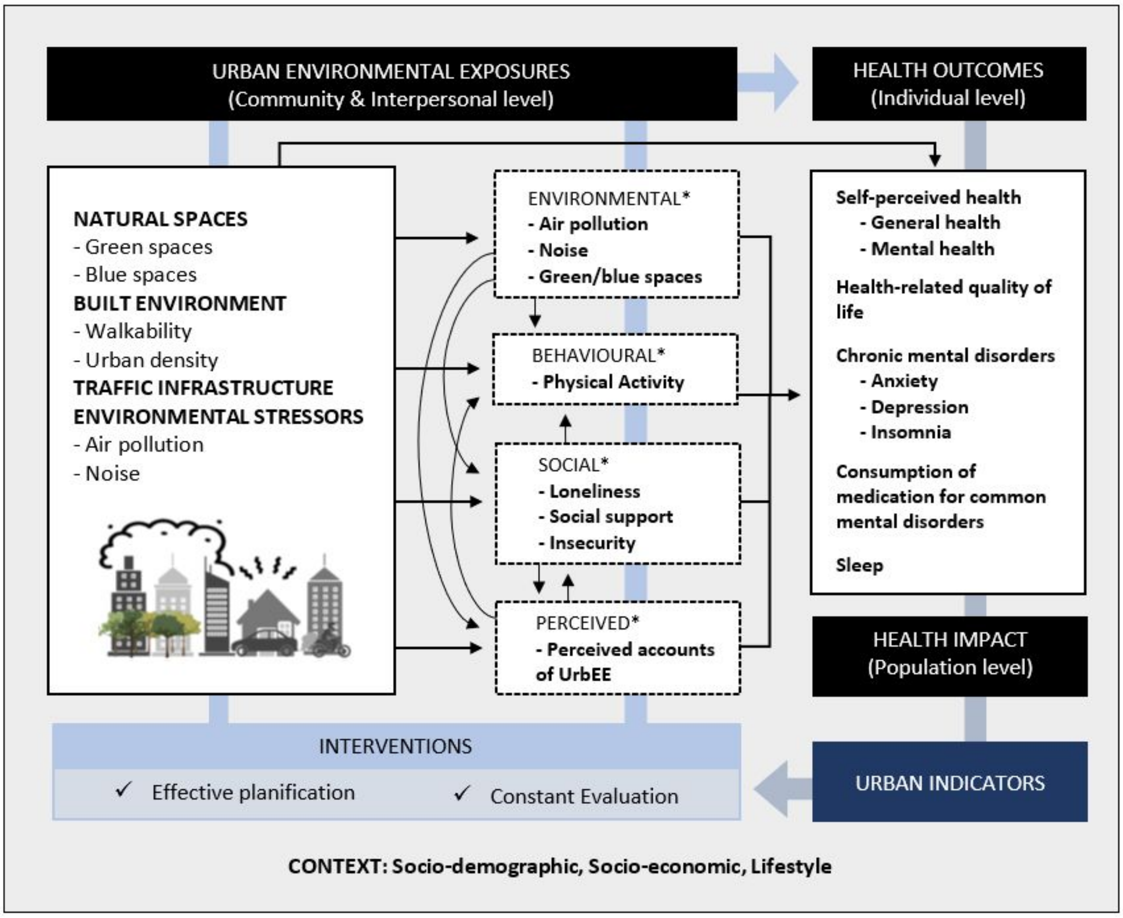


**Figure 1.** Conceptual framework designed within the scope of this project, including potential direct and indirect effects of urban environmental exposures (UrbEE) on the health outcomes under study. * Potential mediators on the association between UrbEE and the health outcomes under evaluation.

## 2. Methods and analysis

### 2.1. Study design

This is a cross-sectional study based on adult population data from Population Health Surveys (PHS) that live in urban areas with more than 100,000 inhabitants in the autonomous communities of the Basque Country and Andalusia, the Valencian Community, and the city of Barcelona in Spain. The study integrates observational data collected within the four independent PHS in 2021-2023 with Geographic Information System (GIS) estimations of individual UrbEE. It entails the following research activities: 1) preparation, integration, and calibration of PHS data from each study area, 2) harmonising the variables that have been collected differently in the four study areas, 3) georeferencing survey respondents' home addresses, 4) characterizing each home address in terms of UrbEE by GIS, 5) linking UrbEE estimates with PHS data, and 6) pooling of datasets from the four study areas (Figure 2). Using the final pooled database, we will analyse the association between UrbEE and health in a cross-sectional manner, taking into account sociodemographic, socioeconomic and lifestyle factors. Figure 1 shows the conceptual framework designed within the scope of this project. DAS-EP received Ethics Approval from the regional ethics committee competent at each study area (see more Supplementary file section 5). This project has received funding from the Instituto de Salud Carlos III (ISCIII) under the Strategic Action in Health with the Health Research Fund (FIS) in the call 2022 (file No. PI22/01051 and No. PI22/00512). The project runs from 2023 to 2025.

## 2.2. Study population

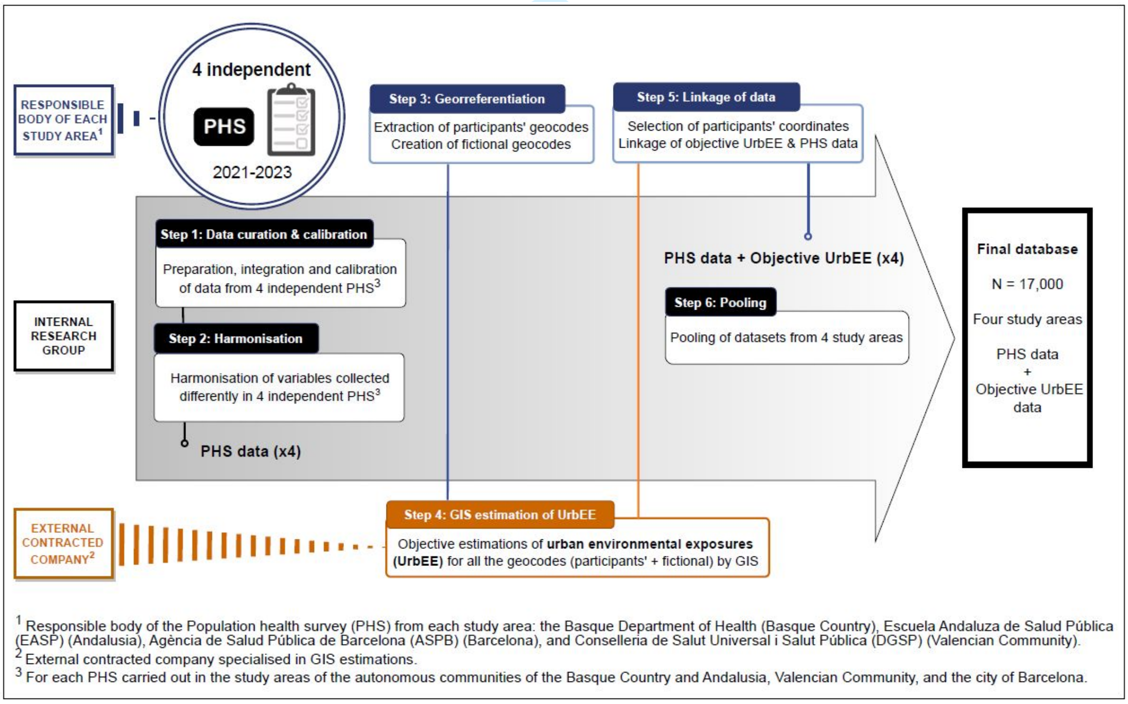


**Figure 2.** Summary of data management plan and the institutions involved during the development of the final database (DB) to be used by the research group in the analyses.

The target population is the inhabitants of the autonomous communities of the Basque Country and Andalusia, Valencian Community, and the city of Barcelona. The sampling frames are made up of people over 15 or 16 years of age of the respective study areas. The study population includes the PHS' participants living in urban areas with more than 100,000 inhabitants in the autonomous communities of the Basque Country and Andalusia, the Valencian Community, and the city of Barcelona (Figure S1, S2). The cities and metropolitan areas participating in this study are: the city of Vitoria-Gasteiz, and the metropolitan areas of Bilbao and Donostia-San Sebastián in the Basque Country; the cities of Almeria, Cadiz, Cordoba, Huelva, Jaen, and the metropolitan areas of Granada, Malaga, and Seville in Andalusia; the cities of Castellon, Valencia, Elche and Alicante in Valencian Community; and the city of Barcelona (Table S1).

The PHS included in this project are official statistical operations that are incorporated in the Statistical Plans of each study area. These activities are conducted by every regional or local public administrations with competence in health and are a fundamental tool to monitor the status and evolution of relevant health conditions in the population, their main determinants, and the use of health services (54–57). Accordingly, these regional and local cross-sectional epidemiological surveys are carried out by the Basque Department of Health in the Basque Country (54), Andalusian School of Public Health (EASP) in Andalusia (55), Barcelona Public Health Agency (ASPB) in Barcelona (56), and Foundation for the Promotion of Health and Biomedical Research in the Valencian Region (DGSP) in Valencian Community (57). They have been organised every 4-5 years since 1986 (Basque Country), 1999 (Andalusia), 1983 (Barcelona) and 1991 (Valencian Community). The sample design and the selection of the sample is carried out independently by the statistical institutes (EUSTAT in the Basque Country, Institute of Statistics and Cartography of Andalusia or IECA in Andalusia, and municipal statistical office of the Barcelona city council in Barcelona) or health population information systems (Valencian Community). The latest version of these surveys are included in this project. After the surveys are completed, it is estimated to obtain a total sample of 16,953 individuals, with a number of 7,846 participants in the Basque Country, 3,085 in Andalusia, 3,134 in Valencian Community and 4,000 in the city of Barcelona. A more detailed information is provided in Table S1.

## 2.3. Data collection

### 2.3.1. GIS estimates of urban environmental exposures (UrbEE)

Objective measures of UrbEE are estimated by a company specialised in GIS based on the geographic coordinates of the participants' home addresses. A significant number of these variables will be expressed in buffers around each participant's residence or at the building level. All environmental exposures will be assessed preceding, and as close as possible to the time the PHS are being conducted (2021-2023) in order to avoid temporal mismatch (58). The objective UrbEE under study in this project include exposures originated from surrounding natural spaces, built environment, traffic-infrastructure, and environmental stressors. Detailed information on the UrbEE estimated within the scope of this project can be found in the Supplementary file (Table S2).

*Surrounding natural spaces*

- <u>Green spaces.</u> Five green space exposure metrics will be calculated in buffers of 100, 300 and 500m around each geocode: 1) percentage of green space; 2) mean Normalised Difference Vegetation Index (NDVI) (59,60); 3) percentage of tree cover; 4) Euclidean distance to the nearest green space larger than 5,000$m^2$ (61), and 5) presence of a major green area (greater than 5,000 $m^2$).
- <u>Blue spaces.</u> Any blue environment, including lake, river, or coastline will be considered as blue space. Three blue space exposure variables will be estimated: 1) presence of water surface; 2) percentage of water surface; and 3) Euclidean distance to nearest water surface

greater than 5,000m$^2$. The first two refer 100, 300 and 500m buffers around each geocode (62).

*Built environment*

- Building density. The building density around each home address in 100, 300 and 500m buffers will be estimated, accounting not only for the perimeter of the buildings but also for their height (63).
- Walkability. An overall walkability index in 100, 300 and 500m buffers around the participants' home addresses will be calculated. This index will be calculated through the sum of the following subindices: 1) population density (referring to the census tract of the address), 2) destination density, 3) street density, 4) street connectivity, 5) land use, 6) facility richness, and 7) average slope (64,65).

*Traffic infrastructure*

- Major road (Yes vs. No). Presence of a major road (with >3 million vehicle passages per year) in 100, 300 and 500m buffers around the participants' home addresses (63).
- Distance to major road. Distance to the nearest major road (with >3 million vehicle passages per year) from the participants home addresses (63).

*Environmental stressors*

- Air pollution. Spatiotemporal daily models at household-level for particulate matter ($PM_{10}$ and $PM_{2.5}$) and nitrogen dioxide ($NO_2$) will be constructed for all study areas using multistage mixed models. These models are known as spatiotemporal land-use random-forest model (66) and combine ground-level and satellite measurements, land use and meteorology. A precise daily estimate of the exposures will be obtained for all study subjects (period 2006 to 2023). Using the daily estimates, annual average for the last five years and the five-year average of $NO_2$, $PM_{10}$ and $PM_{2.5}$ exposure levels will be calculated at PHS respondents' home address as indicators for long-term air quality.

- Environmental noise. The Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge will be used. All potential sources of environmental noise at street level will be examined, including road traffic, rail, industrial, airports and total noise (67,68). Major roads, major railways, and major airports will be included in cities where this information is available and not included in the agglomeration layer. Agglomerations corresponding to the closest street to the dwelling, and major roads and airports corresponding to the closest isoline will be used. In all cases, the Euclidean distance to each source will also be calculated. The daytime ($L_d$), evening ($L_e$), night-time ($L_n$), and total ($L_{den}$) noise indices will be assigned.

2.3.2. Information collected through Population Health Surveys

Information from four independent PHS that represent four study areas is included in the study. The surveys are carried out between 2021-2023, being Barcelona city the earliest in completing the collection (2021 February – 2022 March), followed by the Valencian Community (2022 April – 2022 December), Andalusia (2022 April – 2023 April), and the Basque Country (2022 October – 2023 June) (Table S1). During each survey, detailed information is collected though face-to-face interviews and self-administered questionnaires. The PHS collect information on different health aspects, morbidity and use of health services. It also gathers information on health determinants of health such as socio-economic status, working conditions, social cohesion, health-related behaviours and perception on residential environment. Most of these variables are measured with validated screening tools. The selection of relevant variables to be included in this project was based on a literature review and the most appropriate variables to meet the objectives of the study were selected from among the variables collected by the PHS. All the study areas collected the main variables of the study (i.e., mental health, health-related quality of life, physical activity, social cohesion, and sleep), however, in some cases, the measuring instruments differ across the study areas. Detailed information about the variables and the measuring instruments used in each study area can be found in Table S3.

*Health outcomes*

Several health outcome variables are included in this study.

- Self-perceived general health. Self-assessment of health was measured as an ordinal response, with five categories (1, Excellent; 2, Very good; 3, Good; 4, Fair; 5, Poor).
- Self-perceived mental health. This variable was collected with the Mental Health Inventory (69), the SF-12 (Short-Form Health Survey 12) scale (70) or the General Health Questionnaire (GHQ-12) (71).
- Health-related quality of life. This variable was measured with the Euroqol-5D-5L-EAV scale (72) or the SF-12 (Short-Form Health Survey 12) scale (70).
- Sleep duration and quality. The duration of sleep, indicated as the total number of hours per day spent on sleep including napping was calculated. The quality of sleep was collected using the SATED scale (Satisfaction Alertness Timing Efficiency and Duration Scale) (73) or discrete items.
- Prevalence of chronic mental health problems. Self-reported diagnosis of anxiety, depression and sleeping disorders was collected through the PHS. These dichotomised indicators were based on the physician diagnosis or self-diagnosis for depression, anxiety and sleeping problems at any time throughout the life.
- Consumption of medication for common mental disorders. Information on consumption of medication for common mental disorders, such as, anxiolytics, antidepressants and hypnotics was reported on bi-daily or bi-weekly basis depending on the study area.

*Covariates*

A set of individual level variables will be used as control variables in the statistical analyses.

- Anthropometric variables. The surveys collect information on sex, age, weight, and height of individuals. A Body Mass Index (BMI) ($kg/m^2$) will be calculated using information given by the participants about their height and weight at the moment of filling the questionnaire.
- Socio-demographic and socio-economic variables. To describe respondents' individual-level socioeconomic status (SES), seven variables will be selected: country of birth, household size, level of education, employment and occupational status, reported household income, and economic difficulty of the household. Further, neighbourhood-level SES will be calculated based on the deprivation index by census tract in 2021 from the MEDEA project (forthcoming paper).
- Lifestyle factors. These will include consumption habits such as alcohol consumption, passive smoking at home and tobacco use.
- Physical health. A chronicity index will be calculated based on presence of one or more non-psychological chronic conditions (e.g., diabetes, heart disease, cancer, etc.).

The following social and behavioural variables will be treated as potential mediators.

- Social cohesion and loneliness. Social cohesion is measured with the Duke-UNC-11 scale (74) or the OSLO-3 tool (75). While perceived loneliness is collected with a single item.
- Physical activity. The International Physical Activity Questionnaire (IPAQ) (76) to measure the physical activity performed by the participants. Days per week and time spent in vigorous physical activity, in moderate physical activity, and walking more than 10 minutes, and time spent sitting on a normal day will be available.

*Perception of the neighbourhood*

Perceived accounts of UrbEE are collected through PHS employing 3-point or 5-point Likert format questions depending on the study area. These include: 1) perception of noise outside the dwelling, 2) perception of shortage of green areas in the residential environment, 3) perception of air pollution in the residential environment, and 4) perception of insecurity in the neighbourhood.

## 2.4. Data analysis

Initially, all databases will be cleaned. The variables will be harmonised, when needed, following the Maelstrom Research Guidelines for rigorous harmonisation of retrospective data (77). Nonetheless, because most variables have already been collected consistently in the respective Population Health Surveys, few variables will require harmonisation (see Supplementary file Section 3). Among the few variables requiring harmonisation, most will be re-categorised. For more information, see Supplementary file Section 4. Subsequently, both exploratory and descriptive analysis will be applied using numerical and graphical techniques (78). Before proceeding to inference, sample weights for each survey will be adjusted through calibration (79), so that we may compensate for non-response and coverage biases as well as to improve accuracy. This calibration will be carried out separately for each study area, so that region-level estimates are obtained first, and then harmonized to obtain estimates at population level.

The relationships between the various UrbEE and health outcomes will be analysed according to the multilevel, or hierarchical structure (80) that the data will possess, as census tracts are nested within cities, and cities are nested within autonomous communities. Generalised linear mixed models (GLMMs) will be applied to investigate the relationship between urban environment and health. The sets of adjustment covariates used in these models will be chosen by applying robust causal inference techniques based on directed acyclic graphs (DAGs) (81), both for the estimation of direct effects and hypothetical indirect effects mediated by air pollution, environmental noise, physical activity, and social cohesion. This will imply the prior design of a DAG describing the relationships between UrbEE, health outcomes and other potentially implicated variables (82; 83). The testable implications derived from this DAG will be checked following the procedure described by Ankan and colleagues (84), thereby updating the DAG if needed (85,86). The length of time living in the same home/place will be taken into account by excluding individuals living at the same place of residence for less than one and less than five years in separate models.

In case of demonstrating a significant relationship between a given exposure and a certain outcome, we also intend to identify the specific exposures that cause most disease in the populations of interest via the population attributable fraction (PAF) (87). To estimate the PAF we will require previous estimations of relative risk (RR) and either the prevalence of exposure in the population or the prevalence of exposure among the cases of disease. All these previous estimates will be available. The possible existence of spatial clusters in the UrbEE distribution will also be studied using the standard spatial scan statistic method (88) and calculating the posteriori probabilities for the smoothed standardised ratios to be greater than unity, in the general framework of Bayesian hierarchical standardised ratio smoothing models.

The analyses will be implemented using the latest version of the R software packages *dagitty* (89)*, DClusterm* (90,91)*, R INLA* (92), *Sampling* (93) and others.

## 2.5. Data Management Plan

The data management plan can be found in the Supplementary file Section 4. The source and type of data that will be collected within the scope of this project is described in this plan, together with the accessibility and ownership of data. Data storage and processing, as well as the procedure to guarantee the specific ethical and legal requirements, are likewise explained.

## 2.6. Patient and Public Involvement

Patients and the public will not be involved in the design, or conduct, or reporting, or dissemination plans of our research.

## 3. Discussion

The present study is a clear commitment to the generation of urban environmental indicators potentially explanatory of self-perceived health (physical and mental), chronic mental disorders, health-related quality of life, consumption of medication for common mental disorders and sleep quality with a health equity perspective. This project responds to the national Spanish Strategic Plan for Health and the Environment (PESMA) 2022-2026 (94), to the local implementation of the Strategy for Health Promotion and Prevention in the National Health System (NHS) (95) as well as to the main objective of the Spanish Urban Agenda 2019 (96) that cities should have a global vision that takes into account the physical, mental, and social well-being of their inhabitants. Likewise, it is aligned with three of the Sustainable Development Goals (SDG) of the World Health Organization (SDG.3 - Good Health and Well-being, SDG.10 – Reduced Inequalities, and SDG.11 – Sustainable Cities and Communities) (97,98).

When it comes to health-promoting urban and transport design, there is a lack of standardized, quantitative indicators to guide the integration of health components right from the outset (53,100). In this context, the DAS-EP project not only aims to obtain individual UrbEE estimates but also to assess their association with and impact on various health outcomes. By means of PHS, the health effects to be studied in this study are derived from an unbiased population, which allows to obtain an approximate estimate of the impact at population level. Moreover, it is important to identify the precise routes that connect urban environment to health because they can guide the most efficient interventions, allowing us to design healthy(er) cities (52,101). In this sense, the DAS-EP project investigates various components of the urban environment and health at individual level. Besides using complementary indicators that describe both the physical and the social urban environment (e.g., neighbourhood insecurity), combines objective and perceived indicators to deepen the characterization of the urban environment. By combining these data, it is possible to develop a more precise understanding of the effects of urban environment on health, while describing the complexity of the relationship influenced by neighbourhood environmental and individual characteristics (99,102,103).

The main limitation of this study is its cross-sectional nature. Due to the chronic character of the health conditions included in the study (e.g., depression, insomnia) and the possible long-term effects of UrbEE, a longitudinal design would be more informative and appropriate. Although PHS have a cross-sectional approach, the question "since when have you been living at your current address" enables to account for the extent of exposures. Drawing on this mobility data, sensitivity analysis of the models will be fitted reducing the risk of exposure misclassification. Another limitation is that the samples from the study areas of the Basque Country, Andalusia, and Valencian community, although representative of the study population (considering the inclusion criteria) may not be representative of the autonomous communities from which they come as we are not considering the non-urban municipalities (<100,000 inhabitants). Despite the weight calibration will be conducted to reduce coverage and representativeness biases, the reweighting procedure will not guarantee the elimination of other response biases that may affect data collection from PHS (as acquiescence, social desirability, etc.) that could affect the validity of the results (104,105). Further, the project is subject to residual confounding which in turn implies confounders that could not be controlled and, importantly, measurement errors in the confounders that have been included. In this regard, the estimation UrbEE by GIS is affected by the problem of uncertainty of the temporal and geographical context (106). Finally, the heterogeneity across study areas in terms of geographic scale (autonomous communities vs. city) may be a source of information bias. In this vein, the majority but not all the scales and variables are included in the different PHS are identical. These minor differences in data collection across PHS may lead to additional information biases hindering the comparability of the data. To minimize this problem, special attention will be paid to the selection and harmonization of the variables to be included in order to ensure the consistency of data before making the comparisons across study areas.

As for the strengths of this project, pooling linked surveys across study areas will make it possible to compare the results in different populations, providing a comprehensive dataset that is larger than most existing cohort studies, and that have an unique national and population perspective. The results will be novel in terms of their thematic (objective & subjective UrbEE) and methodological approach (combination of PHS from different study areas and GIS estimates), as well as in terms of the large volume of information that will be handled and the large sample size of the study. Beyond that, the standardization of the procedure here described will generate useful information to assist in the planning of national health surveillance programs, research studies and, more importantly, interventions to strengthen population's health.

