# Vitamin D Status as Potential Indicator of Healthy City – a Case Study of London

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Kuching, Sarawak, Malaysia 28 Sep-02 Oct. 2026
Design & Health
15TH WORLD CONGRESS & EXHIBITION





# Vitamin D: Introduction

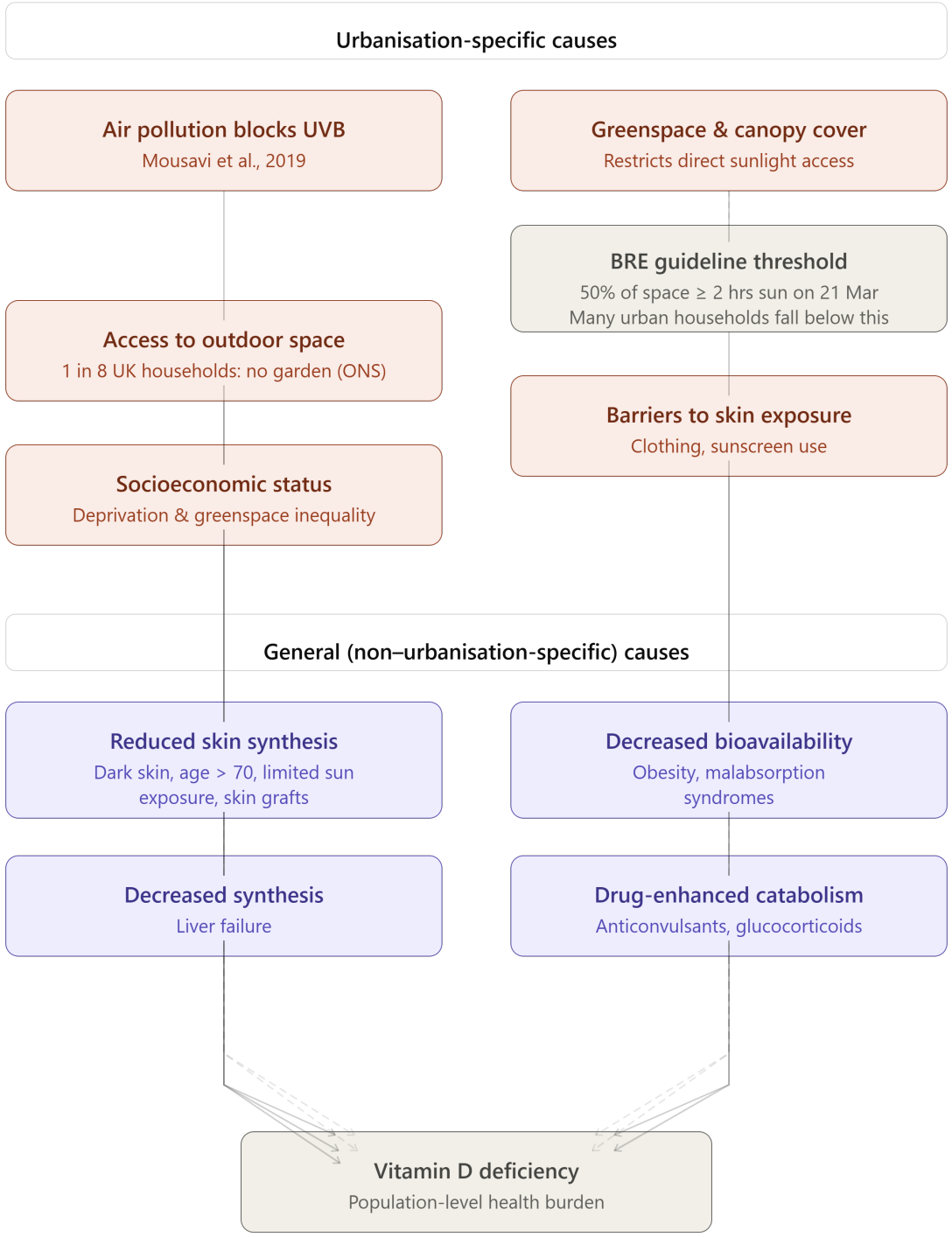
- Vitamin D (VD) is a steroid hormone: 80% derived from ultraviolet B (UVB) induced photoconversion in the skin of 7-dehydrocholesterol to previtamin D3. Remaining is from dietary sources: oily fish, cod liver oil, fortified foods or supplementation.
- Primary role in calcium homeostasis and subsequently, musculoskeletal health, but also regulates cell proliferation and differentiation. Adequate VD lowers risk of several chronic diseases (e.g., cardiovascular disease, some cancers, cognitive decline, and infections).
- **Our earlier work demonstrated COVID-19 mortality was significantly different across London boroughs and related to urban determinants that may influence vitamin D status, including local air pollution levels and greenspace access (Borna et al., 2021).**
- The long-standing and growing issue of VD deficiency in urban areas challenges the framing of VD Deficiency as a clinical or dietary problem only amenable to interventions at the individual level.
- If the built environment has a role in modifying vitamin D levels, then can vitamin D status tell us something about the health of a city?