In short, the results and products (i.e., databases, computer codes) of this project will greatly contribute to estimate the proportion of the population exposed to different UrbEE, identify health disparities while considering UrbEE, estimate how these exposures relate to and affect various health variables, and conduct a health impact assessment of UrbEE. We will have taken a further step towards understanding and improving the urban environment and being able to establish corrective measures in the urban development plans of the cities.

# Declarations

## Ethics and dissemination

The study was approved by the regional Research Ethics Committee of the **Basque Country**, ETHICS COMMITTEE FOR RESEARCH INVOLVING MEDICINAL PRODUCTS IN THE BASQUE COUNTRY *(CEIm-E)* (protocol code PI2022138, dated $9^{th}$ November 2022); **Andalusia**, BIOMEDICAL RESEARCH ETHICS COMMITTEE OF THE PROVINCE OF GRANADA (CEI/CEIM GRANADA) (protocol code 2078-N-22, dated $27^{th}$ December 2022); **Barcelona**, PARC DE SALUT MAR CLINICAL RESEARCH ETHICS COMMITTE (CEIm) (protocol code 2022/10667, dated $2^{nd}$ December 2022); **Valencian Community**, ETHICS COMMITTEE FOR CLINICAL RESEARCH OF THE DIRECTORATE GENERAL OF PUBLIC HEALTH AND CENTER FOR ADVANCED RESEARCH IN PUBLIC HEALTH (CEIC DGSP / CSISP) (protocol code 20221125/04, dated $25^{th}$ November 2022). The results will be communicated to the general population, health professionals and institutions through conferences, reports, and scientific articles.

## Competing interests

The authors declare that they have no competing interests.


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## Authors' contributions

Conceptualisation, A.L., A.C.-L., M.S-P

Methodology, A.L., A.C.-L., M.S-P

Writing, original draft preparation, A.B., A.L., M.S-P., A.C-L

Writing, review and editing, A.B., A.L., M.S-P., A.C-L., S.C.G., G.G-B., S.D.G., F.B., M.E., A.M., A.E., M.A.I., C.B., R.M., L.F-R., X.B., K.P., L.O., A-C.B., A.D., L.G., H.G.C., M.L.N., R.C., M.M.R., M.S

Project administration, A.L., A.C-L., A.B., M.S-P

Funding acquisition, A.L., A.C-L., M.S-P

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# Supplementary file

**File name:** Supplementary file_DAS-EP

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**Title of data:** Supplementary data of Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project), study protocol.

**Table of contents**

## Section 1. GENERAL CHARACTERISTICS OF THE STUDY AREAS

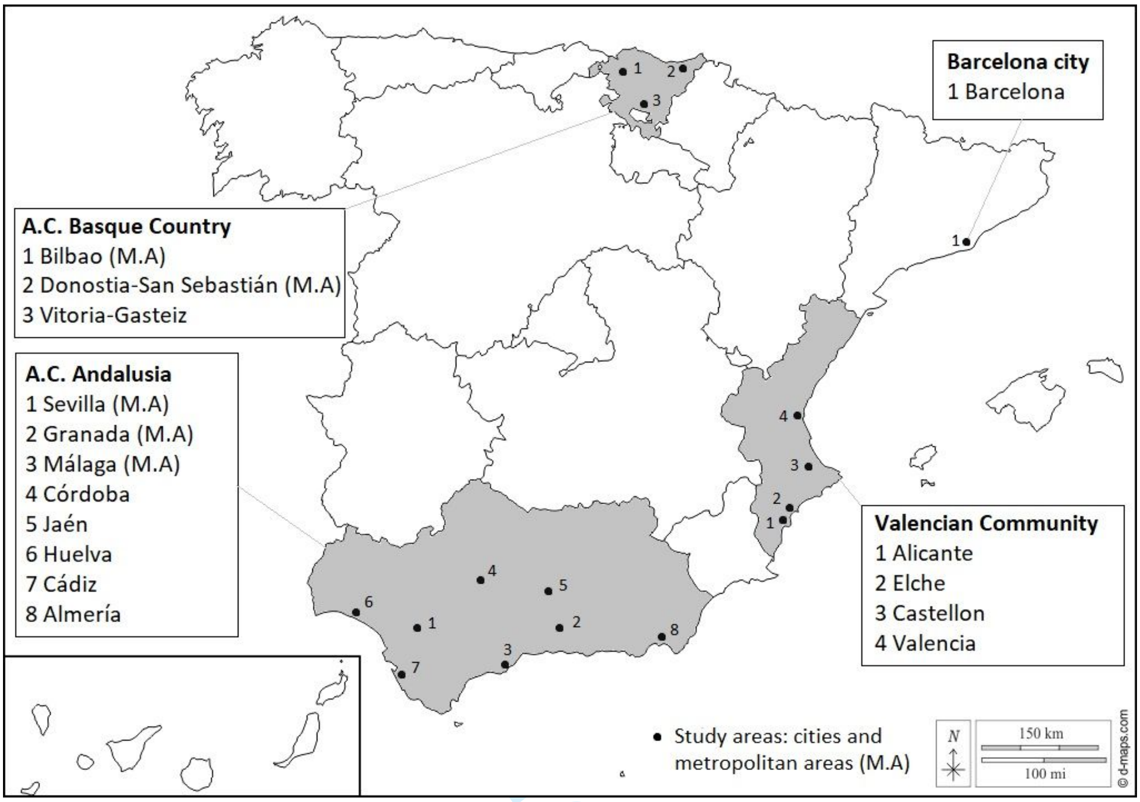


**Figure S1.** Study areas of the project, being the cities and metropolitan areas (M.A) with more than 100,000 inhabitants from the autonomous communities of the Basque Country and Andalusia, Valencian Community, and the city of Barcelona. Figure edited from Daniel Dalet / d-maps.com.

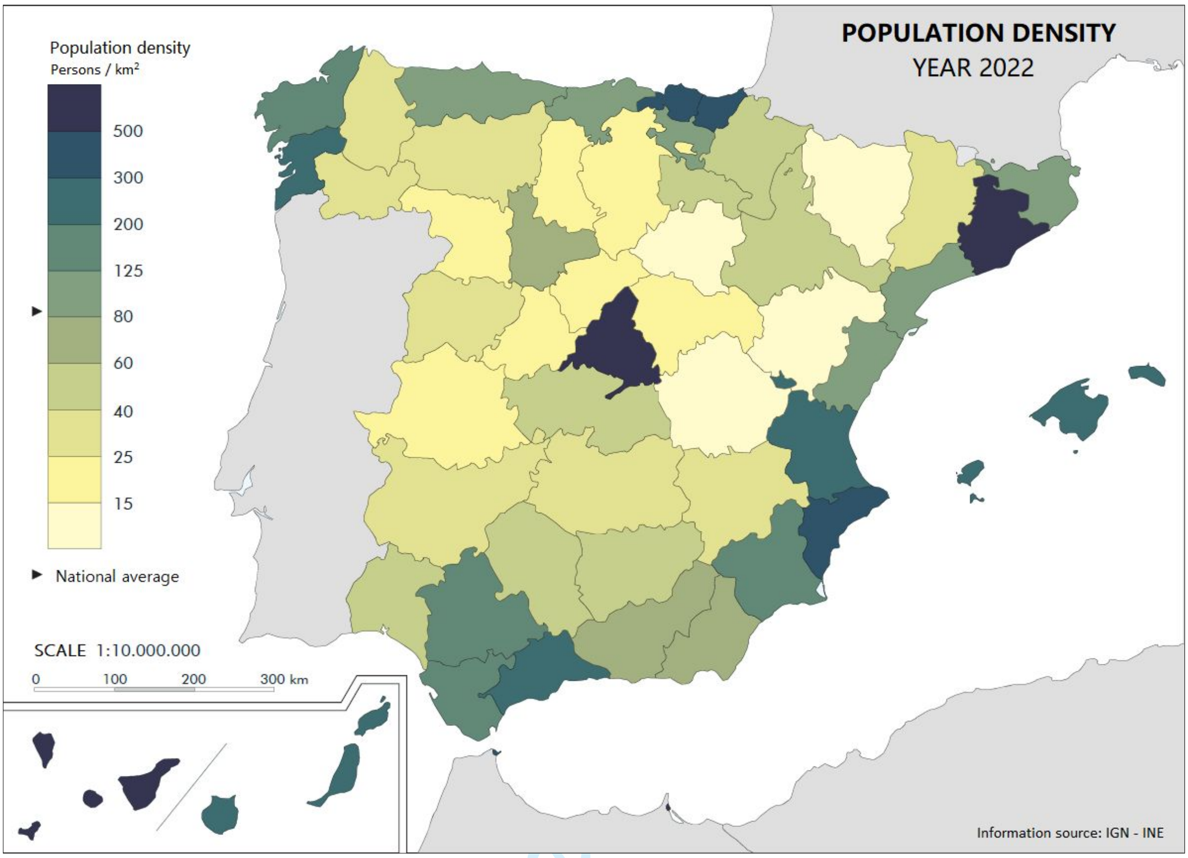


**Figure S2.** Population density of Spanish provinces in 2022. Figure edited from Instituto Geográfico Nacional, *La población en España 2022*. Accessed through: https://www.ign.es/pobesp/pe1.htm

## Section 2. GENERAL CHARACTERISTICS OF THE POPULATION HEALTH SURVEYS

**Table S1.** Characteristics of the study areas and the population health surveys comprised in the project.

| Study area | Cities and areas of influence | Population health survey | Responsible body | Sample size | Data collection period |
|---|---|---|---|---|---|
| A.C. Basque Country | Vitoria-Gasteiz<br>Donostia-San Sebastián (M.A)<br>Bilbao (M.A) | Encuesta de Salud de la Comunidad Autónoma País Vasco (ESCAV) | ✓ Basque Department of Health | 7,846 | 2022 October – 2023 June |
| A.C. Andalusia | Almería<br>Cádiz<br>Córdoba<br>Huelva<br>Jaén<br>Granada (M.A)<br>Malaga (M.A)<br>Sevilla (M.A) | Encuesta Andaluza de Salud (EAS) | ✓ Andalusian School of Public Health (EASP) | 3,085 | 2022 April – 2023 April |
| Barcelona city | Barcelona | Encuesta de Salud de Barcelona (ESB) | ✓ Barcelona Public Health Agency (ASPB) | 4,000 | 2021 February – 2022 March |
| Valencian Community | Castellon<br>Valencia<br>Elche<br>Alicante | Encuesta Salud Comunidad Valenciana (ESCV) | ✓ Foundation for the Promotion of Health and Biomedical Research in the Valencian Region (DGSP) | 3,134 | 2022 April – 2022 December |

Abbreviations: A.C., Autonomous community; M.A, Metropolitan Area.

**Section 3. OVERVIEW OF THE VARIABLES OF THE STUDY PER STUDY AREA**

**Table S2.** Objective urban environmental exposures obtained through GIS estimations.

| GIS Variables | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona | |
|---|---|---|
| OBJECTIVE URBAN ENVIRONMENTAL EXPOSURES | Scale | Variable |
| a) Surrounding natural spaces | | |
| Green Spaces | | |
| Green space percentage | 100, 300, 500m buffers | Percentage of green space. |
| NDVI | 100, 300, 500m buffers | Annual mean Normalised Difference Vegetation Index (NDVI) of the year when the surveys were conducted and the mean NDVI of the last 5 years previous to the surveys. |
| Tree percentage | 100, 300, 500m buffers | Percentage of tree cover based on Growing stock volume (GSV) data. |
| Distance to green space | | Euclidean distance to the nearest major green space (green surface over 5,000m$^2$). |
| Green spaces Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of major green spaces (green surface over 5,000m$^2$) from local topographical or Europe-wide maps (Urban atlas). |
| Blue spaces | | |
| Blue spaces Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of water surfaces. Based on Urban Atlas. |
| Blue space percentage | 100, 300, 500m buffers | Percentage of water surface. Based on Urban Atlas. |
| Distance to blue space | | Euclidean distance to the nearest water surface over 5,000m$^2$. Based on Urban |

| | | |
|---|---|---|
| | | Atlas. |
| **b) Built environment** | | |
| Building density | 100, 300, 500m buffers | The building density around each household will be calculated accounting for the perimeter and height of the buildings from local cadastre data or Europe-wide maps (Urban Atlas). |
| Population density | 100, 300, 500m buffers | The number of inhabitants (per $km^2$) surrounding the home addresses. |
| Street connectivity | 100, 300, 500m buffers | Using data from OpenStreetMap® . |
| Accessibility (bus lines) | 100, 300, 500m buffers | Access to public transport bus lines from local topographical maps or OpenStreetMap®. |
| Accessibility (bus stops) | 100, 300, 500m buffers | Access to public transport bus stops from local topographical maps or OpenStreetMap®. |
| Facility richness | 100, 300, 500m buffers | Using local topographical maps or OpenStreetMap®. |
| Facility density | 100, 300, 500m buffers | Using local topographical maps or OpenStreetMap®. |
| Land use | 100, 300, 500m buffers | Mixed land use will be estimated by Shannon's Eveness Index based on Urban Atlas data. |
| Walkability index | 100, 300, 500m buffers | Index constructed from seven indicators: population density, street connectivity, facility richness, land use, destination density, street density, and average slope. |
| **c) Traffic infrastructure** | | |
| Major road Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of a major road (OpenStreetMap®). |

| | | |
|---|---|---|
| Inverse distance | | Inverse distance to the nearest major road (OpenStreetMap®). |

| **GIS Variables** | **Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona** | |
|---|---|---|
| **OBJECTIVE URBAN ENVIRONMENTAL EXPOSURES** | **Scale** | **Variable** |
| **d) Environmental stressors** | | |
| **Air pollution** | | |
| $PM_{2.5}$ | Street level (at residential address) | $PM_{2.5}$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| $PM_{10}$ | Street level (at residential address) | $PM_{10}$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| $NO_2$ | Street level (at residential address) | $NO_2$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| **Noise** | | |
| Day ($L_d$) | Street level (at residential address) | Exposition to environmental noise at street level during the day indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Evening ($L_e$) | Street level (at residential address) | Exposition to environmental noise at street level during the evening indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive |

| | | |
|---|---|---|
| | | 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Night ($L_n$) | Street level (at residential address) | Exposition to environmental noise at street level during the night indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Total ($L_{den}$) | Street level (at residential address) | Total exposition to environmental noise at street level indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |

Abbreviations: A.C., Autonomous community; NDVI, Normalised Difference Vegetation Index; GSV, Growing stock volume; $PM_{2.5}$, Fine particulate matter with a diameter of 2.5μm or less; $PM_{10}$, Fine particulate matter with a diameter of 10μm or less; $NO_2$, Nitrogen dioxide

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**Table S3.** Variables collected through Population Health Surveys.

| Population Health Survey Variables | Study areas | | | |
|---|---|---|---|---|
| | A.C. Basque Country | A.C. Andalusia | Barcelona city | Valencian Community |
| **OUTCOMES** | | | | |
| **a) Self-perceived health** | | | | |
| General Health | Ordinal 1-5 | Ordinal 1-5 | Ordinal 1-5 | Ordinal 1-5 |
| Mental Health | Ordinal 1-5 [Mental Health Inventory /5 items] | Ordinal 1-6 [SF-12 / 3 items] | Ordinal 1-4 [GHQ-12/ 12 items] | Ordinal 1-4 [GHQ-12 / 12 items] |
| **b) Quality of life** | | | | |
| Health-related quality of life | Ordinal 1-5 [EuroQoL / 5 items] | Ordinal 1-6/1-5 [SF-12 / 5 items] | Ordinal 1-5 [EuroQoL / 5 items] | Ordinal 1-5 [EuroQoL / 5 items] |
| **c) Sleep** | | | | |
| Sleep duration | Continuous - Total hours/day | Continuous - Total hours/day | Continuous - Total hours/day | Continuous - Total hours/day |
| Quality of sleep | Ordinal 1-5 [SATED / 5 items] | yes/no & Ordinal 1-4 [4 items] | Ordinal 1-10 | Ordinal 1-5 [SATED / 5 items] |
| **d) Consumption of medication for common mental disorders**[1] | | | | |
| Antidepressants | yes/no – reference 2 days | yes/no – reference 2 weeks | yes/no - reference 2 days | yes/no - reference 2 weeks |
| Hypnotics | yes/no - reference 2 days | yes/no - reference 2 weeks | yes/no - reference 2 days | yes/no – reference 2 weeks |
| Anxiolytics | yes/no - reference 2 days | yes/no - reference 2 weeks | yes/no - reference 2 days | yes/no - reference 2 weeks |
| **e) Chronic mental health problems**[2] | | | | |
| Anxiety | yes/no - reference ever | yes/no – reference present | yes/no - reference ever | yes/no – reference ever |
| Depression | yes/no - reference ever | yes/no - reference present | yes/no - reference ever | yes/no - reference ever |

| | | | | |
|---|---|---|---|---|
| Insomnia | yes/no - reference ever | - | - | yes/no - reference ever |
| Other | yes/no - reference ever | - | yes/no - reference ever | yes/no - reference ever |
| COVARIATES | | | | |
| **a) Anthropometric variables** | | | | |
| Age | Discrete | Discrete | Discrete | Discrete |
| Weight | Continuous | Continuous | Continuous | Continuous |
| Height | Continuous | Continuous | Continuous | Continuous |
| BMI | Continuous | Continuous | Continuous | Continuous |
| Biologic sex | Categorical - 3 conditions | Categorical - 2 conditions | Categorical - 2 conditions | Categorical - 2 conditions |
| Gender identity | Categorical - 3 conditions | - | Categorical - 3 conditions | - |
| **b) Socioeconomic variables** | | | | |
| Education level | Categorical - 9 conditions | Categorical - 13 conditions | Categorical - 11 conditions | Categorical - 9 conditions |
| Occupational status | Categorical [CNO11] | Categorical [CNO11] | Categorical [CNO11] | Categorical [CNO11] |
| Household size | Discrete | Discrete | Discrete | Discrete |
| **Population Health Survey** | **Study areas** | | | |
| **Variables** | **A.C. Basque Country** | **A.C. Andalusia** | **Barcelona city** | **Valencian Community** |
| Household income | Categorical - 11 conditions | - | - | Categorical - 8 conditions |
| Economic difficulty | Categorical - 6 conditions | Categorical - 6 conditions | Categorical - 6 conditions | Categorical - 6 conditions |
| Employment status | yes/no | yes/no | yes/no | yes/no |
| Country of birth | Categorical & Open | Categorical & Open | Categorical & Open | Categorical & Open |
| Marital status | Categorical - 6 conditions | Categorical - 5 conditions | Categorical - 5 conditions | Categorical - 5 conditions |
| **c) Lifestyle factors** | | | | |
| Alcohol consumption | Categorical - 8 conditions | Categorical - 10 conditions | Categorical - 4 conditions | Categorical - 8 conditions |
| Passive smoking at home | Likert 1-5 | yes/no | Discrete (Nº smokers) | yes/no |

| | | | | |
|---|---|---|---|---|
| Daily tobacco consumption | yes/no | Categorical - 4 conditions | Categorical - 3 conditions | Categorical - 4 conditions |
| **e) Physical Health** | | | | |
| Non-mental chronic health problems | Categorical - 38 conditions | Categorical - 25 conditions | Categorical - 25 conditions | Categorical - 21 conditions |
| **d ) Mobility** | | | | |
| Years at household | Discrete | - | Discrete | Discrete |
| **MEDIATORS** | | | | |
| **a) Physical activity** | | | | |
| Physical activity | Discrete - IPAQ | Discrete - IPAQ | Discrete - IPAQ | Discrete - IPAQ |
| - Vigorous | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Moderate | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Walking | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Sitting | Time spent (hours + minutes) | Time spent (hours + minutes) | Time spent (hours + minutes) | Time spent (hours + minutes) |
| **b) Social cohesion** | | | | |
| Social support | Ordinal 1-5 [Duke / 11 items] | Ordinal 1-5 [Duke / 11 items] | Ordinal 1-5/1-4 [OSLO/ 3 items] | Ordinal 1-5 [Duke / 11 items] |
| Loneliness | Ordinal 1-4 | Ordinal 1-4 | Ordinal 1-4 | Ordinal 1-4 |
| **SUBJECTIVE URBAN ENVIRONMENTAL EXPOSURES** | | | | |
| **a) Perception of the neighbourhood** | | | | |
| Noise outside dwelling | Likert 1-3 | Likert 1-3 | Likert 1-5 | Likert 1-3 |
| Neighbourhood air pollution | Likert 1-3 | Likert 1-3 | - | Likert 1-3 |

| | | | | |
|---|---|---|---|---|
| Shortage of green spaces | Likert 1-3 | Likert 1-3 | - | Likert 1-3 |
| Insecurity | Likert 1-3 | Likert 1-3 | Likert 1-5 | Likert 1-3 |

[1] The subjects are provided with a list of medications and are asked if they have consumed any of them in the last 2 days or 2 weeks depending on the study area.

[2] The subjects are provided with a list of chronic health problems and are asked if they currently suffer or have ever suffered (depending on the study area) from any of them.

**Section 4. DATA MANAGEMENT PLAN**

A) RESEARCH ACTIVITIES

Step 1. Population Health Surveys' (PHS) data curation and calibration

The selected individuals were contacted by a phone call, SMS, or letter to arrange an appointment for a face-to face interview for the purpose of the survey. The database produced with the interviews will be pseudonymised from that with the personal data for the contact by assigning a unique code for each participant and remains under the custody of the responsible body in each study area; the Basque Department of Health in the Basque Country, Escuela Andaluza de Salud Pública (EASP) in Andalusia, Agència de Salud Pública de Barcelona (ASPB) in Barcelona, and Conselleria de Salut Universal i Salut Pública (DGSP) in Valencian Community.

Step 2. Harmonisation

Initially, the databases of each study area will be cleaned, and the variables that require it will be harmonised. The vast majority of the variables to be used in the project have been collected identically in the Population Health Surveys of the study areas included. The variables to be harmonized are listed below and the measures used in each study area can be found in Table S2.

The variables that need harmonisation can be distinguished between simple or complex variables, depending on the level of difficulty and the manipulation of data that require the harmonisation of the respective variable:

- Simple variables: Chronic mental health problems, Educational level, Occupation status, Household income, Loneliness, Noise outside dwelling, and Insecurity.

- Complex variables: mental health, health-related quality of life, sleep quality, consumption of medication for common mental disorders, alcohol consumption, passive smoking at home, tobacco consumption, physical health, and social support.

The Maelstrom Research Guidelines for the rigorous harmonisation of retrospective data (77) will be applied. Among the variables that need harmonisation, the majority can be easily re-categorised (simple variables). For instance, in the case of scales with different score ranges (e.g., Likert scale levels), standardised scores will be calculated, or other procedures will be followed to ensure comparability. The procedure to follow with variables measured with different scales will be more complex (complex variables). For these, the content of each variable will be studied to detect the common content (e.g., items) in each of the study areas. Once detected, aggregate scores will be calculated for the common items, and these scores will be used for statistical analyses. The remaining non-harmonizable variables will be assessed for their potential for performing separate statistical analysis for each study area.