# VD Deficiency: Prevalence & Causes

- According to National Institute of Clinical Excellence UK:
  - Serum vitamin D: < 50nmol/L – insufficiency, <25nmol/L - deficiency
- 1 in 6 adults and 1 in 5 children in the United Kingdom have insufficient VD.
  - Higher in ethnic minority groups - winter levels were 5.9% in White Britons, 30.8% in Black Britons and 50.8% in South Asians (Sutherland et al., 2021).

**Deficiency across the globe:**

- 24% US, 37% Canada, 40% Europe
- >70% Bangladesh, 90% of UAE, Brazil >80%, >45% Thailand
- **Evidence on the prevalence of vitamin D deficiency in sunny countries suggests that, despite the abundance of sunlight, there might be a public health issue (Augustine et al., 2021).**



# Research Approach

The aim was to identify **modifiable** predictors of vitamin D deficiency at hyperlocal level

Hypothesis: BMI, ethnicity, air pollution, and reduced access to greenspace at the hyperlocal level are associated with lower levels of vitamin D across London.

Methods:

- This study used data from the UK Biobank (included 500,000 adults aged 37 to 73 years from 2006 to 2010 across the UK).
- London borough shapefile data were imported from the UK Data Service and coordinates from Biobank for participants within London were extracted and joined to 2011 Middle Layer Super Output Area (MSOA) boundaries using a spatial join.
- Cases with missing MSOA codes were removed. This procedure led to a final sample of 43235 participants.
- Vitamin D deficiency defined as serum 25-hydroxyvitaminD<25nmolL, insufficiency defined as 25-50nmol/L.

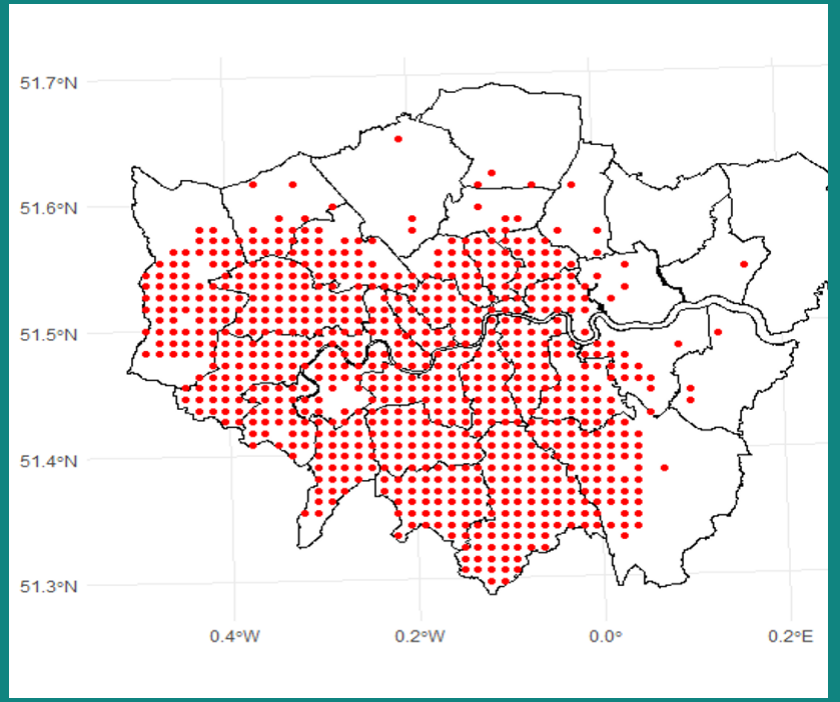



Figure 1. Spatial distribution of data points for the London Biobank subset.



# Air Pollution Assessment

- Annual concentrations of particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and nitrogen oxides (NOx) were modelled for the year 2010 using a Land Use Regression (LUR) model developed as a part of the European Study of Cohorts for Air Pollution Effects.
- LUR model was applied to determine the spatial variations of annual average air pollution concentrations using geographic predictor variables
- These variables included traffic, land use, topography, and population density.