Step 3. Georeferentiation

The responsible bodies, in collaboration with regional Statistical Institutes or Population Registers, will link the health survey data to the geographical coordinates of each respondent's home address. The geographical coordinates will also be pseudonymised and sent this way to the research group specialised in Geographic Information System (GIS) estimations that will calculate UrbEE. In order to further ensure the protection of the personal data of the survey participants and enhance their anonymity, fictional coordinates will be created in a number five times the number of participants selected for the study in each study area and sent to the research group specialised in GIS estimations together with the real coordinates.

Step 4. GIS estimation of Urban Environmental Exposures (UrbEE)

A company specialised in GIS estimations will calculate the objective urban environmental exposures (UrbEE) of all the geocodes, including the participants' coordinates and the fictional coordinates by GIS.

Step 5. Selection and linkage of data

After the estimations are finalised, the responsible bodies of the surveys in each study area will re-select the geocodes of the participants and add the new urban environmental variables to the database with the PHS data. The researchers will be provided with the resultant database of each study area composed by the PHS data and the UrbEE (without geocodes and personal data of the participants). This guarantees that the data supplied are protected by statistical secrecy, not misused and treated anonymously and globally at all times.

Step 6. Pooling

Finally, the final databases of all the study areas will be pooled, creating the final pooled database to be used in the planned analyses.

B) DATA STORAGE AND PROCESSING

Data will be kept at all times on servers located in the responsible centre of this project. This way, data will be stored on the University of the Basque Country UPV/EHU's own servers, complying with the greater security and privacy requirements of the LOPD as the data is not sent to external servers. The entire process of recording, dumping and storage of the data will be anonymised, with the data collected being exclusively linked to a sample unit code. Access to the anonymised microdata will be limited to technicians from the responsible centres of each study area through profiles with regulated permissions that allow for supervising and controlling access to the information. Supervision of the data management will be assigned to the principal investigators with expert advice, and to the data protection officer of the centre responsible for the project.

C) ETHICAL CONSIDERATIONS AND ACCOUNTABILY

The study was approved by the regional Research Ethics Committee of the **Basque Country**, ETHICS COMMITTEE FOR RESEARCH INVOLVING MEDICINAL PRODUCTS IN THE BASQUE COUNTRY (CEIm-E) (protocol code PI2022138, dated 9th November 2022); **Andalusia**, BIOMEDICAL RESEARCH ETHICS COMMITTEE OF THE PROVINCE OF GRANADA (CEI/CEIM GRANADA) (protocol code 2078-N-22, dated 27th December 2022); **Barcelona**, PARC DE SALUT MAR CLINICAL RESEARCH ETHICS COMMITTE (CEIm) (protocol code 2022/10667, dated 2nd December 2022); **Valencian Community**, ETHICS COMMITTEE FOR CLINICAL RESEARCH OF THE DIRECTORATE GENERAL OF PUBLIC HEALTH AND CENTER FOR ADVANCED RESEARCH IN PUBLIC HEALTH (CEIC DGSP / CSISP) (protocol code 20221125/04, dated 25th November 2022).

This study is based on secondary data obtained from four independent Population Health Surveys (PHS) from Spain. Since the present study does not involve the activity of data collection, to obtain the informed consent from the subjects is not applicable for this study. However, the PHS included this project are official statistical operations included in the respective Statistical Plans of each study area. This ensures that the data provided is protected by statistical confidentiality, it is not misused, its treatment is anonymous and global at all times, and that indirect identification is impossible. Data are collected and processed in accordance with the provisions of the General Data Protection Regulation (GDPR) and in accordance with the provisions of Article 5 of the Organic Law 3/2018 of 5 December on the Protection of Personal Data and the guarantee of digital rights (Regulation (EU) 2016/679), they will be treated confidentially, with access to them being granted to personnel who strictly need to process them in the framework of the study.

Furthermore, the transfer of data occurs between organisations within the Public Health System of each region and the regional or local government itself. This is done in the context of a research project conducted exclusively in the public sphere and with the legitimacy of the use of administrative records as research infrastructures in accordance with the General Health Act, the Biomedical Research Act and the General Law on Public Health. The results of the study will provide information at a sufficiently aggregated territorial level to prevent indirect identification. Furthermore, the project's results will be beneficial to the general population in a holistic way, thanks to its socioeconomic and environmental context, and its evolution over several years from the onset of the COVID-19 pandemic. Therefore, the risk to the privacy of the study population is minimal compared to the potential benefits the results will bring.

BMJ Open

# Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project), study protocol.

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**Title**

Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project); study protocol.



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# Abstract

**Introduction:** The European Environment Agency estimates that 75% of the European population lives in cities. Despite the many advantages of city life, the risks and challenges to health arising from urbanization need to be addressed in order to tackle the growing burden of disease and health inequalities in cities. This study, *Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain* (DAS-EP project), aims to investigate the complex association between the urban environmental exposures (UrbEEs) and health.

**Methods and analysis:** DAS-EP is a Spanish multiregional cross-sectional project that combines Population Health Surveys (PHS) and Geographical Information System (GIS) allowing to collect rich individual level data from 17,000 adult citizens participating in the PHS conducted in the autonomous regions of the Basque Country, Andalusia, and the Valencian Community, and the city of Barcelona in years 2021 to 2023. This study focuses on the population living in cities or metropolitan areas with more than 100,000 inhabitants. UrbEEs are described by objective estimates at participants' home addresses by GIS, and subjective indicators present in PHS. The health outcomes included in the PHS and selected for this study are self-perceived health (general and mental), prevalence of chronic mental disorders, health-related quality of life, consumption of medication for common mental disorders, and sleep quality. We aim to further understand the direct and indirect effect between UrbEEs and health, as well as to estimate the impact at the population level taking respondents' socio-demographic and socio-economic characteristics, and lifestyle into consideration.

**Ethics and dissemination:**

The study was approved by the regional Research Ethics Committee of the Basque Country (CEIm-E; PI2022138), Andalusia (CEIM GRANADA; 2078-N-22), Barcelona (CEIC-PSMar; 2022/10667), and Valencian Community (CEIC DGSP/CSISP; 20221125/04). The results will be

communicated to the general population, health professionals and institutions through conferences, reports, and scientific articles.

**Strengths and limitations of this study**

- The linkage of four independent population health surveys (PHS) will provide the study with a large volume of information and sample size.
- The method is novel for the inclusion of objective & subjective UrbEEs as well as the combination of PHS from different study areas and GIS estimates.
- Despite the cross-sectional nature of the study, the results will ultimately help identify urban indicators, increasing the capacity to detect and intervene in community health outcomes, improving the routine surveillance and monitoring of the cities' health information systems.

## 1. Introduction

According to the World Health Organization, modifiable environmental factors are responsible for 23% and 22% of the global mortality and morbidity respectively [1]. As reported by the European Environment Agency, in 2021 75% of the European population lived in urban areas including cities but also smaller urban settlements and suburban areas, developed for residential, industrial or recreational purposes [2]. The local urban environment influences people's health by determining their level of urban environmental exposures (UrbEEss) [3,4]. The UrbEEss include the totality of the surrounding natural (e.g.., green and blue spaces), built (e.g., walkability, urbanisation level, traffic,) and social (e.g.., security, public services) environments within which people live, move, and interact, as well as environmental stressors like air pollution and noise. Increasing evidence shows that UrbEEss such as lack of greenness, air pollution and noise can impact population's mental and physical health and quality of life [5–9]. The health implications of environmental exposures become even more relevant in the contemporary demographic setting, given that they are perhaps starker in urban areas [10–14]. Moreover, in many regions, environmental exposures are not evenly distributed across socioeconomic status and thus, socio-economically vulnerable populations are also affected by poorer environmental quality [10,11]. In fact, this double jeopardy may result in individuals from poorer socioeconomic backgrounds more significantly affected by environmental exposures [4,15]. A comprehensive approach is crucial for understanding the interplay of various environmental determinantswith health and well-being within urban settings. A holistic multi-exposure framework should be adopted, as outlined by Hammersen et al. [16], that extends beyond traditional considerations and incorporates critical urban contextual issues such as substandard housing, crowding, economic inequality, and the evolving challenges posed by climate change, as well as individual psychosocial factors [17,18]).

UrbEEs, including environmental stressors, traffic-infrastructure, natural spaces, and built environment, have all been studied in relation to health. Widespread evidence in the literature shows that air pollution, noise, and lack of green space are related to a range of chronic physical diseases [19–24]. Recently, it has been suggested that air pollution is associated with a range of mental disorders and poorer sleep quality [21,25–28]. Other recent studies observed that environmental noise has negative effects on mental health, well-being, and sleep quality [27,29–31], while evidence on its impact on prescriptions and consumption of medication for common mental disorders has yet to be scientifically confirmed [32]. Otherwise, current scientific evidence indicates that residential greenness is positively associated with mental health and quality of life [31,33,34], and lower consumption of anxiolytics, antidepressants, and sleeping pills [27,35]. Blue spaces (aquatic environments such as rivers, lakes, and the coast) are expected to have similar health effects to those described here, however, evidence on this subject is limited [35,36]. As for the built environment, walkability or accessibility have also been related to reduced obesity and better cardiovascular health [37], improved mental health [38,39] and well-being [40]. To date, the main mechanisms proposed to explain these associations are the mitigation of exposure to environmental pollutants, the promotion of physical activity, and the strengthening of social cohesion [33,34,37,41–43]. Moreover, these mechanisms are probably synergistic [44]. The correlations between several UrbEEs and their relationship with behavioural exposures, such as physical activity and social cohesion, makes the assessment of these associations and pathways highly challenging [45–49]. Hence, noise and air pollution could act both as exposures, mediators, or potential confounders. Overall, results of previous studies are quite mixed and the associations as well as the underlying mechanisms between UrbEEs and mental health outcomes need more robust scientific evidence [5,47,50–52].

This knowledge gap can be partly explained by the heterogeneity and limitations of exposure and outcome metrics used in the studies [19,52,53]. Moreover, there is a lack of studies addressing the impact of UrbEEs on health integrating objective and perceived accounts of such exposures [54]. Therefore, it is evident that more research is needed to determine which UrbEEs are associated with health, the potential mechanisms involved, and the role of social aspects in those associations. Beyond this, researchers are increasingly called to provide information that can guide the selection of the best and most feasible interventions to improve public health in cities. In this respect, experts in the field have claimed the vital role that health impact assessment tools play when integrating the evidence in the decision-making process [55,56].

*Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain* (DAS-EP project) is a 3-year project (2023-2025) aimed at further investigating the associations and underlying mechanisms, including direct and indirect effects, between UrbEEs and health with a health equity perspective. Five main objectives have been established for this project:

1. To estimate, describe, and compare the objective and subjective levels of UrbEEs in the study areas.
2. To describe urban environmental inequalities according to socio-demographic and socio-economic variables, as well as the study area.
3. To estimate the association of UrbEEs with self-perceived general and mental health, health-related quality of life, chronic mental disorders, consumption of medication for common mental disorders, and sleep quality (Figure 1)[1].
4. To estimate the impact of UrbEEs on the health outcomes under evaluation, at the population level, and to conduct a health impact assessment.

[1] For a summary of current prevalence of common mental disorders in Spain, please see section 3.A in the Supplementary file.

5. To assess the mediating role of physical activity, social cohesion, and environmental stressors on the association between UrbEEs and the health outcomes under evaluation (Figure 1).

The general hypothesis of this research project is that the urban environment directly or indirectly affects mental health and quality of life. In line with the first objective of the project, we expect significant differences in levels of exposure to urban environmental variables among the cities under study. Regarding the second objective, we expect participants with lower socio-economic status, lower educational levels, and less remunerated occupations to live in residential environments of poorer environmental quality. We expect them to live in areas with less availability of green and blue spaces, lower walkability scores, and higher levels of noise and air pollution. Finally, we expect the various environmental exposures reported in this study to be significantly associated with the various health and mental health variables studied in the project. Notably, we anticipate that air pollution and noise may have negative effects on mental health, while exposure to natural (green and blue), and more walkable spaces will show protective effects against bad mental health. Furthermore, in line with recent literature, we expect that part of these potential effects on mental health might be produced through increased physical activity and social cohesion.

## 2. Methods and analysis

### 2.1. Study design

This is a cross-sectional study based on information from Population Health Surveys (PHS) carried out in adult population living in urban areas, with more than 100,000 inhabitants, in the autonomous regions of the Basque Country, Andalusia, the Valencian Community, and the city of Barcelona in Spain. The study integrates observational data collected within the four independent PHS in 2021-2023 with Geographic Information System (GIS) estimations of individual UrbEEs. It entails the following research activities: 1) preparing, integrating, and calibrating PHS data from each study area, 2) harmonising the variables that have been collected differently in the four study areas, 3) georeferencing survey respondents' home addresses, 4) characterizing each home address in terms of UrbEEs by GIS, 5) linking UrbEEs estimates with PHS data, and 6) pooling of datasets from the four study areas (Figure 2). Using the final pooled database, we will analyse the association between UrbEEs and health in a cross-sectional manner, considering sociodemographic, socioeconomic and lifestyle factors. Figure 1 shows the conceptual framework designed within the scope of this project. DAS-EP received Ethics Approval from the relevant regional ethics committees (see more Supplementary file section 5). This project has received funding from the Instituto de Salud Carlos III (ISCIII) under the Strategic Action in Health with the Health Research Fund (FIS) in the call 2022 (file No. PI22/01051 and No. PI22/00512). The project runs from 2023 to 2025.

**2.2. Study population**

The target population are inhabitants of the autonomous communities of the Basque Country, Andalusia, the Valencian Community, and the city of Barcelona. The sampling frames are made up of people over 15 or 16 years of age of the respective study areas. The study population includes the PHS' participants living in urban areas with more than 100,000 inhabitants in the regions mentioned before (Figure S1, S2). The cities and metropolitan areas participating in this study are: the city of Vitoria-Gasteiz, and the metropolitan areas of Bilbao and Donostia-San Sebastián in the Basque Country; the cities of Almeria, Cadiz, Cordoba, Huelva, Jaen, and the metropolitan areas of Granada, Malaga, and Seville in Andalusia; the cities of Castellon, Valencia, Elche and Alicante in the Valencian Community; and the city of Barcelona (Table S1).

The PHS included in this project are official statistical operations that are incorporated in the Statistical Plans of each study area. These activities are conducted by every regional or local public administration with jurisdiction in health and are a fundamental tool to monitor the status and evolution of relevant health conditions in the population, their main determinants, and the use of health services [57–60]. Accordingly, these regional and local cross-sectional epidemiological surveys are carried out by the Basque Department of Health in the Basque Country [57], Andalusian School of Public Health (EASP) in Andalusia [58], Barcelona Public Health Agency (ASPB) in Barcelona [59], and Foundation for the Promotion of Health and Biomedical Research in the Valencian Region (DGSP) in Valencian Community [60]. They have been organised every 4-5 years since 1986 (Basque Country), 1999 (Andalusia), 1983 (Barcelona) and 1991 (Valencian Community). The sample design and the selection of the sample is carried out independently in each region by the statistical institute (The Basque Institute for Statistics in the Basque Country, Institute of Statistics and Cartography of Andalusia in Andalusia, and municipal statistical office of the Barcelona city council in Barcelona) or health population information system (Valencian Community). Data from the latest version of these surveys is included in this project. After the surveys are completed, we expect a total estimated sample of 16,953 individuals, of which 7,846 participants will be from the Basque Country, 3,085 from Andalusia, 3,134 from the Valencian Community, and 4,000 from the city of Barcelona. More detailed information is provided in Table S1.

## 2.3. Data collection

### 2.3.1. GIS estimates of urban environmental exposures (UrbEEs)

Objective measures of UrbEEs are estimated by a company specialised in GIS based on the geographic coordinates of the participants' home addresses. A significant number of these variables will be expressed in buffers around each participant's residence or at the building level. All environmental exposures will be assessed preceding to, and as close as possible to the time the PHS are being conducted (2021-2023) to avoid temporal mismatch [61]. The objective UrbEEs of interest in this project include exposures originated from surrounding natural spaces, built environment, traffic-infrastructure, and environmental stressors. Detailed information on the UrbEEs estimated within the scope of this project can be found in the Supplementary file (Table S2).

*Surrounding natural spaces*

- Green spaces. Five green space exposure metrics will be calculated in buffers of 100, 300 and 500 m around each geocode: 1) percentage of green space; 2) mean Normalised Difference Vegetation Index (NDVI) [62,63]; 3) percentage of tree cover; 4) Euclidean distance to the nearest green space larger than 5,000 $m^2$ [64], and 5) presence of a major green area (greater than 5,000 $m^2$).
- Blue spaces. Any blue environments, including lakes, rivers, or coastline will be considered as blue space. Three blue space exposure variables will be estimated: 1) presence of water surface; 2) percentage of water surface; and 3) Euclidean distance to nearest water surface greater than 5,000$m^2$. The first two refer 100, 300 and 500 m buffers around each geocode [65].

*Built environment*

- Building density. The building density around each home address in 100, 300 and 500 m buffers will be estimated, considering not only the perimeter of the buildings but also their height [66].
- Walkability. An overall walkability index in 100, 300 and 500 m buffers around the participants' home addresses will be calculated. This index will include of the following subindices: 1) population density (at the census tract level), 2) street density, 3) street connectivity, 4) land use Shannon Evenness Index, 5) facility richness, 6) facility density, 7) average slope, and 8) transport density [67,68].

*Traffic infrastructure*

- Major road (Yes vs. No). Presence of a major road (with >3 million vehicle passages per year) in 100, 300 and 500 m buffers around the participants' home addresses [66].
- Distance to major road. Distance to the nearest major road (with >3 million vehicle passages per year) from the participants home addresses [66].

*Environmental stressors*

- Air pollution. Spatiotemporal daily models at household-level for particulate matter ($PM_{10}$ and $PM_{2.5}$) and nitrogen dioxide ($NO_2$) will be constructed for all study areas using multistage mixed models. These models are known as spatiotemporal land-use random-forest model [69] and combine ground-level and satellite measurements, land use and meteorology. A precise daily estimate of the exposures will be obtained for all study subjects (period 2006 to 2023). Using the daily estimates, annual average for the last five years and the five-year average of $NO_2$, $PM_{10}$ and $PM_{2.5}$ exposure levels will be calculated at PHS respondents' home address as indicators for long-term air quality.
- Environmental noise. The Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge will be used. All potential sources of environmental noise at street level will be examined, including road traffic, rail, industrial, airports and total noise [70,71]. Major roads, major railways, and major airports will be included in cities where this information is available and not included in the agglomeration layer. Agglomerations corresponding to the closest street to the dwelling, and major roads and airports corresponding to the closest isoline will be used. In all cases, the Euclidean distance to each source will also be calculated. The daytime ($L_d$), evening ($L_e$), night-time ($L_n$), and total ($L_{den}$) noise indices will be assigned.

### 2.3.2. Contextual socioeconomic variables

Neighbourhood-level socioeconomic status (SES) will be considered via three variables, namely, mean income, income distribution P80/P20, and the MEDEA deprivation index (composed by percentage of the population with manual labour, percentage of the population with casual labour, percentage of the population unemployed, percentage of the population with insufficient education, percentage of the population of young people with insufficient education) [72]. All these metrics will be obtained from the publicly available data developed by the Spanish National Institute for Statistics (INE) and expressed at the census tract level (Table S3).

### 2.3.3 Individual socio-demographic and socio-economic variables

To describe respondents' individual-level SES, eight variables will be selected: country of birth, marital status, household size, level of education, employment and occupational status, reported household income, and economic difficulty of the household (Table S4)

### 2.3.4 Information collected through Population Health Surveys

Information from four independent PHS that represent four study areas is included in the study. The surveys are carried out between 2021-2023, being Barcelona city the earliest in completing the collection (2021 February – 2022 March), followed by the Valencian Community (2022 April – 2022 December), Andalusia (2022 April – 2023 April), and the Basque Country (2022 October – 2023 June) (Table S1). During each survey, detailed information is collected though face-to-face interviews and self-administered questionnaires. The PHS collect information on different health aspects, morbidity, and use of health services. It also gathers information on social determinants of health such as socio-economic status, working conditions, social cohesion, health-related behaviours and perception on residential environment. Most of these variables are measured with validated screening tools. The selection of relevant variables to be included in this project was based on a literature review and the most appropriate variables to meet the objectives of the study were selected from among the variables collected by the PHS. All the study areas collected the main variables of the study (i.e., mental health, health-related quality of life, physical activity, social cohesion, and sleep), however, in some cases, the measuring instruments differ across the study areas. Detailed information about the variables and the measuring instruments used in each study area can be found in Table S4.

*Health outcomes*

Several health outcome variables are included in this study.

- <u>Perceived general health.</u> Self-assessment of health was measured as an ordinal response, with five categories (1, Excellent; 2, Very good; 3, Good; 4, Fair; 5, Poor).
- <u>Perceived mental health.</u> This variable was collected with the Mental Health Inventory [73], the SF-12 (Short-Form Health Survey 12) scale [74] or the General Health Questionnaire (GHQ-12) [75].
- <u>Health-related quality of life.</u> This variable was measured with the Euroqol-5D-5L-EAV scale [76] or the SF-12 (Short-Form Health Survey 12) scale [74].
- <u>Sleep duration and quality.</u> The duration of sleep, indicated as the total number of hours per day spent on sleep including napping was calculated. The quality of sleep was collected using the SATED scale (Satisfaction Alertness Timing Efficiency and Duration Scale) [77] or discrete items.
- <u>Prevalence of chronic mental health problems.</u> Participants had to indicate whether they had been diagnosed with depression, anxiety, and sleeping disorders at any time throughout the life. We then built a dichotomized (yes/no) variable for each condition.
- <u>Consumption of medication for common mental disorders.</u> Information on consumption of medication for common mental disorders, such as, anxiolytics, antidepressants and hypnotics was reported on bi-daily or bi-weekly basis depending on the study area.

*Covariates*

A set of individual level variables will be used as control variables in the statistical analyses.

- Anthropometric variables. The surveys collect information on sex, age, weight, and height of individuals. A Body Mass Index (BMI) (kg/m$^2$) will be calculated using information given by the participants about their height and weight at the moment of filling the questionnaire.
- Individual socio-demographic and socio-economic variables. To describe respondents' individual-level SES, eight variables will be selected: country of birth, marital status, household size, level of education, employment and occupational status, reported household income, and economic difficulty of the household.
- Lifestyle factors. These will include consumption habits such as alcohol consumption, passive smoking at home, and tobacco use.
- Physical health. A chronicity index will be calculated based on presence of one or more non-psychological chronic conditions (e.g., diabetes, heart disease, cancer, etc.).

The following social and behavioural variables will be treated as potential mediators.

Social cohesion and loneliness. Social cohesion is measured with the Duke-UNC-11 scale [78] or the OSLO-3 tool [79]. Perceived loneliness is collected with a single item for participants to report about the frequency in which they feel loneliness. The variable is displayed in a 1 to 4 (1= always; 2= often; 3= sometimes; 4= never) response scale.

- Physical activity. The International Physical Activity Questionnaire (IPAQ) [80] to measure the physical activity performed by the participants. Days per week and time spent in vigorous physical activity, in moderate physical activity, and walking more than 10 minutes, and time spent sitting on a normal day will be available.

*Perception of the neighbourhood*

Perceived accounts of UrbEEs are collected through PHS employing 3-point or 5-point Likert format questions depending on the study area. These include: 1) perception of noise outside the dwelling, 2) perception of shortage of green areas in the residential environment, 3) perception of air pollution in the residential environment, and 4) perception of insecurity in the neighbourhood.

## 2.4. Data analysis

Initially, all databases will be cleaned. The variables will be harmonised, when needed, following the Maelstrom Research Guidelines for rigorous harmonisation of retrospective data [81]. Nonetheless, because most variables have already been collected consistently in the respective Population Health Surveys, few variables will require harmonisation (see Supplementary file Section 3). Among the few variables requiring harmonisation, most will be re-categorised. For more information, see Supplementary file Section 4. Subsequently, both exploratory and descriptive analysis will be applied using numerical and graphical techniques [82]. Before proceeding to inference, sample weights for each survey will be adjusted through calibration [83], so that we may compensate for non-response and coverage biases and improve accuracy. This calibration will be carried out separately for each study area, so that region-level estimates are obtained first, and then harmonized to obtain estimates at population level.

The relationships between the various UrbEEs and health outcomes will be analysed according to the multilevel, or hierarchical structure [84] that the data possesses, as census tracts are nested within cities, and cities are nested within autonomous regions. Generalised linear mixed models (GLMMs) will be applied to investigate the relationship between urban environment and health. The sets of adjustment covariates used in these models will be chosen by applying robust causal inference techniques based on directed acyclic graphs (DAGs) [85], both for the estimation of direct effects and hypothetical indirect effects mediated by air pollution, environmental noise, physical activity, and social cohesion. This will imply the prior design of a DAG describing the relationships among UrbEEs, health outcomes and other potentially implicated variables [86,87]. The testable implications derived from this DAG will be checked following the procedure described by Ankan and colleagues [88], thereby updating the DAG if needed [89,90]. These graphical models will guide the inclusion of relevant socio-demographic and socioeconomic variables, allowing us to account for potential confounding factors and illuminate causal relationships. The length of time living in the same home/place will be considered by excluding individuals living at the same place of residence for less than one and less than five years in separate models. Equity will be addressed performing subgroup analysis to investigate potential vulnerable groups such as lower-income populations, the elderly, women, and marginalized communities.

In case of demonstrating a significant relationship between a given exposure and a certain outcome, we also intend to identify the specific exposures that cause most disease in the populations of interest via the population attributable fraction (PAF) [91]. To estimate the PAF we will require previous estimations of relative risk (RR) and either the prevalence of exposure in the population or the prevalence of exposure among the cases of disease. All these previous estimates will be available. The possible existence of spatial clusters in the UrbEEs distribution will also be studied using the standard spatial scan statistic method [92] and calculating the posteriori probabilities for the smoothed standardised ratios to be greater than unity, in the general framework of Bayesian hierarchical standardised ratio smoothing models.

The analyses will be implemented using the latest version of the R software packages *dagitty* [85]*, DClusterm* [93,94]*, R INLA* [95], *Sampling* [96] and others.

## 2.5. Data Management Plan

The data management plan can be found in the Supplementary file Section 4. The source and type of data that will be collected within the scope of this project is described in this plan, together with the accessibility and ownership of data. Data storage and processing, as well as the procedure to guarantee the specific ethical and legal requirements, are likewise explained.

### 2.6. Patient and Public Involvement

Patients and the public will not be involved in the design, or conduct, or reporting, or dissemination plans of our research.

## 3. Discussion

The present study is a clear commitment to the generation of urban environmental indicators potentially explanatory of self-perceived health (physical and mental), chronic mental disorders, health-related quality of life, consumption of medication for common mental disorders and sleep quality with a health equity perspective. This project responds to the national Spanish Strategic Plan for Health and the Environment (PESMA) 2022-2026 [97], to the local implementation of the Strategy for Health Promotion and Prevention in the National Health System [98] as well as to the main objective of the Spanish Urban Agenda 2019 [99] that cities should have a global vision that takes into consideration the physical, mental, and social well-being of their inhabitants. Likewise, it is aligned with three of the Sustainable Development Goals (SDG) of the World Health Organization (SDG.3 - Good Health and Well-being, SDG.10 – Reduced Inequalities, and SDG.11 – Sustainable Cities and Communities) (97,98).

When it comes to health-promoting urban and transport design, there is a lack of standardized, quantitative indicators to guide the integration of health components right from the outset [57,100]. In this context, the DAS-EP project not only aims to obtain individual UrbEEs estimates but also to assess their association with, and impact on various health outcomes. By means of PHS, the health effects to be studied in this project are derived from an unbiased population, which allows to obtain an approximate estimate of the impact at population level. Moreover, it is important to identify the precise routes that connect urban environment to health because they can guide the most efficient interventions, allowing us to design healthy(er) cities [55,101]. In this sense, the DAS-EP project investigates various components of the urban environment and health at individual level. Besides using complementary indicators that describe both the physical and the social urban environment (e.g., neighbourhood insecurity), combines objective and perceived indicators to deepen the characterization of the urban environment. By combining these data, it is possible to develop a more precise understanding of the effects of urban environment on health, while describing the complexity of the relationship influenced by neighbourhood environmental and individual characteristics [102–104].

The main limitation of this study is its cross-sectional nature. Due to the chronic character of the health conditions included in the study (e.g., depression, insomnia) and the possible long-term effects of UrbEEs, a longitudinal design would be more informative and appropriate. Although PHS have a cross-sectional approach, the question "since when have you been living at your current address" enables to account for the extent of exposures. Drawing on this mobility data, sensitivity analysis of the models will be fitted reducing the risk of exposure misclassification. Another limitation is that the samples from the study areas of the Basque Country, Andalusia, and Valencian community, although representative of the study population (considering the inclusion criteria) may not be representative of the autonomous communities from which they come as we are not considering the non-urban municipalities (<100,000 inhabitants). Despite the weight calibration to be conducted to reduce coverage and representativeness biases, the reweighing procedure will not guarantee the elimination of other response biases that may affect data collection from PHS (as acquiescence, social desirability, etc.) which could affect the validity of the results [105,106]. Furthermore, the project is subject to residual confounding, which in turn implies confounders that could not be controlled and, importantly, measurement errors in the confounders that have been included. In this regard, the estimation UrbEEs by GIS is affected by the problem of uncertainty of the temporal and geographical context [107].

The use of buffer zones may not be appropriate to evaluate contextual effects on health because they fail to analyze the spatial-temporal distribution of residents' activities and their relationship with built environment factors. Using activity space measures would be preferable to comprehensively assess of environmental exposures by capturing the complexity of individual movements [108–110]. The reliance on publicly available data applicable to all study areas together with scalability challenges were major barriers to estimate street-level (or microscale) variables like bicycle and pedestrian infrastructure [111–113]. Moreover, future studies should not only include more variables reflecting the social capital (e.g., perceived sense of community) but also analyse the health implications of other relevant urban exposures like substandard housing, crowding, and indoor air pollution. Finally, the heterogeneity across study areas in terms of geographic scale (autonomous communities vs. city) may be a source of information bias. In this vein, the majority -but not all- of the scales and variables included in the different PHS are identical. These minor differences in data collection across PHS may lead to additional information biases hindering the comparability of the data. To minimize this problem, special attention will be paid to the selection and harmonization of the variables to be included to ensure the consistency of data before making the comparisons across study areas.

As for the strengths of this project, pooling linked surveys across study areas will make it possible to compare the results in different populations, providing a comprehensive dataset that is larger than most existing cohort studies, and that have an unique national and population perspective. The results will be novel in terms of their thematic (objective & subjective UrbEEs) and methodological approach (combination of PHS from different study areas and GIS estimates), as well as in terms of the large volume of information that will be handled and the large sample size of the study. Beyond that, the standardization of the procedure described herein will generate useful information to assist in the planning of national health surveillance programs, research studies and, more importantly, interventions to strengthen population's health.

In short, the results and products (i.e., databases, computer codes) of this project will greatly contribute to estimate the proportion of the population exposed to different UrbEEs, identify health disparities while considering UrbEEs, estimate how these exposures relate to and affect various health variables, and conduct a health impact assessment of UrbEEs. We will have taken a further step towards understanding and improving the urban environment and being able to establish corrective measures in the urban development plans of the cities.

# Declarations

## Ethics and dissemination

The study was approved by the regional Research Ethics Committee of the **Basque Country**, ETHICS COMMITTEE FOR RESEARCH INVOLVING MEDICINAL PRODUCTS IN THE BASQUE COUNTRY *(CEIm-E)* (protocol code PI2022138, dated 9th November 2022); **Andalusia**, BIOMEDICAL RESEARCH ETHICS COMMITTEE OF THE PROVINCE OF GRANADA (CEI/CEIM GRANADA) (protocol code 2078-N-22, dated 27th December 2022); **Barcelona**, PARC DE SALUT MAR CLINICAL RESEARCH ETHICS COMMITTE (CEIm) (protocol code 2022/10667, dated 2nd December 2022); **Valencian Community**, ETHICS COMMITTEE FOR CLINICAL RESEARCH OF THE DIRECTORATE GENERAL OF PUBLIC HEALTH AND CENTER FOR ADVANCED RESEARCH IN PUBLIC HEALTH (CEIC DGSP / CSISP) (protocol code 20221125/04, dated 25th November 2022). The results will be communicated to the general population, health professionals and institutions through conferences, reports, and scientific articles.

## Competing interests

The authors declare that they have no competing interests.

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## Authors' contributions

Conceptualisation, A.L., A.C.-L., M.S-P

Methodology, A.L., A.C.-L., M.S-P

Writing, original draft preparation, A.B., A.L., M.S-P., A.C-L

Writing, review and editing, A.B., A.L., M.S-P., A.C-L., S.C.G., G.G-B., S.D.G., F.B., M.E., A.M., A.E., M.A.I., C.B., R.M., L.F-R., X.B., K.P., L.O., A-C.B., A.D., L.G., H.G.C., M.L.N., R.C., M.M.R., M.S

Project administration, A.L., A.C-L., A.B., M.S-P

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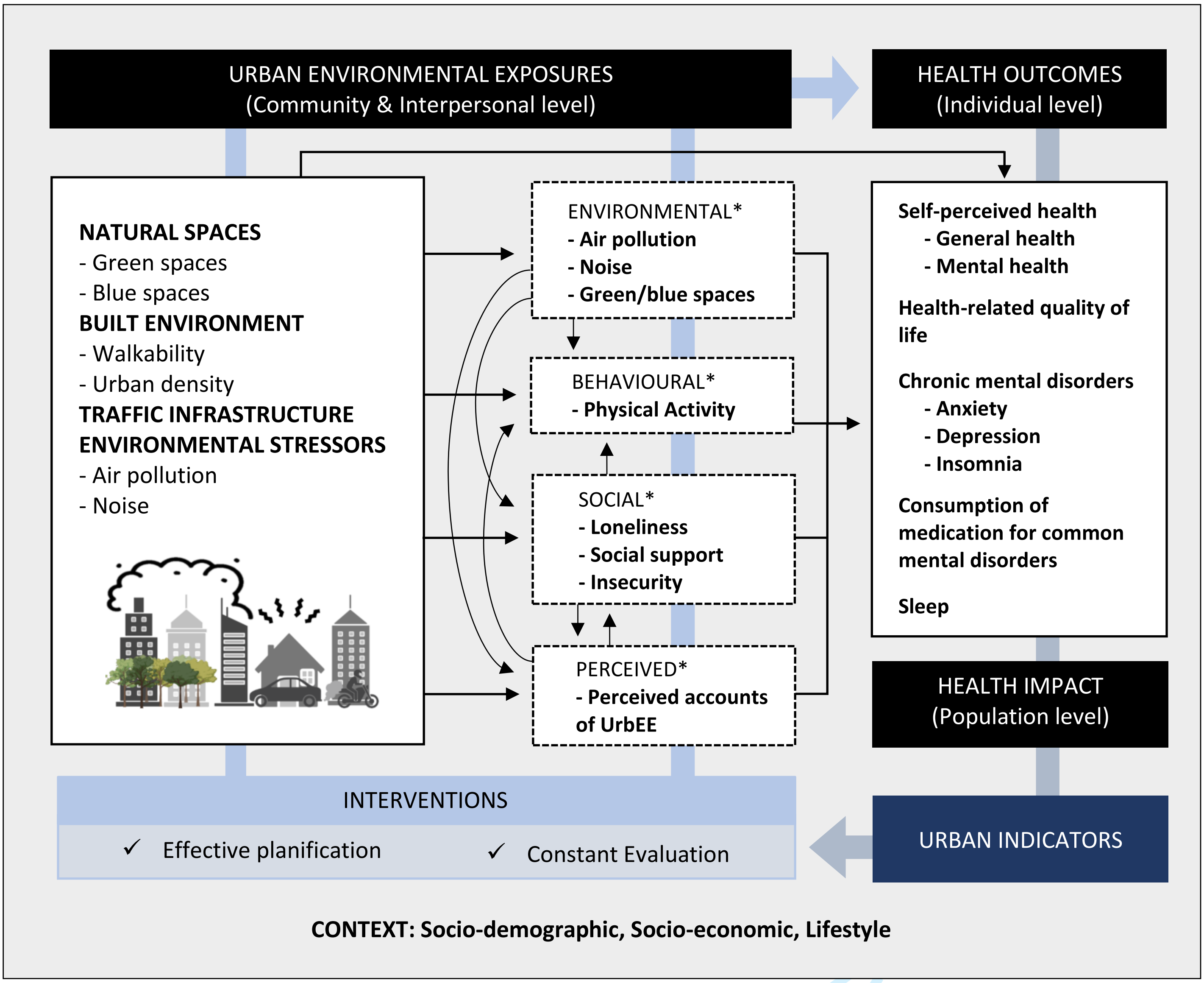
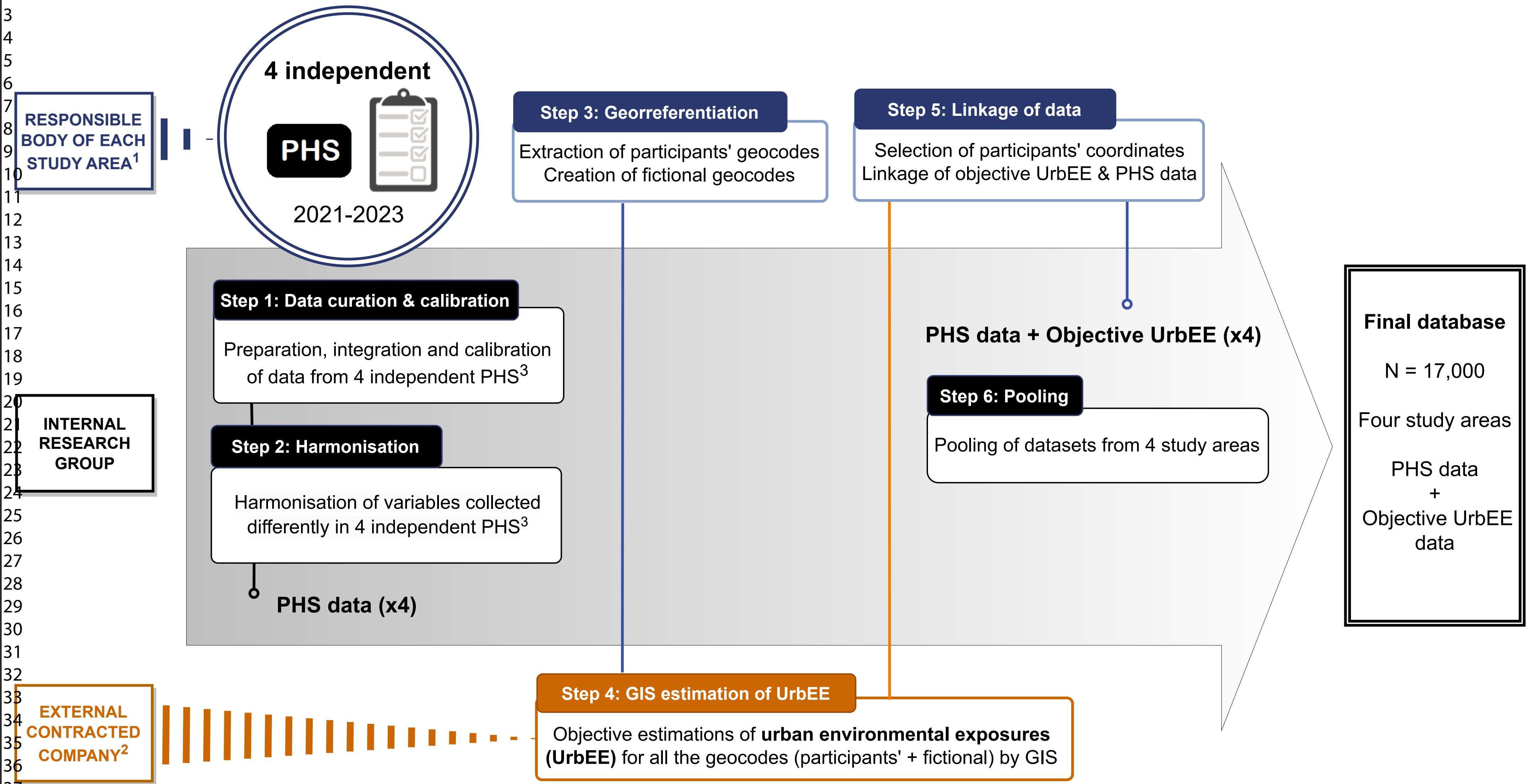
## Legends

**Figure 1.** Conceptual framework designed within the scope of this project, including potential direct and indirect effects of urban environmental exposures (UrbEEs) on the health outcomes under study. * Potential mediators on the association between UrbEEs and the health outcomes under evaluation.

**Figure 2.** Summary of data management plan and the institutions involved during the development of the final database (DB) to be used by the research group in the analyses.


URBAN ENVIRONMENTAL EXPOSURES
(Community & Interpersonal level)
HEALTH OUTCOMES
(Individual level)
NATURAL SPACES
- Green spaces
- Blue spaces
BUILT ENVIRONMENT
- Walkability
- Urban density
TRAFFIC INFRASTRUCTURE
ENVIRONMENTAL STRESSORS
- Air pollution
- Noise
ENVIRONMENTAL*
- Air pollution
- Noise
- Green/blue spaces
BEHAVIOURAL*
- Physical Activity
SOCIAL*
- Loneliness
- Social support
- Insecurity
PERCEIVED*
- Perceived accounts of UrbEE
Self-perceived health
- General health
- Mental health
Health-related quality of life
Chronic mental disorders
- Anxiety
- Depression
- Insomnia
Consumption of medication for common mental disorders
Sleep
HEALTH IMPACT
(Population level)
INTERVENTIONS
✓ Effective planification
✓ Constant Evaluation
URBAN INDICATORS
CONTEXT: Socio-demographic, Socio-economic, Lifestyle




[1] Responsible body of the Population health survey (PHS) from each study area: the Basque Department of Health (Basque Country), Escuela Andaluza de Salud Pública (EASP) (Andalusia), Agència de Salud Pública de Barcelona (ASPB) (Barcelona), and Conselleria de Salut Universal i Salut Pública (DGSP) (Valencian Community).

[2] External contracted company specialised in GIS estimations.

[3] For each PHS carried out in the study areas of the autonomous communities of the Basque Country and Andalusia, Valencian Community, and the city of Barcelona.

# Supplementary file

**File name:** Supplementary file_DAS-EP

**File format:** Word document (.docx)

**Title of data:** Supplementary data of Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project), study protocol.

## Table of contents

## Section 1. GENERAL CHARACTERISTICS OF THE STUDY AREAS

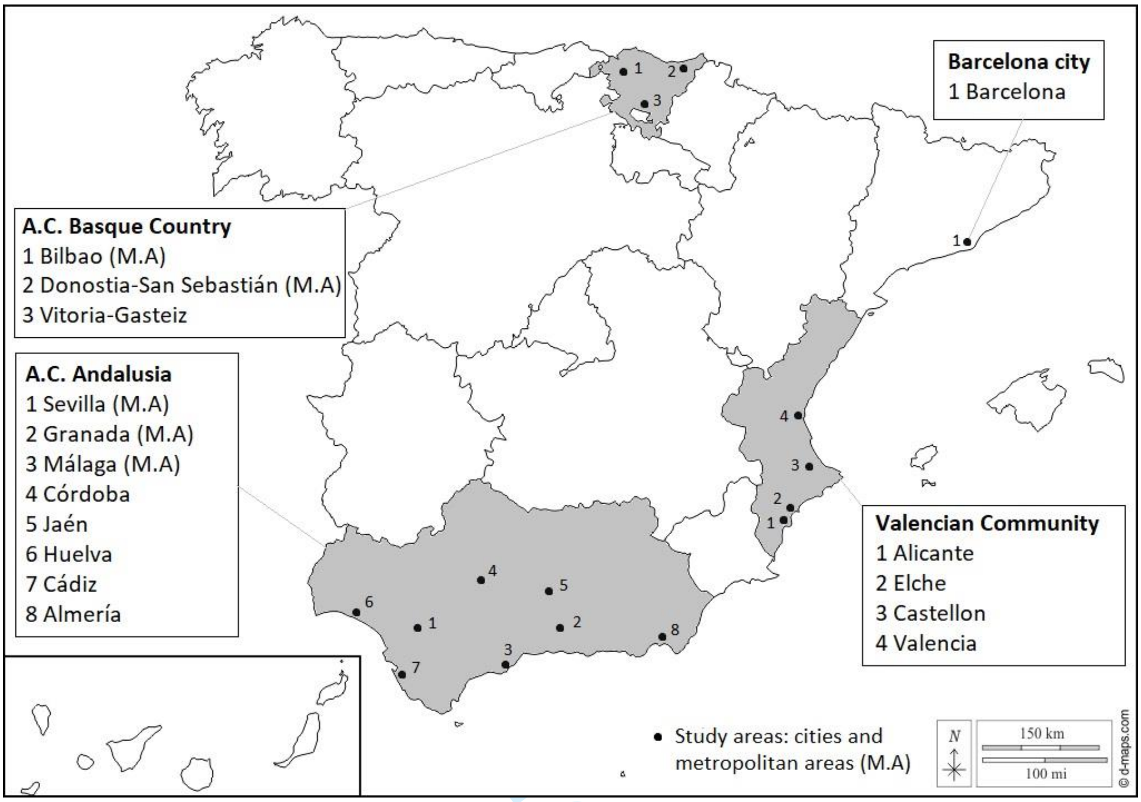



**Figure S1.** Study areas of the project, being the cities and metropolitan areas (M.A) with more than 100,000 inhabitants from the autonomous communities of the Basque Country and Andalusia, Valencian Community, and the city of Barcelona. Figure edited from Daniel Dalet / d-maps.com.