# Green Space and Built Environment Assessment

- Proportion of land classified as greenspace or domestic garden was modelled using data from 2005 Generalized Land Use Database for England (GLUD) for 2001 Census Output Areas.
- GLUD classified greenspace as green land cover designated for public spaces: parks, communal gardens, cemeteries and agricultural land. Domestic gardens defined as parcels of land annexed to residential buildings.
- Proximity of residential addresses to major roads determined by address location within 50 meters of a class 1 or 2 type road and/or within 100meters of a class 0 road based on the central road network.
- Traffic intensity on nearest major road defined as average total motor vehicles per 24hrs on the nearest major road based on a local road network. Traffic count data obtained from Road Traffic Statistics Branch at the Department for Transport.

# Statistical Analysis and Confounding Factors

- Analyses conducted in R version 4.1.2. Packages were loaded for spatial data wrangling and geographically weighted regression (GWR) analysis.
- GWR model specified with VD as dependent variable and assessment centre, and all confounding factors were independent variables.
- Model diagnostics, local R2 values assessed for spatial non-stationarity. Results visualized by mapping the local R2 values.
- Statistical significance was considered at $p < 0.05$ for all tests.

### Sex
- Lower in females vs males
- Fat mass
- Exposure to air pollutants

### Age
- Reduced cutaneous synthesis with increased ageing
- Changes in mobility and health behaviours

### Ethnicity
- Higher melanin content reduced absorption of UV
- Cultural practices
- Socioeconomic status

### Index of Multiple Deprivation
- Access to nutrition and opportunities to engage with outdoors

### Season of blood collection
- Lower VD in winter
- Supplementation recommended in winter

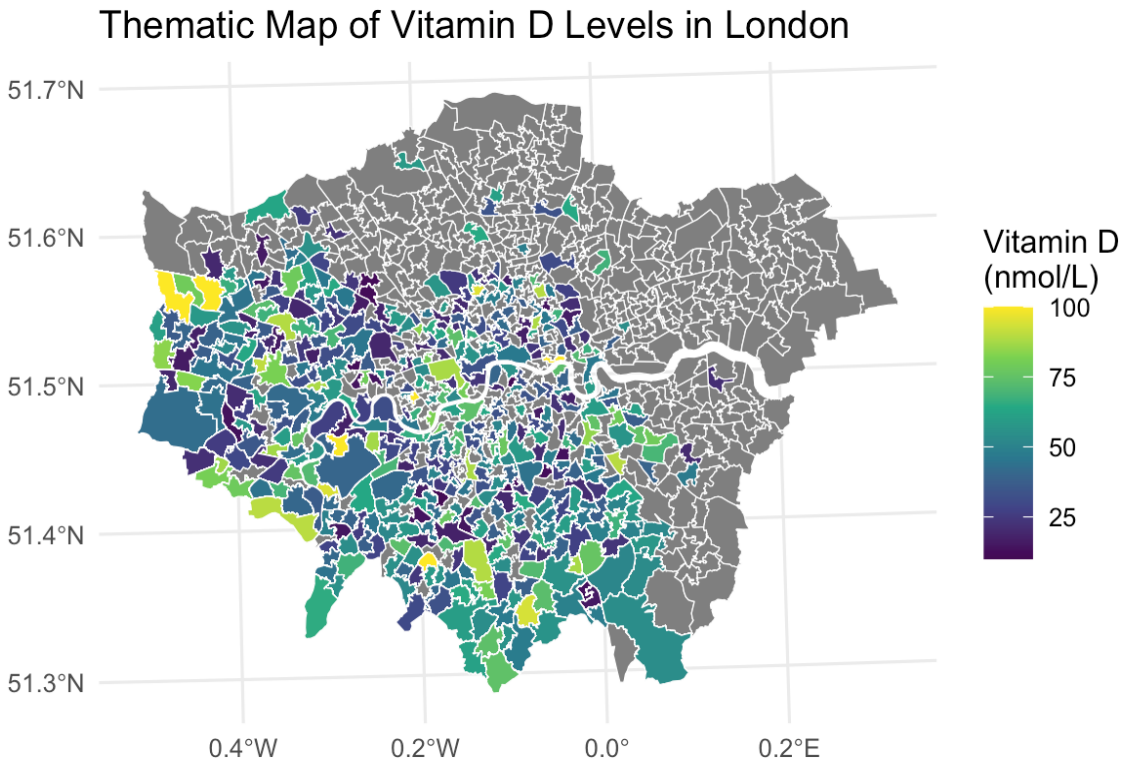
### Type of accommodation lived in
- Living conditions and private access