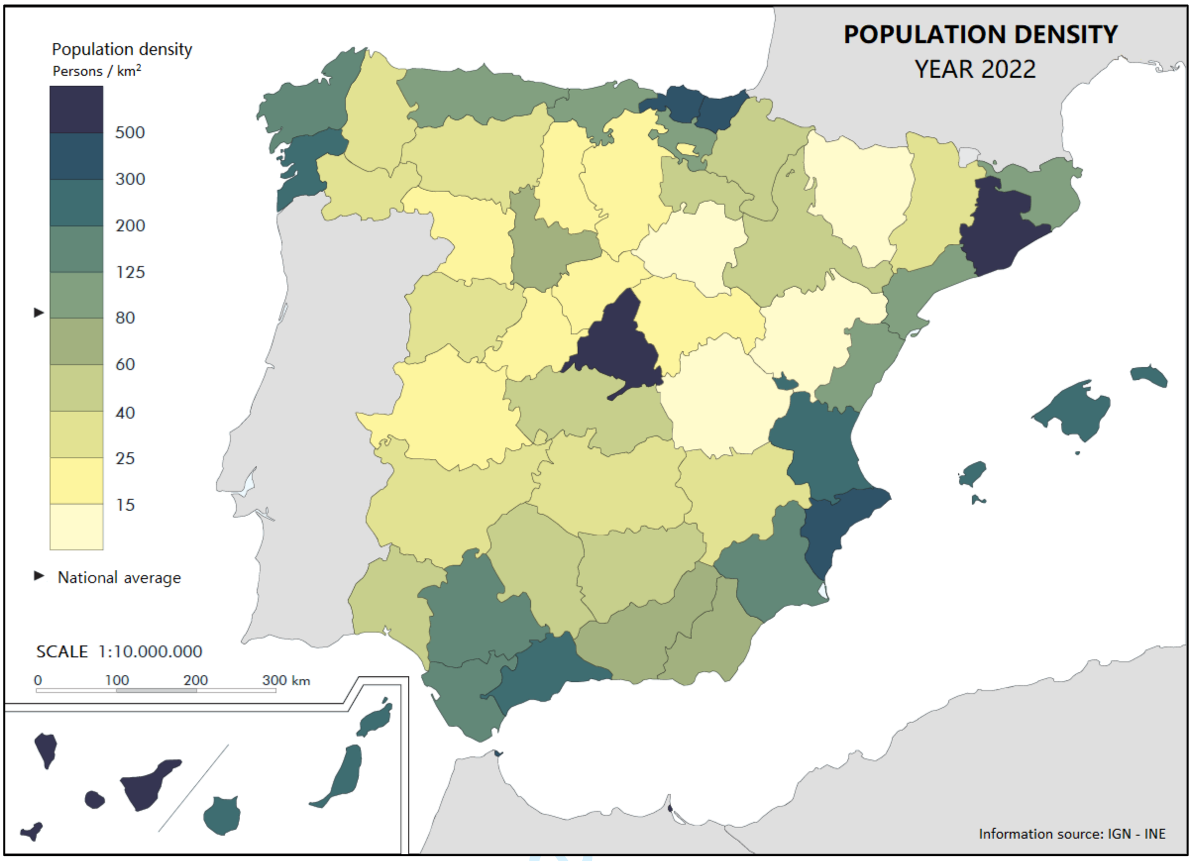



**Figure S2.** Population density of Spanish provinces in 2022. Figure edited from Instituto Geográfico Nacional, *La población en España 2022*. Accessed through: https://www.ign.es/pobesp/pe1.htm

**Section 2. GENERAL CHARACTERISTICS OF THE POPULATION HEALTH SURVEYS**

**Table S1.** Characteristics of the study areas and the population health surveys comprised in the project.

| Study area | Cities and areas of influence | Population health survey | Responsible body | Sample size | Data collection period |
|---|---|---|---|---|---|
| A.C. Basque Country | Vitoria-Gasteiz<br>Donostia-San Sebastián (M.A)<br>Bilbao (M.A) | Encuesta de Salud de la Comunidad Autónoma País Vasco (ESCAV) | ✓ Basque Department of Health | 7,846 | 2022 October – 2023 June |
| A.C. Andalusia | Almería<br>Cádiz<br>Córdoba<br>Huelva<br>Jaén<br>Granada (M.A)<br>Malaga (M.A)<br>Sevilla (M.A) | Encuesta Andaluza de Salud (EAS) | ✓ Andalusian School of Public Health (EASP) | 3,085 | 2022 April – 2023 April |
| Barcelona city | Barcelona | Encuesta de Salud de Barcelona (ESB) | ✓ Barcelona Public Health Agency (ASPB) | 4,000 | 2021 February – 2022 March |
| Valencian Community | Castellon<br>Valencia<br>Elche<br>Alicante | Encuesta Salud Comunidad Valenciana (ESCV) | ✓ Foundation for the Promotion of Health and Biomedical Research in the Valencian Region (DGSP) | 3,134 | 2022 April – 2022 December |

Abbreviations: A.C., Autonomous community; M.A, Metropolitan Area.

### Section 3. OVERVIEW OF THE VARIABLES OF THE STUDY PER STUDY AREA

**Table S2.** Objective urban environmental exposures obtained through GIS estimations.

| GIS Variables | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona | |
|---|---|---|
| OBJECTIVE URBAN ENVIRONMENTAL EXPOSURES | Scale | Variable |
| a) Surrounding natural spaces | | |
| Green Spaces | | |
| Green space percentage | 100, 300, 500m buffers | Percentage of green space. |
| NDVI | 100, 300, 500m buffers | Annual mean Normalised Difference Vegetation Index (NDVI) of the year when the surveys were conducted and the mean NDVI of the last 5 years previous to the surveys. |
| Tree percentage | 100, 300, 500m buffers | Percentage of tree cover based on Growing stock volume (GSV) data. |
| Distance to green space | | Euclidean distance to the nearest major green space (green surface over 5,000$m^2$). |
| Green spaces Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of major green spaces (green surface over 5,000$m^2$) from local topographical or Europe-wide maps (Urban atlas). |
| Blue spaces | | |
| Blue spaces Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of water surfaces. Based on Urban Atlas. |
| Blue space percentage | 100, 300, 500m buffers | Percentage of water surface. Based on Urban Atlas. |
| Distance to blue space | | Euclidean distance to the nearest water surface over 5,000$m^2$. Based on Urban Atlas. |
| b) Built environment | | |
| Building density | 100, 300, 500m buffers | The building density around each household will be calculated accounting for the perimeter and height of the buildings from local cadastre data or Europe-wide maps (Urban Atlas). |
| Population density | 100, 300, 500m buffers | The number of inhabitants (per $km^2$) surrounding the home addresses. |
| Street connectivity | 100, 300, 500m buffers | Using data from OpenStreetMap® . |
| Accessibility (bus lines) | 100, 300, 500m buffers | Access to public transport bus lines from local topographical maps or OpenStreetMap®. |
| Accessibility (bus stops) | 100, 300, 500m buffers | Access to public transport bus stops from local topographical maps or OpenStreetMap®. |
| Facility richness | 100, 300, 500m buffers | Using local topographical maps or OpenStreetMap®. |
| Facility density | 100, 300, 500m buffers | Using local topographical maps or OpenStreetMap®. |
| Land use | 100, 300, 500m buffers | Mixed land use will be estimated by Shannon's Eveness Index based on Urban Atlas data. |
| Walkability index | 100, 300, 500m buffers | Index constructed from seven indicators: population density, street connectivity, street density, facility richness, facility density, land use, transport density, and average slope. |
| c) Traffic infrastructure | | |
| Major road Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of a major road (OpenStreetMap®). |
| Inverse distance | | Inverse distance to the nearest major road (OpenStreetMap®). |

| GIS Variables | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona | |
|---|---|---|
| OBJECTIVE URBAN ENVIRONMENTAL EXPOSURES | Scale | Variable |
| d) Environmental stressors | | |
| Air pollution | | |
| $PM_{2.5}$ | Street level (at residential address) | $PM_{2.5}$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| $PM_{10}$ | Street level (at residential address) | $PM_{10}$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| $NO_2$ | Street level (at residential address) | $NO_2$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| Noise | | |
| Day ($L_d$) | Street level (at residential address) | Exposition to environmental noise at street level during the day indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Evening ($L_e$) | Street level (at residential address) | Exposition to environmental noise at street level during the evening indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Night ($L_n$) | Street level (at residential address) | Exposition to environmental noise at street level during the night indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Total ($L_{den}$) | Street level (at residential address) | Total exposition to environmental noise at street level indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |

Abbreviations: A.C., Autonomous community; NDVI, Normalised Difference Vegetation Index; GSV, Growing stock volume; $PM_{2.5}$, Fine particulate matter with a diameter of 2.5µm or less; $PM_{10}$, Fine particulate matter with a diameter of 10µm or less; $NO_2$, Nitrogen dioxide

**Table S3.** Area-level socioeconomic (SES) variables obtained through GIS estimations.

| GIS Variables | | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona |
|---|---|---|
| AREA-LEVEL SES VARIABLES | Scale | Variable |
| a) Mean income | | |
| Average household net income | Census tract | Average household net income. Income data collection is based on standardised annual requests to the different collaborating tax organisations. Data from 2021. Data source INE[1]. |
| Average household gross income | Census tract | Average household gross income. As components of gross income, five exhaustive categories are considered: wages, pensions, unemployment benefits, other benefits, other income. Data from 2021. Data source INE[1]. |
| Average net income per person | Census tract | Net income per person is obtained, for each household, by dividing the net household income by the number of members of said household. Data from 2021. Data source INE[1]. |
| Average gross income person | Census tract | Gross income per person is obtained, for each household, by dividing the gross household income by the number of members of said household. Data from 2021. Data source INE[1]. |
| Average income per consumption unit | Census tract | Equivalised income is a measure of household income that takes account of the differences in a household's size and composition, and thus is equivalised or made equivalent for all household sizes and compositions. The equivalised income is calculated by dividing the household's total net income by its equivalent size, which is calculated using the modified OECD equivalence scale. This scale attributes a weight to all members of the household: 1.0 to the first adult; 0.5 to the second and each subsequent person aged 14 and over; 0.3 to each child aged under 14. Data from 2021. Data source INE[1]. |
| b) Income distribution P80/P20 | Census tract | Ratio between the 80th percentile and the 20th percentile of the income distribution per unit of consumption. Data from 2021. Data source INE[1]. |
| c) Gini index | Census tract | The Gini index measures the degree of inequality in the distribution of income/wealth, used to estimate how far a country's wealth or income distribution deviates from an equal distribution[2]. A Gini coefficient of 0 reflects perfect equality, where all income or wealth values are the same, while a Gini coefficient of 1 (or 100%) reflects maximal inequality among values, a situation where a single individual has all the income while all others have none. Data from 2021. Data source INE[1]. |
| d) MEDEA deprivation index | Census tract | A deprivation index developed to study the social inequalities in health in Spain. The index is composed by percentage of the population with manual labour, percentage of the population with casual labour, percentage of the population unemployed, percentage of the population with insufficient education, percentage of the population of young people with insufficient education[3]. Data from 2021. |

Abbreviations: A.C., Autonomous community; SES., Socioeconomic status

[1] INEbase. Atlas de Distribución de Renta de los Hogares (ADRH). INE. Retrieved 19 December 2023, from https://www.ine.es/metodologia/metodologia_adrh.pdf

[2] Gini, Corrado (1936). "On the Measure of Concentration with Special Reference to Income and Statistics", Colorado College Publication, General Series No. 208, 73–79.

[3] Domínguez-Berjón, M. F., Borrell, C., Cano-Serral, G., Esnaola, S., Nolasco, A., Pasarín, M. I., Ramis, R., Saurina, C., & Escolar-Pujolar, A. (2008). Construcción de un índice de privación a partir de datos censales en grandes ciudades españolas: (Proyecto MEDEA). *Gaceta Sanitaria*, 22(3), 179–187.

**Table S4.** Variables collected through Population Health Surveys.

| Population Health Survey Variables | Study areas | | | |
|---|---|---|---|---|
| | A.C. Basque Country | A.C. Andalusia | Barcelona city | Valencian Community |
| OUTCOMES | | | | |
| a) Perceived health | | | | |
| General Health | Ordinal 1-5 | Ordinal 1-5 | Ordinal 1-5 | Ordinal 1-5 |
| Mental Health | Ordinal 1-5 [MHI/5 items] | Ordinal 1-6 [SF-12/3 items] | Ordinal 1-4 [GHQ-12/12 items] | Ordinal 1-4 [GHQ-12 /12 items] |
| b) Quality of life | | | | |
| Health-related quality of life | Ordinal 1-5 [EuroQoL / 5 items] | Ordinal 1-6/1-5 [SF-12 / 5 items] | Ordinal 1-5 [EuroQoL / 5 items] | Ordinal 1-5 [EuroQoL / 5 items] |
| c) Sleep | | | | |
| Sleep duration | Continuous - Total hours/day | Continuous - Total hours/day | Continuous - Total hours/day | Continuous - Total hours/day |
| Quality of sleep | Ordinal 1-5 [SATED / 5 items] | Ordinal 1-4 [4 items] | Ordinal 1-10 | Ordinal 1-5 [SATED / 5 items] |
| d) Consumption of medication for common mental disorders[1] | | | | |
| Antidepressants | yes/no – reference 2 days | yes/no – reference 2 weeks | yes/no - reference 2 days | yes/no - reference 2 weeks |
| Hypnotics | yes/no - reference 2 days | yes/no - reference 2 weeks | yes/no - reference 2 days | yes/no – reference 2 weeks |
| Anxiolytics | yes/no - reference 2 days | yes/no - reference 2 weeks | yes/no - reference 2 days | yes/no - reference 2 weeks |
| e) Chronic mental health problems[2] | | | | |
| Anxiety | yes/no - reference ever | yes/no – reference present | yes/no - reference ever | yes/no – reference ever |
| Depression | yes/no - reference ever | yes/no - reference present | yes/no - reference ever | yes/no - reference ever |
| Insomnia | yes/no - reference ever | - | - | yes/no - reference ever |
| Other | yes/no - reference ever | - | yes/no - reference ever | yes/no - reference ever |
| COVARIATES | | | | |
| a) Anthropometric variables | | | | |
| Age | Discrete | Discrete | Discrete | Discrete |
| Weight | Continuous | Continuous | Continuous | Continuous |
| Height | Continuous | Continuous | Continuous | Continuous |
| BMI | Continuous | Continuous | Continuous | Continuous |
| Biologic sex | Categorical - 3 conditions | Categorical - 2 conditions | Categorical - 2 conditions | Categorical - 2 conditions |
| Gender identity | Categorical - 3 conditions | - | Categorical - 3 conditions | - |
| b) Individual socioeconomic variables | | | | |
| Education level | Categorical - 9 conditions | Categorical - 13 conditions | Categorical - 11 conditions | Categorical - 9 conditions |
| Occupational status | Categorical [CNO11] | Categorical [CNO11] | Categorical [CNO11] | Categorical [CNO11] |
| Household size | Discrete | Discrete | Discrete | Discrete |

| Population Health Survey Variables | Study areas | | | |
|---|---|---|---|---|
| | A.C. Basque Country | A.C. Andalusia | Barcelona city | Valencian Community |
| Household income | Categorical - 11 conditions | - | - | Categorical - 8 conditions |
| Economic difficulty | Categorical - 6 conditions | Categorical - 6 conditions | Categorical - 6 conditions | Categorical - 6 conditions |
| Employment status | yes/no | yes/no | yes/no | yes/no |
| Country of birth | Categorical & Open | Categorical & Open | Categorical & Open | Categorical & Open |
| Marital status | Categorical - 6 conditions | Categorical - 5 conditions | Categorical - 5 conditions | Categorical - 5 conditions |
| **c) Lifestyle factors** | | | | |
| Alcohol consumption | Categorical - 8 conditions | Categorical - 10 conditions | Categorical - 4 conditions | Categorical - 8 conditions |
| Passive smoking at home | Likert 1-5 | yes/no | Discrete (Nº smokers) | yes/no |
| Daily tobacco consumption | yes/no | Categorical - 4 conditions | Categorical - 3 conditions | Categorical - 4 conditions |
| **e) Physical Health** | | | | |
| Chronic health problems | Categorical - 38 conditions | Categorical - 25 conditions | Categorical - 25 conditions | Categorical - 21 conditions |
| **d) Mobility** | | | | |
| Years at household | Discrete | - | Discrete | Discrete |
| MEDIATORS | | | | |
| **a) Physical activity** | | | | |
| Physical activity | Discrete - IPAQ | Discrete - IPAQ | Discrete - IPAQ | Discrete - IPAQ |
| - Vigorous | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Moderate | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Walking | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Sitting | Time spent (hours + minutes) | Time spent (hours + minutes) | Time spent (hours + minutes) | Time spent (hours + minutes) |
| **b) Social cohesion** | | | | |
| Social support | Ordinal 1-5 [Duke / 11 items] | Ordinal 1-5 [Duke / 11 items] | Ordinal 1-5/1-4 [OSLO/ 3 items] | Ordinal 1-5 [Duke / 11 items] |
| Loneliness | Ordinal 1-4 | Ordinal 1-4 | Ordinal 1-4 | Ordinal 1-4 |
| SUBJECTIVE URBAN ENVIRONMENTAL EXPOSURES | | | | |
| **a) Perception of the neighbourhood** | | | | |
| Noise outside dwelling | Likert 1-3 | Likert 1-3 | Likert 1-5 | Likert 1-3 |
| Neighbourhood air pollution | Likert 1-3 | Likert 1-3 | - | Likert 1-3 |
| Shortage of green spaces | Likert 1-3 | Likert 1-3 | - | Likert 1-3 |
| Insecurity | Likert 1-3 | Likert 1-3 | Likert 1-5 | Likert 1-3 |

[1] The subjects are provided with a list of medications and are asked if they have consumed any of them in the last 2 days or 2 weeks depending on the study area.

[2] Subjects are provided with a list of chronic health problems and are asked if they currently suffer or have ever suffered (depending on the study area) from any of them.

1

### A) Prevalence of common mental disorders in Spain.

A recent report published by the Spanish National Health System (2020), based on a representative sample of users of said system, found that the overall prevalence of mental health problems in Spain is 27.4%. The most common general mental health issues were anxiety, depression, and sleep disorders, with a prevalence of 6.7%, 4.1%, and 5.4%, respectively. Higher prevalence of these disorders was observed in the female population, those born in Spain and with increasing age. The same report notes that in the case of anxiety and depression, a clear social gradient is observed, with both disorders being 3.4 and 2.5 times more prevalent in the population with lower income levels. In the case medication prescriptions, anxiolytics, antidepressants, and hypnotics were prescribed at rates of 34% for women and 17% for males over 40. The 2020 European Health Survey revealed no discernible territorial differences in the prevalence of chronic mental health conditions among individuals aged 15 and older in Spain. However perceived health status showed slight regional disparities, with Valencia reporting the highest percentage of "bad or very bad" health at 9.4%, followed by Andalucía (7.4%), the Basque Country (7%), and Catalonia (4.9%). However, given that the results presented in this report pertain to a timeframe predating the onset of the COVID-19 pandemic, it is anticipated that the prevalence of these conditions has risen universally among all age groups and regions (Henares Montiel et al., 2020). This increase can be attributed to escalated stress and health-related concerns stemming from the pandemic, exacerbated by associated constraints like lockdown measures and the resultant impact on mental health care services during the pandemic (Balluerka et al., 2020).

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**Section 4. DATA MANAGEMENT PLAN**

A) RESEARCH ACTIVITIES

Step 1. Population Health Surveys' (PHS) data curation and calibration

The selected individuals were contacted by a phone call, SMS, or letter to arrange an appointment for a face-to face interview for the purpose of the survey. The database produced with the interviews will be pseudonymised from that with the personal data for the contact by assigning a unique code for each participant and remains under the custody of the responsible body in each study area; the Basque Department of Health in the Basque Country, Escuela Andaluza de Salud Pública (EASP) in Andalusia, Agència de Salud Pública de Barcelona (ASPB) in Barcelona, and Conselleria de Salut Universal i Salut Pública (DGSP) in Valencian Community.

Step 2. Harmonisation

Initially, the databases of each study area will be cleaned, and the variables that require it will be harmonised. The vast majority of the variables to be used in the project have been collected identically in the Population Health Surveys of the study areas included. The variables to be harmonized are listed below and the measures used in each study area can be found in Table S2.

The variables that need harmonisation can be distinguished between simple or complex variables, depending on the level of difficulty and the manipulation of data that require the harmonisation of the respective variable:

- Simple variables: Chronic mental health problems, Educational level, Occupation status, Household income, Loneliness, Noise outside dwelling, and Insecurity.

- Complex variables: mental health, health-related quality of life, sleep quality, consumption of medication for common mental disorders, alcohol consumption, passive smoking at home, tobacco consumption, physical health, and social support.

The Maelstrom Research Guidelines for the rigorous harmonisation of retrospective data (77) will be applied. Among the variables that need harmonisation, the majority can be easily re-categorised (simple variables). For instance, in the case of scales with different score ranges (e.g., Likert scale levels), standardised scores will be calculated, or other procedures will be followed to ensure comparability. The procedure to follow with variables measured with different scales will be more complex (complex variables). For these, the content of each variable will be studied to detect the common content (e.g., items) in each of the study areas. Once detected, aggregate scores will be calculated for the common items, and these scores will be used for statistical analyses. The remaining non-harmonizable variables will be assessed for their potential for performing separate statistical analysis for each study area.

Step 3. Georeferentiation

The responsible bodies, in collaboration with regional Statistical Institutes or Population Registers, will link the health survey data to the geographical coordinates of each respondent's home address. The geographical coordinates will also be pseudonymised and sent this way to the research group specialised in Geographic Information System (GIS) estimations that will calculate UrbEE. In order to further ensure the protection of the personal data of the survey participants and enhance their anonymity, fictional coordinates will be created in a number five times the number of participants selected for the study in each study area and sent to the research group specialised in GIS estimations together with the real coordinates.

Step 4. GIS estimation of Urban Environmental Exposures (UrbEE)

A company specialised in GIS estimations will calculate the objective urban environmental exposures (UrbEE) of all the geocodes, including the participants' coordinates and the fictional coordinates by GIS.

Step 5. Selection and linkage of data

After the estimations are finalised, the responsible bodies of the surveys in each study area will re-select the geocodes of the participants and add the new urban environmental variables to the database with the PHS data. The researchers will be provided with the resultant database of each study area composed by the PHS data and the UrbEE (without geocodes and personal data of the participants). This guarantees that the data supplied are protected by statistical secrecy, not misused and treated anonymously and globally at all times.

Step 6. Pooling

Finally, the final databases of all the study areas will be pooled, creating the final pooled database to be used in the planned analyses.

B) DATA STORAGE AND PROCESSING

Data will be kept at all times on servers located in the responsible centre of this project. This way, data will be stored on the University of the Basque Country UPV/EHU's own servers, complying with the greater security and privacy requirements of the LOPD as the data is not sent to external servers. The entire process of recording, dumping and storage of the data will be anonymised, with the data collected being exclusively linked to a sample unit code. Access to the anonymised microdata will be limited to technicians from the responsible centres of each study area through profiles with regulated permissions that allow for supervising and controlling access to the information. Supervision of the data management will be assigned to the principal investigators with expert advice, and to the data protection officer of the centre responsible for the project.

C) ETHICAL CONSIDERATIONS AND ACCOUNTABILY

The study was approved by the regional Research Ethics Committee of the **Basque Country**, ETHICS COMMITTEE FOR RESEARCH INVOLVING MEDICINAL PRODUCTS IN THE BASQUE COUNTRY (CEIm-E) (protocol code PI2022138, dated 9th November 2022); **Andalusia**, BIOMEDICAL RESEARCH ETHICS COMMITTEE OF THE PROVINCE OF GRANADA (CEI/CEIM GRANADA) (protocol code 2078-N-22, dated 27th December 2022); **Barcelona**, PARC DE SALUT MAR CLINICAL RESEARCH ETHICS COMMITTE (CEIm) (protocol code 2022/10667, dated 2nd December 2022); **Valencian Community**, ETHICS COMMITTEE FOR CLINICAL RESEARCH OF THE DIRECTORATE GENERAL OF PUBLIC HEALTH AND CENTER FOR ADVANCED RESEARCH IN PUBLIC HEALTH (CEIC DGSP / CSISP) (protocol code 20221125/04, dated 25th November 2022).

This study is based on secondary data obtained from four independent Population Health Surveys (PHS) from Spain. Since the present study does not involve the activity of data collection, to obtain the informed consent from the subjects is not applicable for this study. However, the PHS included this project are official statistical operations included in the respective Statistical Plans of each study area. This ensures that the data provided is protected by statistical confidentiality, it is not misused, its treatment is anonymous and global at all times, and that indirect identification is impossible. Data are collected and processed in accordance with the provisions of the General Data Protection Regulation (GDPR) and in accordance with the provisions of Article 5 of the Organic Law 3/2018 of 5 December on the Protection of Personal Data and the guarantee of digital rights (Regulation (EU) 2016/679), they will be treated confidentially, with access to them being granted to personnel who strictly need to process them in the framework of the study.

Furthermore, the transfer of data occurs between organisations within the Public Health System of each region and the regional or local government itself. This is done in the context of a research project conducted exclusively in the public sphere and with the legitimacy of the use of administrative records as research infrastructures in accordance with the General Health Act, the Biomedical Research Act and the General Law on Public Health. The results of the study will provide information at a sufficiently aggregated territorial level to prevent indirect identification. Furthermore, the project's results will be beneficial to the general population in a holistic way, thanks to its socioeconomic and environmental context, and its evolution over several years from the onset of the COVID-19 pandemic. Therefore, the risk to the privacy of the study population is minimal compared to the potential benefits the results will bring.

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# Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project), study protocol.



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## Abstract

**Introduction:** The European Environment Agency estimates that 75% of the European population lives in cities. Despite the many advantages of city life, the risks and challenges to health arising from urbanization need to be addressed in order to tackle the growing burden of disease and health inequalities in cities. This study, *Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain* (DAS-EP project), aims to investigate the complex association between the urban environmental exposures (UrbEEs) and health.

**Methods and analysis:** DAS-EP is a Spanish multiregional cross-sectional project that combines Population Health Surveys (PHS) and Geographical Information System (GIS) allowing to collect rich individual level data from 17,000 adult citizens participating in the PHS conducted in the autonomous regions of the Basque Country, Andalusia, and the Valencian Community, and the city of Barcelona in years 2021 to 2023. This study focuses on the population living in cities or metropolitan areas with more than 100,000 inhabitants. UrbEEs are described by objective estimates at participants' home addresses by GIS, and subjective indicators present in PHS. The health outcomes included in the PHS and selected for this study are self-perceived health (general and mental), prevalence of chronic mental disorders, health-related quality of life, consumption of medication for common mental disorders, and sleep quality. We aim to further understand the direct and indirect effect between UrbEEs and health, as well as to estimate the impact at the population level taking respondents' socio-demographic and socio-economic characteristics, and lifestyle into consideration.

**Ethics and dissemination:**

The study was approved by the regional Research Ethics Committee of the Basque Country (CEIm-E; PI2022138), Andalusia (CEIM GRANADA; 2078-N-22), Barcelona (CEIC-PSMar; 2022/10667), and Valencian Community (CEIC DGSP/CSISP; 20221125/04). The results will be

communicated to the general population, health professionals and institutions through conferences, reports, and scientific articles.

**Strengths and limitations of this study**

- Multicentric project in Spain with a cross-sectional approach
- Large volume of data from a large sample of participants
- Linkage of four independent population health surveys and environmental exposures
- Inclusion of objective & subjective urban environmental exposures
- Health equity perspective

## 1. Introduction

According to the World Health Organization, modifiable environmental factors are responsible for 23% and 22% of the global mortality and morbidity respectively [1]. As reported by the European Environment Agency, in 2021 75% of the European population lived in urban areas including cities but also smaller urban settlements and suburban areas, developed for residential, industrial or recreational purposes [2]. The local urban environment influences people's health by determining their level of urban environmental exposures (UrbEEss) [3,4]. The UrbEEss include the totality of the surrounding natural (e.g.., green and blue spaces), built (e.g., walkability, urbanisation level, traffic,) and social (e.g.., security, public services) environments within which people live, move, and interact, as well as environmental stressors like air pollution and noise. Increasing evidence shows that UrbEEss such as lack of greenness, air pollution and noise can impact population's mental and physical health and quality of life [5–9]. The health implications of environmental exposures become even more relevant in the contemporary demographic setting, given that they are perhaps starker in urban areas [10–14]. Moreover, in many regions, environmental exposures are not evenly distributed across socioeconomic status and thus, socio-economically vulnerable populations are also affected by poorer environmental quality [10,11]. In fact, this double jeopardy may result in individuals from poorer socioeconomic backgrounds more significantly affected by environmental exposures [4,15]. A comprehensive approach is crucial for understanding the interplay of various environmental determinantswith health and well-being within urban settings. A holistic multi-exposure framework should be adopted, as outlined by Hammersen et al. [16], that extends beyond traditional considerations and incorporates critical urban contextual issues such as substandard housing, crowding, economic inequality, and the evolving challenges posed by climate change, as well as individual psychosocial factors [17,18]).

UrbEEs, including environmental stressors, traffic-infrastructure, natural spaces, and built environment, have all been studied in relation to health. Widespread evidence in the literature shows that air pollution, noise, and lack of green space are related to a range of chronic physical diseases [19–24]. Recently, it has been suggested that air pollution is associated with a range of mental disorders and poorer sleep quality [21,25–28]. Other recent studies observed that environmental noise has negative effects on mental health, well-being, and sleep quality [27,29–31], while evidence on its impact on prescriptions and consumption of medication for common mental disorders has yet to be scientifically confirmed [32]. Otherwise, current scientific evidence indicates that residential greenness is positively associated with mental health and quality of life [31,33,34], and lower consumption of anxiolytics, antidepressants, and sleeping pills [27,35]. Blue spaces (aquatic environments such as rivers, lakes, and the coast) are expected to have similar health effects to those described here, however, evidence on this subject is limited [35,36]. As for the built environment, walkability or accessibility have also been related to reduced obesity and better cardiovascular health [37], improved mental health [38,39] and well-being [40]. To date, the main mechanisms proposed to explain these associations are the mitigation of exposure to environmental pollutants, the promotion of physical activity, and the strengthening of social cohesion [33,34,37,41–43]. Moreover, these mechanisms are probably synergistic [44]. The correlations between several UrbEEs and their relationship with behavioural exposures, such as physical activity and social cohesion, makes the assessment of these associations and pathways highly challenging [45–49]. Hence, noise and air pollution could act both as exposures, mediators, or potential confounders. Overall, results of previous studies are quite mixed and the associations as well as the underlying mechanisms between UrbEEs and mental health outcomes need more robust scientific evidence [5,47,50–52].

This knowledge gap can be partly explained by the heterogeneity and limitations of exposure and outcome metrics used in the studies [19,52,53]. Moreover, there is a lack of studies addressing the impact of UrbEEs on health integrating objective and perceived accounts of such exposures [54]. Therefore, it is evident that more research is needed to determine which UrbEEs are associated with health, the potential mechanisms involved, and the role of social aspects in those associations. Beyond this, researchers are increasingly called to provide information that can guide the selection of the best and most feasible interventions to improve public health in cities. In this respect, experts in the field have claimed the vital role that health impact assessment tools play when integrating the evidence in the decision-making process [55,56].

*Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain* (DAS-EP project) is a 3-year project (2023-2025) aimed at further investigating the associations and underlying mechanisms, including direct and indirect effects, between UrbEEs and health with a health equity perspective. Five main objectives have been established for this project:

1. To estimate, describe, and compare the objective and subjective levels of UrbEEs in the study areas.
2. To describe urban environmental inequalities according to socio-demographic and socio-economic variables, as well as the study area.
3. To estimate the association of UrbEEs with self-perceived general and mental health, health-related quality of life, chronic mental disorders, consumption of medication for common mental disorders, and sleep quality (Figure 1)[1].
4. To estimate the impact of UrbEEs on the health outcomes under evaluation, at the population level, and to conduct a health impact assessment.

[1] For a summary of current prevalence of common mental disorders in Spain, please see section 0 in the Supplementary file.

5. To assess the mediating role of physical activity, social cohesion, and environmental stressors on the association between UrbEEs and the health outcomes under evaluation (Figure 1).

The general hypothesis of this research project is that the urban environment directly or indirectly affects mental health and quality of life. In line with the first objective of the project, we expect significant differences in levels of exposure to urban environmental variables among the cities under study. Regarding the second objective, we expect participants with lower socio-economic status, lower educational levels, and less remunerated occupations to live in residential environments of poorer environmental quality. We expect them to live in areas with less availability of green and blue spaces, lower walkability scores, and higher levels of noise and air pollution. Finally, we expect the various environmental exposures reported in this study to be significantly associated with the various health and mental health variables studied in the project. Notably, we anticipate that air pollution and noise may have negative effects on mental health, while exposure to natural (green and blue), and more walkable spaces will show protective effects against bad mental health. Furthermore, in line with recent literature, we expect that part of these potential effects on mental health might be produced through increased physical activity and social cohesion.

## 2. Methods and analysis

### 2.1. Study design

This is a cross-sectional study based on information from Population Health Surveys (PHS) carried out in adult population living in urban areas, with more than 100,000 inhabitants, in the autonomous regions of the Basque Country, Andalusia, the Valencian Community, and the city of Barcelona in Spain. The study integrates observational data collected within the four independent PHS in 2021-2023 with Geographic Information System (GIS) estimations of individual UrbEEs. It entails the following research activities: 1) preparing, integrating, and calibrating PHS data from each study area, 2) harmonising the variables that have been collected differently in the four study areas, 3) georeferencing survey respondents' home addresses, 4) characterizing each home address in terms of UrbEEs by GIS, 5) linking UrbEEs estimates with PHS data, and 6) pooling of datasets from the four study areas (Figure 2). Using the final pooled database, we will analyse the association between UrbEEs and health in a cross-sectional manner, considering sociodemographic, socioeconomic and lifestyle factors. Figure 1 shows the conceptual framework designed within the scope of this project. DAS-EP received Ethics Approval from the relevant regional ethics committees (see more Supplementary file section 1). This project has received funding from the Instituto de Salud Carlos III (ISCIII) under the Strategic Action in Health with the Health Research Fund (FIS) in the call 2022 (file No. PI22/01051 and No. PI22/00512). The project runs from December 2023 to December 2025.

## 2.2. Study population

The target population are inhabitants of the autonomous communities of the Basque Country, Andalusia, the Valencian Community, and the city of Barcelona.  The sampling frames are made up of people over 15 or 16 years of age of the respective study areas. The study population includes the PHS' participants living in urban areas with more than 100,000 inhabitants in the regions mentioned before (Figure S1, S2). The cities and metropolitan areas participating in this study are: the city of Vitoria-Gasteiz, and the metropolitan areas of Bilbao and Donostia-San Sebastián in the Basque Country; the cities of Almeria, Cadiz, Cordoba, Huelva, Jaen, and the metropolitan areas of Granada, Malaga, and Seville in Andalusia; the cities of Castellon, Valencia, Elche and Alicante in the Valencian Community; and the city of Barcelona (Table S1).

The PHS included in this project are official statistical operations that are incorporated in the Statistical Plans of each study area. These activities are conducted by every regional or local public administration with jurisdiction in health and are a fundamental tool to monitor the status and evolution of relevant health conditions in the population, their main determinants, and the use of health services [57–60]. Accordingly, these regional and local cross-sectional epidemiological surveys are carried out by the Basque Department of Health in the Basque Country [57], Andalusian School of Public Health (EASP) in Andalusia [58], Barcelona Public Health Agency (ASPB) in Barcelona [59], and Foundation for the Promotion of Health and Biomedical Research in the Valencian Region (DGSP) in Valencian Community [60]. They have been organised every 4-5 years since 1986 (Basque Country), 1999 (Andalusia), 1983 (Barcelona) and 1991 (Valencian Community). The sample design and the selection of the sample is carried out independently in each region by the statistical institute (The Basque Institute for Statistics in the Basque Country, Institute of Statistics and Cartography of Andalusia in Andalusia, and municipal statistical office of the Barcelona city council in Barcelona) or health population information system (Valencian Community). Data from the latest version of these surveys is included in this project. After the surveys are completed, we expect a total estimated sample of 16,953 individuals, of which 7,846 participants will be from the Basque Country, 3,085 from Andalusia, 3,134 from the Valencian Community, and 4,000 from the city of Barcelona. More detailed information is provided in Table S1.

## 2.3. Data collection

### 2.3.1. GIS estimates of urban environmental exposures (UrbEEs)

Objective measures of UrbEEs are estimated by a company specialised in GIS based on the geographic coordinates of the participants' home addresses. A significant number of these variables will be expressed in buffers around each participant's residence or at the building level. All environmental exposures will be assessed preceding to, and as close as possible to the time the PHS are being conducted (2021-2023) to avoid temporal mismatch [61]. The objective UrbEEs of interest in this project include exposures originated from surrounding natural spaces, built environment, traffic-infrastructure, and environmental stressors. Detailed information on the UrbEEs estimated within the scope of this project can be found in the Supplementary file (Table S2).

*Surrounding natural spaces*

- Green spaces. Five green space exposure metrics will be calculated in buffers of 100, 300 and 500 m around each geocode: 1) percentage of green space; 2) mean Normalised Difference Vegetation Index (NDVI) [62,63]; 3) percentage of tree cover; 4) Euclidean distance to the nearest green space larger than 5,000 $m^2$ [64], and 5) presence of a major green area (greater than 5,000 $m^2$).
- Blue spaces. Any blue environments, including lakes, rivers, or coastline will be considered as blue space. Three blue space exposure variables will be estimated: 1) presence of water surface; 2) percentage of water surface; and 3) Euclidean distance to nearest water surface greater than 5,000$m^2$. The first two refer 100, 300 and 500 m buffers around each geocode [65].

*Built environment*

- Building density. The building density around each home address in 100, 300 and 500 m buffers will be estimated, considering not only the perimeter of the buildings but also their height [66].
- Walkability. An overall walkability index in 100, 300 and 500 m buffers around the participants' home addresses will be calculated. This index will include of the following subindices: 1) population density (at the census tract level), 2) street density, 3) street connectivity, 4) land use Shannon Evenness Index, 5) facility richness, 6) facility density, 7) average slope, and 8) transport density [67,68].

*Traffic infrastructure*

- Major road (Yes vs. No). Presence of a major road (with >3 million vehicle passages per year) in 100, 300 and 500 m buffers around the participants' home addresses [66].
- Distance to major road. Distance to the nearest major road (with >3 million vehicle passages per year) from the participants home addresses [66].

*Environmental stressors*

- Air pollution. Spatiotemporal daily models at household-level for particulate matter ($PM_{10}$ and $PM_{2.5}$) and nitrogen dioxide ($NO_2$) will be constructed for all study areas using multistage mixed models. These models are known as spatiotemporal land-use random-forest model [69] and combine ground-level and satellite measurements, land use and meteorology. A precise daily estimate of the exposures will be obtained for all study subjects (period 2006 to 2023). Using the daily estimates, annual average for the last five years and the five-year average of $NO_2$, $PM_{10}$ and $PM_{2.5}$ exposure levels will be calculated at PHS respondents' home address as indicators for long-term air quality.
- Environmental noise. The Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge will be used. All potential sources of environmental noise at street level will be examined, including road traffic, rail, industrial, airports and total noise [70,71]. Major roads, major railways, and major airports will be included in cities where this information is available and not included in the agglomeration layer. Agglomerations corresponding to the closest street to the dwelling, and major roads and airports corresponding to the closest isoline will be used. In all cases, the Euclidean distance to each source will also be calculated. The daytime ($L_d$), evening ($L_e$), night-time ($L_n$), and total ($L_{den}$) noise indices will be assigned.

2.3.2. Contextual socioeconomic variables

Neighbourhood-level socioeconomic status (SES) will be considered via three variables, namely, mean income, income distribution P80/P20, and the MEDEA deprivation index (composed by percentage of the population with manual labour, percentage of the population with casual labour, percentage of the population unemployed, percentage of the population with insufficient education, percentage of the population of young people with insufficient education) [72]. All these metrics will be obtained from the publicly available data developed by the Spanish National Institute for Statistics (INE) and expressed at the census tract level (Table S3).

### 2.3.3 Individual socio-demographic and socio-economic variables

To describe respondents' individual-level SES, eight variables will be selected: country of birth, marital status, household size, level of education, employment and occupational status, reported household income, and economic difficulty of the household (Table S4)

### 2.3.4 Information collected through Population Health Surveys

Information from four independent PHS that represent four study areas is included in the study. The surveys are carried out between 2021-2023, being Barcelona city the earliest in completing the collection (2021 February – 2022 March), followed by the Valencian Community (2022 April – 2022 December), Andalusia (2022 April – 2023 April), and the Basque Country (2022 October – 2023 June) (Table S1). During each survey, detailed information is collected though face-to-face interviews and self-administered questionnaires. The PHS collect information on different health aspects, morbidity, and use of health services. It also gathers information on social determinants of health such as socio-economic status, working conditions, social cohesion, health-related behaviours and perception on residential environment. Most of these variables are measured with validated screening tools. The selection of relevant variables to be included in this project was based on a literature review and the most appropriate variables to meet the objectives of the study were selected from among the variables collected by the PHS. All the study areas collected the main variables of the study (i.e., mental health, health-related quality of life, physical activity, social cohesion, and sleep), however, in some cases, the measuring instruments differ across the study areas. Detailed information about the variables and the measuring instruments used in each study area can be found in Table S4.

*Health outcomes*

Several health outcome variables are included in this study.

- Perceived general health. Self-assessment of health was measured as an ordinal response, with five categories (1, Excellent; 2, Very good; 3, Good; 4, Fair; 5, Poor).
- Perceived mental health. This variable was collected with the Mental Health Inventory [73], the SF-12 (Short-Form Health Survey 12) scale [74] or the General Health Questionnaire (GHQ-12) [75].
- Health-related quality of life. This variable was measured with the Euroqol-5D-5L-EAV scale [76] or the SF-12 (Short-Form Health Survey 12) scale [74].
- Sleep duration and quality. The duration of sleep, indicated as the total number of hours per day spent on sleep including napping was calculated. The quality of sleep was collected using the SATED scale (Satisfaction Alertness Timing Efficiency and Duration Scale) [77] or discrete items.
- Prevalence of chronic mental health problems. Participants had to indicate whether they had been diagnosed with depression, anxiety, and sleeping disorders at any time throughout the life. We then built a dichotomized (yes/no) variable for each condition.
- Consumption of medication for common mental disorders. Information on consumption of medication for common mental disorders, such as, anxiolytics, antidepressants and hypnotics was reported on bi-daily or bi-weekly basis depending on the study area.

*Covariates*

A set of individual level variables will be used as control variables in the statistical analyses.

- Anthropometric variables. The surveys collect information on sex, age, weight, and height of individuals. A Body Mass Index (BMI) ($kg/m^2$) will be calculated using information given by the participants about their height and weight at the moment of filling the questionnaire.
- Individual socio-demographic and socio-economic variables. To describe respondents' individual-level SES, eight variables will be selected: country of birth, marital status, household size, level of education, employment and occupational status, reported household income, and economic difficulty of the household.
- Lifestyle factors. These will include consumption habits such as alcohol consumption, passive smoking at home, and tobacco use.
- Physical health. A chronicity index will be calculated based on presence of one or more non-psychological chronic conditions (e.g., diabetes, heart disease, cancer, etc.).

The following social and behavioural variables will be treated as potential mediators.

Social cohesion and loneliness. Social cohesion is measured with the Duke-UNC-11 scale [78] or the OSLO-3 tool [79]. Perceived loneliness is collected with a single item for participants to report about the frequency in which they feel loneliness. The variable is displayed in a 1 to 4 (1= always; 2= often; 3= sometimes; 4= never) response scale.

- Physical activity. The International Physical Activity Questionnaire (IPAQ) [80] to measure the physical activity performed by the participants. Days per week and time spent in vigorous physical activity, in moderate physical activity, and walking more than 10 minutes, and time spent sitting on a normal day will be available.

*Perception of the neighbourhood*

Perceived accounts of UrbEEs are collected through PHS employing 3-point or 5-point Likert format questions depending on the study area. These include: 1) perception of noise outside the dwelling, 2) perception of shortage of green areas in the residential environment, 3) perception of air pollution in the residential environment, and 4) perception of insecurity in the neighbourhood.

### 2.4. Data analysis

Initially, all databases will be cleaned. The variables will be harmonised, when needed, following the Maelstrom Research Guidelines for rigorous harmonisation of retrospective data [81]. Nonetheless, because most variables have already been collected consistently in the respective Population Health Surveys, few variables will require harmonisation (Table S4). Among the few variables requiring harmonisation, most will be re-categorised. For more information, see Supplementary file section 5. Subsequently, both exploratory and descriptive analysis will be applied using numerical and graphical techniques [82]. Before proceeding to inference, sample weights for each survey will be adjusted through calibration [83], so that we may compensate for non-response and coverage biases and improve accuracy. This calibration will be carried out separately for each study area, so that region-level estimates are obtained first, and then harmonized to obtain estimates at population level.

The relationships between the various UrbEEs and health outcomes will be analysed according to the multilevel, or hierarchical structure [84] that the data possesses, as census tracts are nested within cities, and cities are nested within autonomous regions. Generalised linear mixed models (GLMMs) will be applied to investigate the relationship between urban environment and health. The sets of adjustment covariates used in these models will be chosen by applying robust causal inference techniques based on directed acyclic graphs (DAGs) [85], both for the estimation of direct effects and hypothetical indirect effects mediated by air pollution, environmental noise, physical activity, and social cohesion. This will imply the prior design of a DAG describing the relationships among UrbEEs, health outcomes and other potentially implicated variables [86,87]. The testable implications derived from this DAG will be checked following the procedure described by Ankan and colleagues [88], thereby updating the

DAG if needed [89,90]. These graphical models will guide the inclusion of relevant socio-demographic and socioeconomic variables, allowing us to account for potential confounding factors and illuminate causal relationships. The length of time living in the same home/place will be considered by excluding individuals living at the same place of residence for less than one and less than five years in separate models. Equity will be addressed performing subgroup analysis to investigate potential vulnerable groups such as lower-income populations, the elderly, women, and marginalized communities.

In case of demonstrating a significant relationship between a given exposure and a certain outcome, we also intend to identify the specific exposures that cause most disease in the populations of interest via the population attributable fraction (PAF) [91]. To estimate the PAF we will require previous estimations of relative risk (RR) and either the prevalence of exposure in the population or the prevalence of exposure among the cases of disease. All these previous estimates will be available. The possible existence of spatial clusters in the UrbEEs distribution will also be studied using the standard spatial scan statistic method [92] and calculating the posteriori probabilities for the smoothed standardised ratios to be greater than unity, in the general framework of Bayesian hierarchical standardised ratio smoothing models.

The analyses will be implemented using the latest version of the R software packages *dagitty* [85], *DClusterm* [93,94], *R INLA* [95], *Sampling* [96] and others.

### 2.5. Data Management Plan

The data management plan can be found in the Supplementary file section 5. The source and type of data that will be collected within the scope of this project is described in this plan, together with the accessibility and ownership of data. Data storage and processing, as well as the procedure to guarantee the specific ethical and legal requirements, are likewise explained.

### 2.6. Patient and Public Involvement

Patients and the public will not be involved in the design, or conduct, or reporting, or dissemination plans of our research.

## 3. Discussion

The present study is a clear commitment to the generation of urban environmental indicators potentially explanatory of self-perceived health (physical and mental), chronic mental disorders, health-related quality of life, consumption of medication for common mental disorders and sleep quality with a health equity perspective. This project responds to the national Spanish Strategic Plan for Health and the Environment (PESMA) 2022-2026 [97], to the local implementation of the Strategy for Health Promotion and Prevention in the National Health System [98] as well as to the main objective of the Spanish Urban Agenda 2019 [99] that cities should have a global vision that takes into consideration the physical, mental, and social well-being of their inhabitants. Likewise, it is aligned with three of the Sustainable Development Goals (SDG) of the World Health Organization (SDG.3 - Good Health and Well-being, SDG.10 – Reduced Inequalities, and SDG.11 – Sustainable Cities and Communities) (97,98).

When it comes to health-promoting urban and transport design, there is a lack of standardized, quantitative indicators to guide the integration of health components right from the outset [57,100]. In this context, the DAS-EP project not only aims to obtain individual UrbEEs estimates but also to assess their association with, and impact on various health outcomes. By means of PHS, the health effects to be studied in this project are derived from an unbiased population, which allows to obtain an approximate estimate of the impact at population level. Moreover, it is important to identify the precise routes that connect urban environment to health because they can guide the most efficient interventions, allowing us to design healthy(er) cities [55,101]. In this sense, the DAS-EP project investigates various components of the urban environment and health at individual level. Besides using complementary indicators that describe both the physical and the social urban environment (e.g., neighbourhood insecurity), combines objective and perceived indicators to deepen the characterization of the urban environment. By combining these data, it is possible to develop a more precise understanding of the effects of urban environment on health, while describing the complexity of the relationship influenced by neighbourhood environmental and individual characteristics [102–104].

The main limitation of this study is its cross-sectional nature. Due to the chronic character of the health conditions included in the study (e.g., depression, insomnia) and the possible long-term effects of UrbEEs, a longitudinal design would be more informative and appropriate. Although PHS have a cross-sectional approach, the question "since when have you been living at your current address" enables to account for the extent of exposures. Drawing on this mobility data, sensitivity analysis of the models will be fitted reducing the risk of exposure misclassification. Another limitation is that the samples from the study areas of the Basque Country, Andalusia, and Valencian community, although representative of the study population (considering the inclusion criteria) may not be representative of the autonomous communities from which they come as we are not considering the non-urban municipalities (<100,000 inhabitants). Despite the weight calibration to be conducted to reduce coverage and representativeness biases, the reweighing procedure will not guarantee the elimination of other response biases that may affect data collection from PHS (as acquiescence, social desirability, etc.) which could affect the validity of the results [105,106]. Furthermore, the project is subject to residual confounding, which in turn implies confounders that could not be controlled and, importantly, measurement errors in the confounders that have been included. In this regard, the estimation UrbEEs by GIS is affected by the problem of uncertainty of the temporal and geographical context [107].

The use of buffer zones may not be appropriate to evaluate contextual effects on health because they fail to analyze the spatial-temporal distribution of residents' activities and their relationship with built environment factors. Using activity space measures would be preferable to comprehensively assess of environmental exposures by capturing the complexity of individual movements [108–110]. The reliance on publicly available data applicable to all study areas together with scalability challenges were major barriers to estimate street-level (or microscale) variables like bicycle and pedestrian infrastructure [111–113]. Moreover, future studies should not only include more variables reflecting the social capital (e.g., perceived sense of community) but also analyse the health implications of other relevant urban exposures like substandard housing, crowding, and indoor air pollution. Finally, the heterogeneity across study areas in terms of geographic scale (autonomous communities vs. city) may be a source of information bias. In this vein, the majority -but not all- of the scales and variables included in the different PHS are identical. These minor differences in data collection across PHS may lead to additional information biases hindering the comparability of the data. To minimize this problem, special attention will be paid to the selection and harmonization of the variables to be included to ensure the consistency of data before making the comparisons across study areas.

As for the strengths of this project, pooling linked surveys across study areas will make it possible to compare the results in different populations, providing a comprehensive dataset that is larger than most existing cohort studies, and that have an unique national and population perspective. The results will be novel in terms of their thematic (objective & subjective UrbEEs) and methodological approach (combination of PHS from different study areas and GIS estimates), as well as in terms of the large volume of information that will be handled and the large sample size of the study. Beyond that, the standardization of the procedure described herein will generate useful information to assist in the planning of national health surveillance programs, research studies and, more importantly, interventions to strengthen population's health.

In short, the results and products (i.e., databases, computer codes) of this project will greatly contribute to estimate the proportion of the population exposed to different UrbEEs, identify health disparities while considering UrbEEs, estimate how these exposures relate to and affect various health variables, and conduct a health impact assessment of UrbEEs. We will have taken a further step towards understanding and improving the urban environment and being able to establish corrective measures in the urban development plans of the cities.

# Declarations

## Ethics and dissemination

The study was approved by the regional Research Ethics Committee of the **Basque Country**, ETHICS COMMITTEE FOR RESEARCH INVOLVING MEDICINAL PRODUCTS IN THE BASQUE COUNTRY *(CEIm-E)* (protocol code PI2022138, dated 9th November 2022); **Andalusia**, BIOMEDICAL RESEARCH ETHICS COMMITTEE OF THE PROVINCE OF GRANADA (CEI/CEIM GRANADA) (protocol code 2078-N-22, dated 27th December 2022); **Barcelona**, PARC DE SALUT MAR CLINICAL RESEARCH ETHICS COMMITTE (CEIm) (protocol code 2022/10667, dated 2nd December 2022); **Valencian Community**, ETHICS COMMITTEE FOR CLINICAL RESEARCH OF THE DIRECTORATE GENERAL OF PUBLIC HEALTH AND CENTER FOR ADVANCED RESEARCH IN PUBLIC HEALTH (CEIC DGSP / CSISP) (protocol code 20221125/04, dated 25th November 2022). The results will be communicated to the general population, health professionals and institutions through conferences, reports, and scientific articles.

## Competing interests

The authors declare that they have no competing interests.

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## Authors' contributions

Conceptualisation, A.L., A.C.-L., M.S-P

Methodology, A.L., A.C.-L., M.S-P

Writing, original draft preparation, A.B., A.L., M.S-P., A.C-L

Writing, review and editing, A.B., A.L., M.S-P., A.C-L., S.C.G., G.G-B., S.D.G., F.B., M.E., A.M., A.E., M.A.I., C.B., R.M., L.F-R., X.B., K.P., L.O., A-C.B., A.D., L.G., H.G.C., M.L.N., R.C., M.M.R., M.S

Project administration, A.L., A.C-L., A.B., M.S-P

Funding acquisition, A.L., A.C-L., M.S-P

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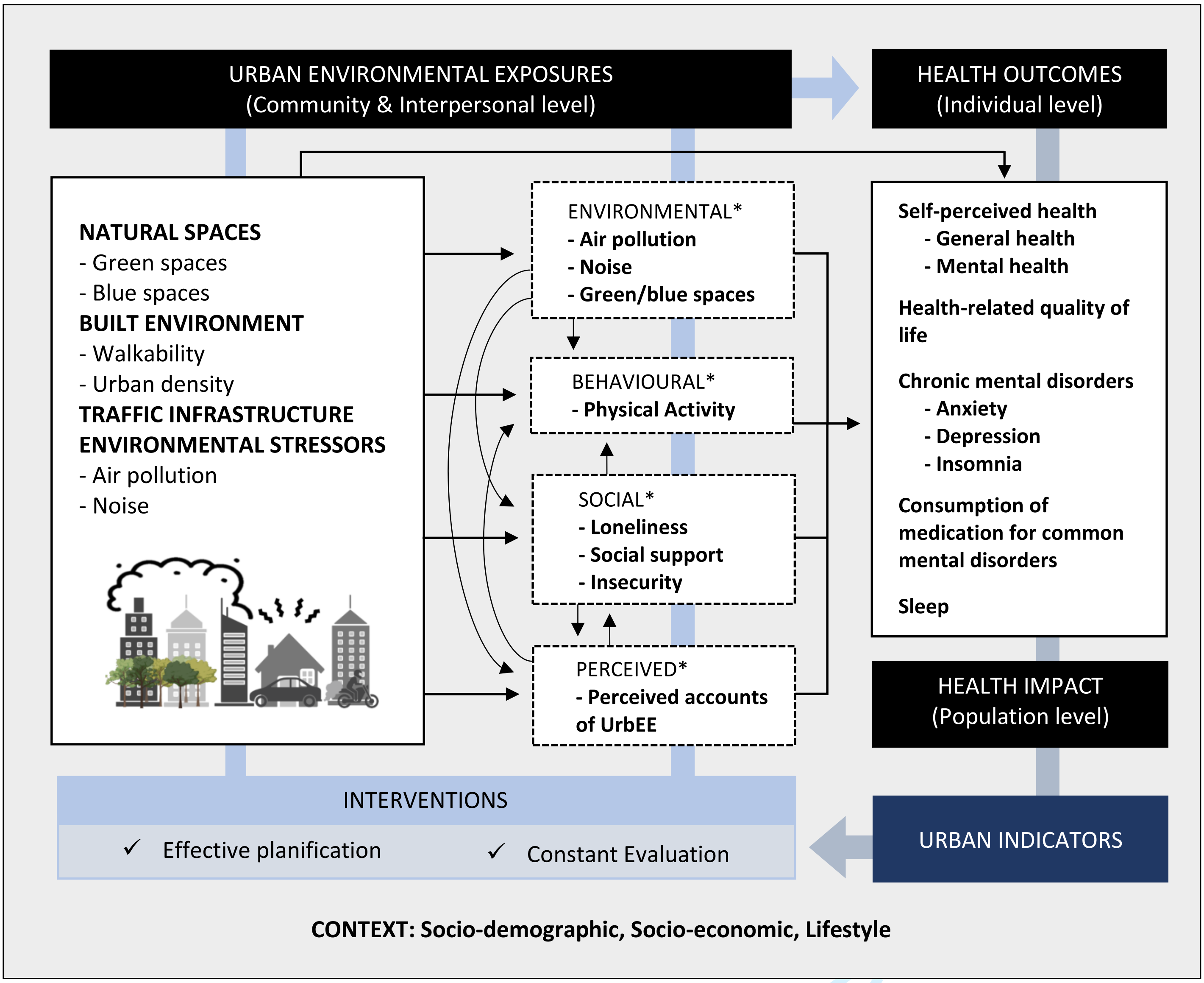
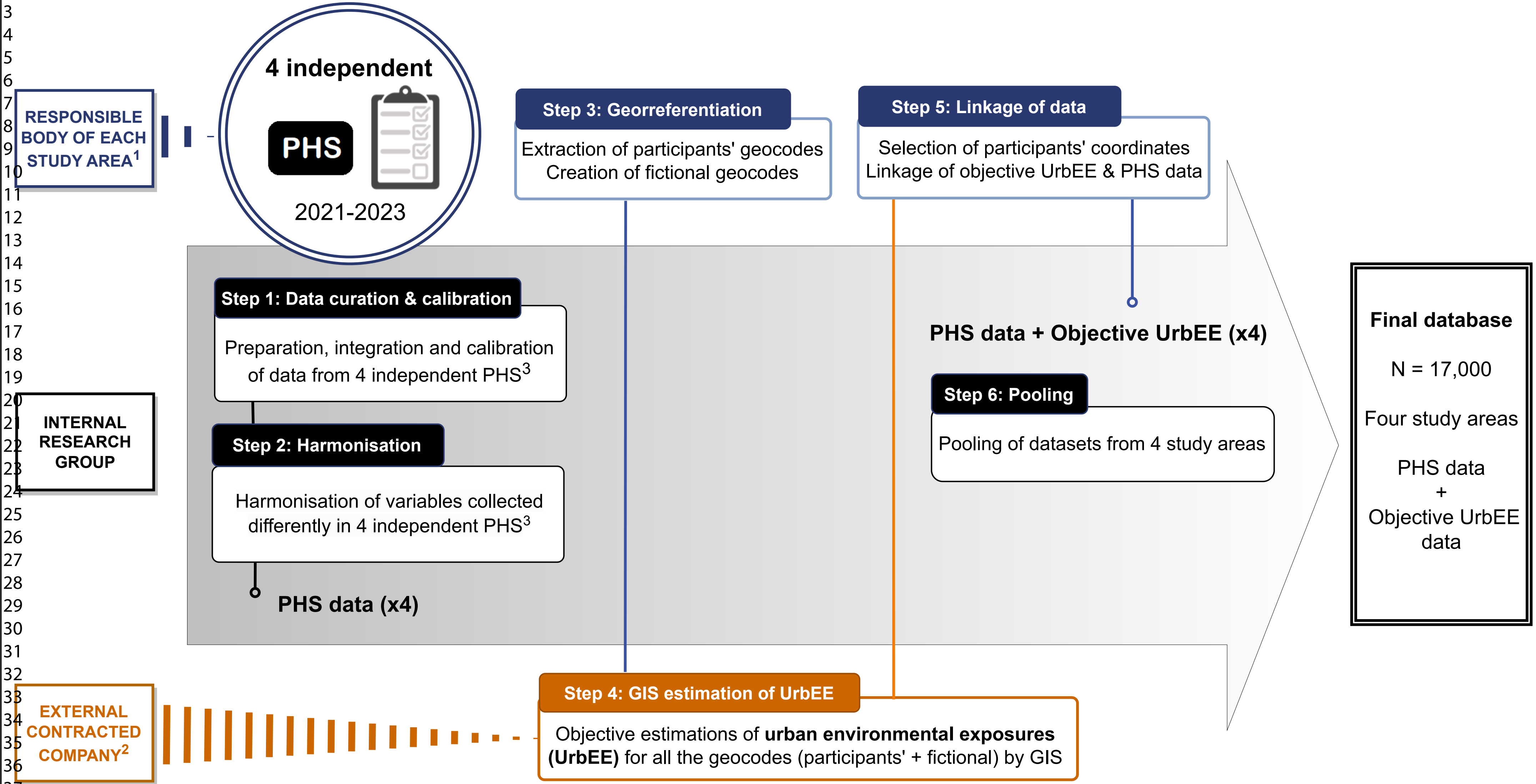
## Legends

**Figure 1.** Conceptual framework designed within the scope of this project, including potential direct and indirect effects of urban environmental exposures (UrbEEs) on the health outcomes under study. * Potential mediators on the association between UrbEEs and the health outcomes under evaluation.

**Figure 2.** Summary of data management plan and the institutions involved during the development of the final database (DB) to be used by the research group in the analyses.


URBAN ENVIRONMENTAL EXPOSURES
(Community & Interpersonal level)
HEALTH OUTCOMES
(Individual level)
NATURAL SPACES
- Green spaces
- Blue spaces
BUILT ENVIRONMENT
- Walkability
- Urban density
TRAFFIC INFRASTRUCTURE
ENVIRONMENTAL STRESSORS
- Air pollution
- Noise
ENVIRONMENTAL*
- Air pollution
- Noise
- Green/blue spaces
BEHAVIOURAL*
- Physical Activity
SOCIAL*
- Loneliness
- Social support
- Insecurity
PERCEIVED*
- Perceived accounts of UrbEE
Self-perceived health
- General health
- Mental health
Health-related quality of life
Chronic mental disorders
- Anxiety
- Depression
- Insomnia
Consumption of medication for common mental disorders
Sleep
HEALTH IMPACT
(Population level)
INTERVENTIONS
✓ Effective planification
✓ Constant Evaluation
URBAN INDICATORS
CONTEXT: Socio-demographic, Socio-economic, Lifestyle




[1] Responsible body of the Population health survey (PHS) from each study area: the Basque Department of Health (Basque Country), Escuela Andaluza de Salud Pública (EASP) (Andalusia), Agència de Salud Pública de Barcelona (ASPB) (Barcelona), and Conselleria de Salut Universal i Salut Pública (DGSP) (Valencian Community).

[2] External contracted company specialised in GIS estimations.

[3] For each PHS carried out in the study areas of the autonomous communities of the Basque Country and Andalusia, Valencian Community, and the city of Barcelona.

# Supplementary file

**File name:** Supplementary file_DAS-EP

**File format:** Word document (.docx)

**Title of data:** Supplementary data of Urban Environment and Health: a cross-sectional multiregional project based on Population Health Surveys in Spain (DAS-EP project), study protocol.

**Table of contents**

**Section 1. GENERAL CHARACTERISTICS OF THE STUDY AREAS**

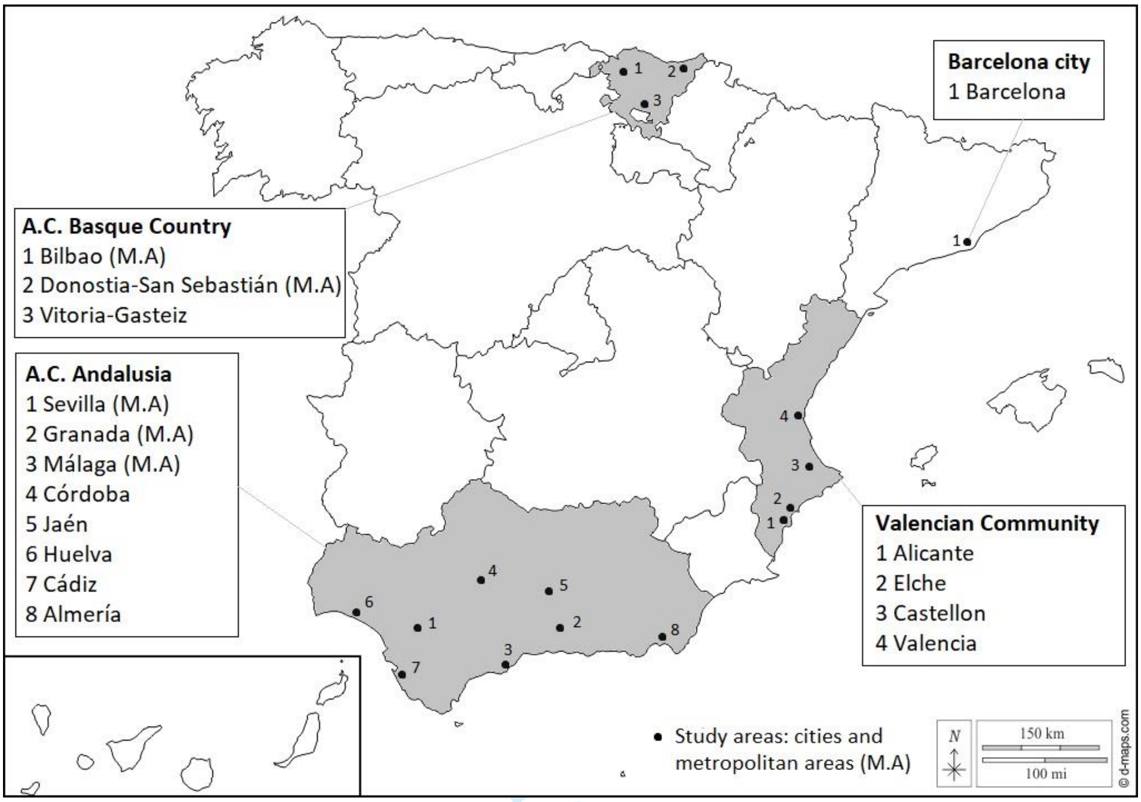



**Figure S1.** Study areas of the project, being the cities and metropolitan areas (M.A) with more than 100,000 inhabitants from the autonomous communities of the Basque Country and Andalusia, Valencian Community, and the city of Barcelona. Figure edited from Daniel Dalet / d-maps.com.

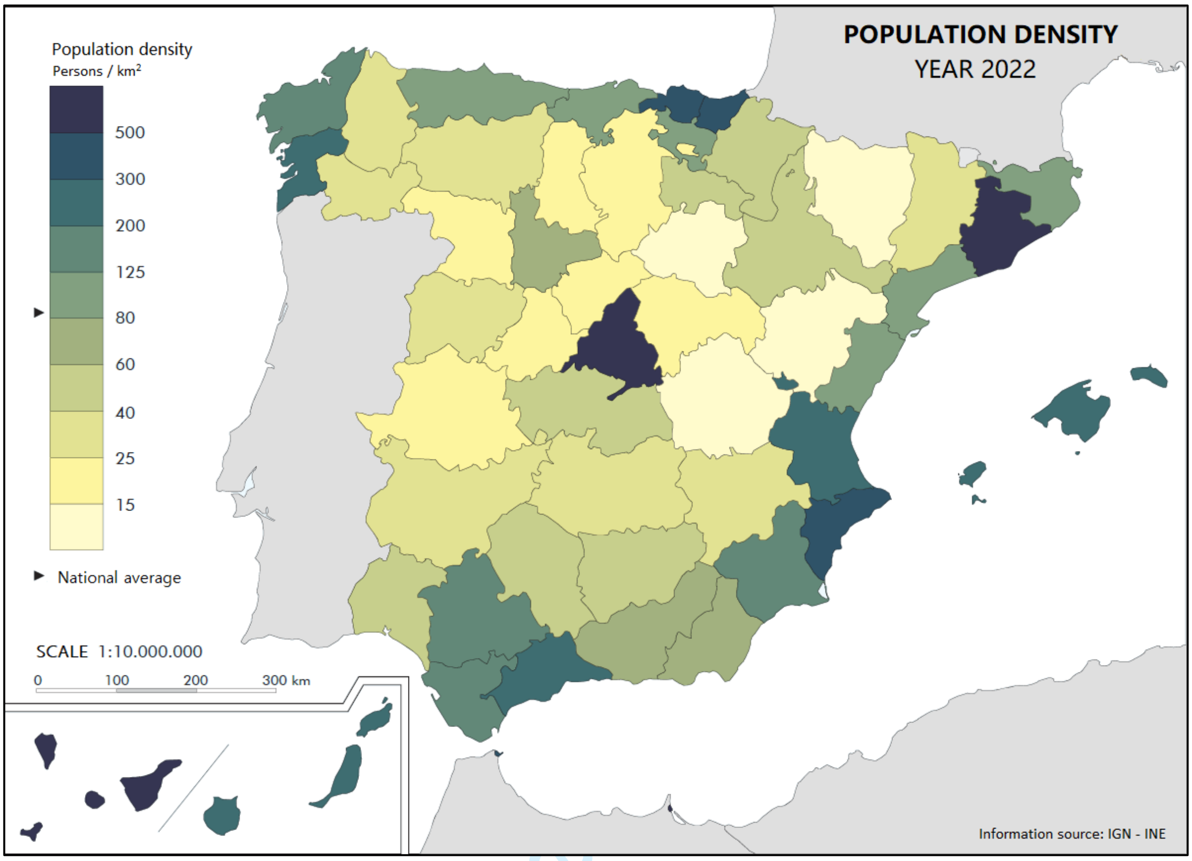



**Figure S2.** Population density of Spanish provinces in 2022. Figure edited from Instituto Geográfico Nacional, *La población en España 2022*. Accessed through: https://www.ign.es/pobesp/pe1.htm

**Section 2. GENERAL CHARACTERISTICS OF THE POPULATION HEALTH SURVEYS**

**Table S1.** Characteristics of the study areas and the population health surveys comprised in the project.

| Study area | Cities and areas of influence | Population health survey | Responsible body | Sample size | Data collection period |
|---|---|---|---|---|---|
| A.C. Basque Country | Vitoria-Gasteiz<br>Donostia-San Sebastián (M.A)<br>Bilbao (M.A) | Encuesta de Salud de la Comunidad Autónoma País Vasco (ESCAV) | ✓ Basque Department of Health | 7,846 | 2022 October – 2023 June |
| A.C. Andalusia | Almería<br>Cádiz<br>Córdoba<br>Huelva<br>Jaén<br>Granada (M.A)<br>Malaga (M.A)<br>Sevilla (M.A) | Encuesta Andaluza de Salud (EAS) | ✓ Andalusian School of Public Health (EASP) | 3,085 | 2022 April – 2023 April |
| Barcelona city | Barcelona | Encuesta de Salud de Barcelona (ESB) | ✓ Barcelona Public Health Agency (ASPB) | 4,000 | 2021 February – 2022 March |
| Valencian Community | Castellon<br>Valencia<br>Elche<br>Alicante | Encuesta Salud Comunidad Valenciana (ESCV) | ✓ Foundation for the Promotion of Health and Biomedical Research in the Valencian Region (DGSP) | 3,134 | 2022 April – 2022 December |

Abbreviations: A.C., Autonomous community; M.A, Metropolitan Area.

**Section 3. OVERVIEW OF THE VARIABLES OF THE STUDY PER STUDY AREA**

**Table S2.** Objective urban environmental exposures obtained through GIS estimations.

| GIS Variables | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona | |
|---|---|---|
| OBJECTIVE URBAN ENVIRONMENTAL EXPOSURES | Scale | Variable |
| a) Surrounding natural spaces | | |
| Green Spaces | | |
| Green space percentage | 100, 300, 500m buffers | Percentage of green space. |
| NDVI | 100, 300, 500m buffers | Annual mean Normalised Difference Vegetation Index (NDVI) of the year when the surveys were conducted and the mean NDVI of the last 5 years previous to the surveys. |
| Tree percentage | 100, 300, 500m buffers | Percentage of tree cover based on Growing stock volume (GSV) data. |
| Distance to green space | | Euclidean distance to the nearest major green space (green surface over 5,000m$^2$). |
| Green spaces Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of major green spaces (green surface over 5,000m$^2$) from local topographical or Europe-wide maps (Urban atlas). |
| Blue spaces | | |
| Blue spaces Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of water surfaces. Based on Urban Atlas. |
| Blue space percentage | 100, 300, 500m buffers | Percentage of water surface. Based on Urban Atlas. |
| Distance to blue space | | Euclidean distance to the nearest water surface over 5,000m$^2$. Based on Urban Atlas. |
| b) Built environment | | |
| Building density | 100, 300, 500m buffers | The building density around each household will be calculated accounting for the perimeter and height of the buildings from local cadastre data or Europe-wide maps (Urban Atlas). |
| Population density | 100, 300, 500m buffers | The number of inhabitants (per km$^2$) surrounding the home addresses. |
| Street connectivity | 100, 300, 500m buffers | Using data from OpenStreetMap® . |
| Accessibility (bus lines) | 100, 300, 500m buffers | Access to public transport bus lines from local topographical maps or OpenStreetMap®. |
| Accessibility (bus stops) | 100, 300, 500m buffers | Access to public transport bus stops from local topographical maps or OpenStreetMap®. |
| Facility richness | 100, 300, 500m buffers | Using local topographical maps or OpenStreetMap®. |
| Facility density | 100, 300, 500m buffers | Using local topographical maps or OpenStreetMap®. |
| Land use | 100, 300, 500m buffers | Mixed land use will be estimated by Shannon's Eveness Index based on Urban Atlas data. |
| Walkability index | 100, 300, 500m buffers | Index constructed from seven indicators: population density, street connectivity, street density, facility richness, facility density, land use, transport density, and average slope. |
| c) Traffic infrastructure | | |
| Major road Yes (vs. No) | 100, 300, 500m buffers | Dichotomous variable of presence of a major road (OpenStreetMap®). |
| Inverse distance | | Inverse distance to the nearest major road (OpenStreetMap®). |

| GIS Variables | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona | |
|---|---|---|
| OBJECTIVE URBAN ENVIRONMENTAL EXPOSURES | Scale | Variable |
| d) Environmental stressors | | |
| Air pollution | | |
| $PM_{2.5}$ | Street level (at residential address) | $PM_{2.5}$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| $PM_{10}$ | Street level (at residential address) | $PM_{10}$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| $NO_2$ | Street level (at residential address) | $NO_2$ exposure indicators include: a) the annual average for the last five years, and b) the five-year average for the last five years based on spatiotemporal land-use random-forest models. |
| Noise | | |
| Day ($L_d$) | Street level (at residential address) | Exposition to environmental noise at street level during the day indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Evening ($L_e$) | Street level (at residential address) | Exposition to environmental noise at street level during the evening indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Night ($L_n$) | Street level (at residential address) | Exposition to environmental noise at street level during the night indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |
| Total ($L_{den}$) | Street level (at residential address) | Total exposition to environmental noise at street level indicated as: a) the annual average for the last five years, and b) the five-year average for the last five years based on Strategic Noise Maps derived under the EU Directive 2002/49/EC from the Ministry for the Ecological Transition and the Demographic Challenge. |

Abbreviations: A.C., Autonomous community; NDVI, Normalised Difference Vegetation Index; GSV, Growing stock volume; $PM_{2.5}$, Fine particulate matter with a diameter of 2.5µm or less; $PM_{10}$, Fine particulate matter with a diameter of 10µm or less; $NO_2$, Nitrogen dioxide

**Table S3.** Area-level socioeconomic (SES) variables obtained through GIS estimations.

| GIS Variables | | Study areas: A.C. s of the Basque Country and Andalusia, Valencian Community & the city of Barcelona |
|---|---|---|
| AREA-LEVEL SES VARIABLES | Scale | Variable |
| a) Mean income | | |
| Average household net income | Census tract | Average household net income. Income data collection is based on standardised annual requests to the different collaborating tax organisations. Data from 2021. Data source INE[1]. |
| Average household gross income | Census tract | Average household gross income. As components of gross income, five exhaustive categories are considered: wages, pensions, unemployment benefits, other benefits, other income. Data from 2021. Data source INE[1]. |
| Average net income per person | Census tract | Net income per person is obtained, for each household, by dividing the net household income by the number of members of said household. Data from 2021. Data source INE[1]. |
| Average gross income person | Census tract | Gross income per person is obtained, for each household, by dividing the gross household income by the number of members of said household. Data from 2021. Data source INE[1]. |
| Average income per consumption unit | Census tract | Equivalised income is a measure of household income that takes account of the differences in a household's size and composition, and thus is equivalised or made equivalent for all household sizes and compositions. The equivalised income is calculated by dividing the household's total net income by its equivalent size, which is calculated using the modified OECD equivalence scale. This scale attributes a weight to all members of the household: 1.0 to the first adult; 0.5 to the second and each subsequent person aged 14 and over; 0.3 to each child aged under 14. Data from 2021. Data source INE[1]. |
| b) Income distribution P80/P20 | Census tract | Ratio between the 80th percentile and the 20th percentile of the income distribution per unit of consumption. Data from 2021. Data source INE[1]. |
| c) Gini index | Census tract | The Gini index measures the degree of inequality in the distribution of income/wealth, used to estimate how far a country's wealth or income distribution deviates from an equal distribution[2]. A Gini coefficient of 0 reflects perfect equality, where all income or wealth values are the same, while a Gini coefficient of 1 (or 100%) reflects maximal inequality among values, a situation where a single individual has all the income while all others have none. Data from 2021. Data source INE[1]. |
| d) MEDEA deprivation index | Census tract | A deprivation index developed to study the social inequalities in health in Spain. The index is composed by percentage of the population with manual labour, percentage of the population with casual labour, percentage of the population unemployed, percentage of the population with insufficient education, percentage of the population of young people with insufficient education[3]. Data from 2021. |

Abbreviations: A.C., Autonomous community; SES., Socioeconomic status

[1] INEbase. Atlas de Distribución de Renta de los Hogares (ADRH). INE. Retrieved 19 December 2023, from https://www.ine.es/metodologia/metodologia_adrh.pdf

[2] Gini, Corrado (1936). "On the Measure of Concentration with Special Reference to Income and Statistics", Colorado College Publication, General Series No. 208, 73–79.

[3] Domínguez-Berjón, M. F., Borrell, C., Cano-Serral, G., Esnaola, S., Nolasco, A., Pasarín, M. I., Ramis, R., Saurina, C., & Escolar-Pujolar, A. (2008). Construcción de un índice de privación a partir de datos censales en grandes ciudades españolas: (Proyecto MEDEA). *Gaceta Sanitaria*, 22(3), 179–187.

**Table S4.** Variables collected through Population Health Surveys.

| Population Health Survey Variables | Study areas | | | |
|---|---|---|---|---|
| | A.C. Basque Country | A.C. Andalusia | Barcelona city | Valencian Community |
| OUTCOMES | | | | |
| a) Perceived health | | | | |
| General Health | Ordinal 1-5 | Ordinal 1-5 | Ordinal 1-5 | Ordinal 1-5 |
| Mental Health | Ordinal 1-5 [MHI/5 items] | Ordinal 1-6 [SF-12/3 items] | Ordinal 1-4 [GHQ-12/12 items] | Ordinal 1-4 [GHQ-12 /12 items] |
| b) Quality of life | | | | |
| Health-related quality of life | Ordinal 1-5 [EuroQoL / 5 items] | Ordinal 1-6/1-5 [SF-12 / 5 items] | Ordinal 1-5 [EuroQoL / 5 items] | Ordinal 1-5 [EuroQoL / 5 items] |
| c) Sleep | | | | |
| Sleep duration | Continuous - Total hours/day | Continuous - Total hours/day | Continuous - Total hours/day | Continuous - Total hours/day |
| Quality of sleep | Ordinal 1-5 [SATED / 5 items] | Ordinal 1-4 [4 items] | Ordinal 1-10 | Ordinal 1-5 [SATED / 5 items] |
| d) Consumption of medication for common mental disorders[1] | | | | |
| Antidepressants | yes/no – reference 2 days | yes/no – reference 2 weeks | yes/no - reference 2 days | yes/no - reference 2 weeks |
| Hypnotics | yes/no - reference 2 days | yes/no - reference 2 weeks | yes/no - reference 2 days | yes/no – reference 2 weeks |
| Anxiolytics | yes/no - reference 2 days | yes/no - reference 2 weeks | yes/no - reference 2 days | yes/no - reference 2 weeks |
| e) Chronic mental health problems[2] | | | | |
| Anxiety | yes/no - reference ever | yes/no – reference present | yes/no - reference ever | yes/no – reference ever |
| Depression | yes/no - reference ever | yes/no - reference present | yes/no - reference ever | yes/no - reference ever |
| Insomnia | yes/no - reference ever | - | - | yes/no - reference ever |
| Other | yes/no - reference ever | - | yes/no - reference ever | yes/no - reference ever |
| COVARIATES | | | | |
| a) Anthropometric variables | | | | |
| Age | Discrete | Discrete | Discrete | Discrete |
| Weight | Continuous | Continuous | Continuous | Continuous |
| Height | Continuous | Continuous | Continuous | Continuous |
| BMI | Continuous | Continuous | Continuous | Continuous |
| Biologic sex | Categorical - 3 conditions | Categorical - 2 conditions | Categorical - 2 conditions | Categorical - 2 conditions |
| Gender identity | Categorical - 3 conditions | - | Categorical - 3 conditions | - |
| b) Individual socioeconomic variables | | | | |
| Education level | Categorical - 9 conditions | Categorical - 13 conditions | Categorical - 11 conditions | Categorical - 9 conditions |
| Occupational status | Categorical [CNO11] | Categorical [CNO11] | Categorical [CNO11] | Categorical [CNO11] |
| Household size | Discrete | Discrete | Discrete | Discrete |

| Population Health Survey Variables | Study areas | | | |
|---|---|---|---|---|
| | A.C. Basque Country | A.C. Andalusia | Barcelona city | Valencian Community |
| Household income | Categorical - 11 conditions | - | - | Categorical - 8 conditions |
| Economic difficulty | Categorical - 6 conditions | Categorical - 6 conditions | Categorical - 6 conditions | Categorical - 6 conditions |
| Employment status | yes/no | yes/no | yes/no | yes/no |
| Country of birth | Categorical & Open | Categorical & Open | Categorical & Open | Categorical & Open |
| Marital status | Categorical - 6 conditions | Categorical - 5 conditions | Categorical - 5 conditions | Categorical - 5 conditions |
| **c) Lifestyle factors** | | | | |
| Alcohol consumption | Categorical - 8 conditions | Categorical - 10 conditions | Categorical - 4 conditions | Categorical - 8 conditions |
| Passive smoking at home | Likert 1-5 | yes/no | Discrete (Nº smokers) | yes/no |
| Daily tobacco consumption | yes/no | Categorical - 4 conditions | Categorical - 3 conditions | Categorical - 4 conditions |
| **e) Physical Health** | | | | |
| Chronic health problems | Categorical - 38 conditions | Categorical - 25 conditions | Categorical - 25 conditions | Categorical - 21 conditions |
| **d) Mobility** | | | | |
| Years at household | Discrete | - | Discrete | Discrete |
| **MEDIATORS** | | | | |
| **a) Physical activity** | | | | |
| Physical activity | Discrete - IPAQ | Discrete - IPAQ | Discrete - IPAQ | Discrete - IPAQ |
| - Vigorous | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Moderate | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Walking | MET-min/week | MET-min/week | MET-min/week | MET-min/week |
| - Sitting | Time spent (hours + minutes) | Time spent (hours + minutes) | Time spent (hours + minutes) | Time spent (hours + minutes) |
| **b) Social cohesion** | | | | |
| Social support | Ordinal 1-5 [Duke / 11 items] | Ordinal 1-5 [Duke / 11 items] | Ordinal 1-5/1-4 [OSLO/ 3 items] | Ordinal 1-5 [Duke / 11 items] |
| Loneliness | Ordinal 1-4 | Ordinal 1-4 | Ordinal 1-4 | Ordinal 1-4 |
| **SUBJECTIVE URBAN ENVIRONMENTAL EXPOSURES** | | | | |
| **a) Perception of the neighbourhood** | | | | |
| Noise outside dwelling | Likert 1-3 | Likert 1-3 | Likert 1-5 | Likert 1-3 |
| Neighbourhood air pollution | Likert 1-3 | Likert 1-3 | - | Likert 1-3 |
| Shortage of green spaces | Likert 1-3 | Likert 1-3 | - | Likert 1-3 |
| Insecurity | Likert 1-3 | Likert 1-3 | Likert 1-5 | Likert 1-3 |

[1] The subjects are provided with a list of medications and are asked if they have consumed any of them in the last 2 days or 2 weeks depending on the study area.

[2] Subjects are provided with a list of chronic health problems and are asked if they currently suffer or have ever suffered (depending on the study area) from any of them.

### A) Prevalence of common mental disorders in Spain.

A recent report published by the Spanish National Health System (2020), based on a representative sample of users of said system, found that the overall prevalence of mental health problems in Spain is 27.4%. The most common general mental health issues were anxiety, depression, and sleep disorders, with a prevalence of 6.7%, 4.1%, and 5.4%, respectively. Higher prevalence of these disorders was observed in the female population, those born in Spain and with increasing age. The same report notes that in the case of anxiety and depression, a clear social gradient is observed, with both disorders being 3.4 and 2.5 times more prevalent in the population with lower income levels. In the case medication prescriptions, anxiolytics, antidepressants, and hypnotics were prescribed at rates of 34% for women and 17% for males over 40. The 2020 European Health Survey revealed no discernible territorial differences in the prevalence of chronic mental health conditions among individuals aged 15 and older in Spain. However perceived health status showed slight regional disparities, with Valencia reporting the highest percentage of "bad or very bad" health at 9.4%, followed by Andalucía (7.4%), the Basque Country (7%), and Catalonia (4.9%). However, given that the results presented in this report pertain to a timeframe predating the onset of the COVID-19 pandemic, it is anticipated that the prevalence of these conditions has risen universally among all age groups and regions (Henares Montiel et al., 2020). This increase can be attributed to escalated stress and health-related concerns stemming from the pandemic, exacerbated by associated constraints like lockdown measures and the resultant impact on mental health care services during the pandemic (Balluerka et al., 2020).

Balluerka, N., Gómez, J., Hidalgo, M., Gorostiaga, A., Espada, P., Padilla, J., & Santed, M. (2020). LAS CONSECUENCIAS PSICOLÓGICAS DE LA COVID-19 Y EL CONFINAMIENTO INFORME DE INVESTIGACIÓN

Henares Montiel J, Ruiz-Pérez I, Sordo L. Salud mental en España y diferencias por sexo y por comunidades autónomas. *Gaceta Sanitaria*. 2020;34:114–9.

INEbase / Society /Health /European Survey of Health in Spain. INE. Retrieved December 2023. https://www.ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736176784&idp=1254735573175

Sistema Nacional de Salud. (2020). Base de Datos Clínicos de Atención Primaria-BDCAP. https://cpage.mpr.gob.es/

**Section 4. DATA MANAGEMENT PLAN**

A) RESEARCH ACTIVITIES

Step 1. Population Health Surveys' (PHS) data curation and calibration

The selected individuals were contacted by a phone call, SMS, or letter to arrange an appointment for a face-to face interview for the purpose of the survey. The database produced with the interviews will be pseudonymised from that with the personal data for the contact by assigning a unique code for each participant and remains under the custody of the responsible body in each study area; the Basque Department of Health in the Basque Country, Escuela Andaluza de Salud Pública (EASP) in Andalusia, Agència de Salud Pública de Barcelona (ASPB) in Barcelona, and Conselleria de Salut Universal i Salut Pública (DGSP) in Valencian Community.

Step 2. Harmonisation

Initially, the databases of each study area will be cleaned, and the variables that require it will be harmonised. The vast majority of the variables to be used in the project have been collected identically in the Population Health Surveys of the study areas included. The variables to be harmonized are listed below and the measures used in each study area can be found in Table S2.

The variables that need harmonisation can be distinguished between simple or complex variables, depending on the level of difficulty and the manipulation of data that require the harmonisation of the respective variable:

- Simple variables: Chronic mental health problems, Educational level, Occupation status, Household income, Loneliness, Noise outside dwelling, and Insecurity.

- Complex variables: mental health, health-related quality of life, sleep quality, consumption of medication for common mental disorders, alcohol consumption, passive smoking at home, tobacco consumption, physical health, and social support.

The Maelstrom Research Guidelines for the rigorous harmonisation of retrospective data (77) will be applied. Among the variables that need harmonisation, the majority can be easily re-categorised (simple variables). For instance, in the case of scales with different score ranges (e.g., Likert scale levels), standardised scores will be calculated, or other procedures will be followed to ensure comparability. The procedure to follow with variables measured with different scales will be more complex (complex variables). For these, the content of each variable will be studied to detect the common content (e.g., items) in each of the study areas. Once detected, aggregate scores will be calculated for the common items, and these scores will be used for statistical analyses. The remaining non-harmonizable variables will be assessed for their potential for performing separate statistical analysis for each study area.

Step 3. Georeferentiation

The responsible bodies, in collaboration with regional Statistical Institutes or Population Registers, will link the health survey data to the geographical coordinates of each respondent's home address. The geographical coordinates will also be pseudonymised and sent this way to the research group specialised in Geographic Information System (GIS) estimations that will calculate UrbEE. In order to further ensure the protection of the personal data of the survey participants and enhance their anonymity, fictional coordinates will be created in a number five times the number of participants selected for the study in each study area and sent to the research group specialised in GIS estimations together with the real coordinates.

Step 4. GIS estimation of Urban Environmental Exposures (UrbEE)

A company specialised in GIS estimations will calculate the objective urban environmental exposures (UrbEE) of all the geocodes, including the participants' coordinates and the fictional coordinates by GIS.

Step 5. Selection and linkage of data

After the estimations are finalised, the responsible bodies of the surveys in each study area will re-select the geocodes of the participants and add the new urban environmental variables to the database with the PHS data. The researchers will be provided with the resultant database of each study area composed by the PHS data and the UrbEE (without geocodes and personal data of the participants). This guarantees that the data supplied are protected by statistical secrecy, not misused and treated anonymously and globally at all times.

Step 6. Pooling

Finally, the final databases of all the study areas will be pooled, creating the final pooled database to be used in the planned analyses.

B) DATA STORAGE AND PROCESSING

Data will be kept at all times on servers located in the responsible centre of this project. This way, data will be stored on the University of the Basque Country UPV/EHU's own servers, complying with the greater security and privacy requirements of the LOPD as the data is not sent to external servers. The entire process of recording, dumping and storage of the data will be anonymised, with the data collected being exclusively linked to a sample unit code. Access to the anonymised microdata will be limited to technicians from the responsible centres of each study area through profiles with regulated permissions that allow for supervising and controlling access to the information. Supervision of the data management will be assigned to the principal investigators with expert advice, and to the data protection officer of the centre responsible for the project.

C) ETHICAL CONSIDERATIONS AND ACCOUNTABILY

The study was approved by the regional Research Ethics Committee of the **Basque Country**, ETHICS COMMITTEE FOR RESEARCH INVOLVING MEDICINAL PRODUCTS IN THE BASQUE COUNTRY (CEIm-E) (protocol code PI2022138, dated 9th November 2022); **Andalusia**, BIOMEDICAL RESEARCH ETHICS COMMITTEE OF THE PROVINCE OF GRANADA (CEI/CEIM GRANADA) (protocol code 2078-N-22, dated 27th December 2022); **Barcelona**, PARC DE SALUT MAR CLINICAL RESEARCH ETHICS COMMITTE (CEIm) (protocol code 2022/10667, dated 2nd December 2022); **Valencian Community**, ETHICS COMMITTEE FOR CLINICAL RESEARCH OF THE DIRECTORATE GENERAL OF PUBLIC HEALTH AND CENTER FOR ADVANCED RESEARCH IN PUBLIC HEALTH (CEIC DGSP / CSISP) (protocol code 20221125/04, dated 25th November 2022).

This study is based on secondary data obtained from four independent Population Health Surveys (PHS) from Spain. Since the present study does not involve the activity of data collection, to obtain the informed consent from the subjects is not applicable for this study. However, the PHS included this project are official statistical operations included in the respective Statistical Plans of each study area. This ensures that the data provided is protected by statistical confidentiality, it is not misused, its treatment is anonymous and global at all times, and that indirect identification is impossible. Data are collected and processed in accordance with the provisions of the General Data Protection Regulation (GDPR) and in accordance with the provisions of Article 5 of the Organic Law 3/2018 of 5 December on the Protection of Personal Data and the guarantee of digital rights (Regulation (EU) 2016/679), they will be treated confidentially, with access to them being granted to personnel who strictly need to process them in the framework of the study.

Furthermore, the transfer of data occurs between organisations within the Public Health System of each region and the regional or local government itself. This is done in the context of a research project conducted exclusively in the public sphere and with the legitimacy of the use of administrative records as research infrastructures in accordance with the General Health Act, the Biomedical Research Act and the General Law on Public Health. The results of the study will provide information at a sufficiently aggregated territorial level to prevent indirect identification. Furthermore, the project's results will be beneficial to the general population in a holistic way, thanks to its socioeconomic and environmental context, and its evolution over several years from the onset of the COVID-19 pandemic. Therefore, the risk to the privacy of the study population is minimal compared to the potential benefits the results will bring.