### Number of vehicles in the household
- Impact on health behaviours

### Oily fish intake
- Maintenance of VD
- Can also be impacted by socioeconomic status

### Time spent outdoors in summer
- Direct sun exposure

# Results

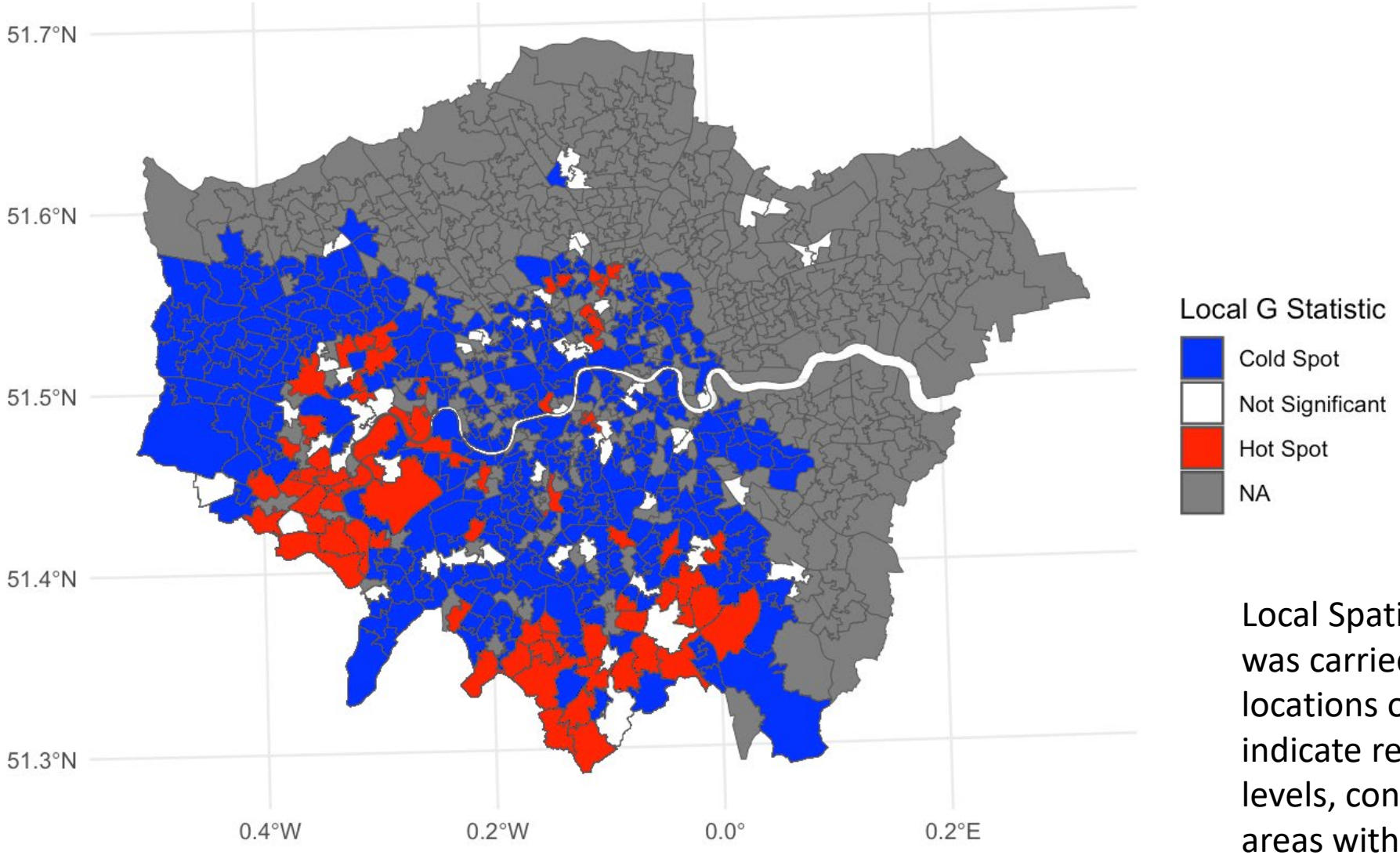



- Average vitamin D levels across London is 20.69 nmol/L (insufficient)
- 15.73% participants deficient, 43.92% insufficient, 30.89% adequate and 9.45% would be considered optimal Vitamin D levels.

**There is significant heterogeneity in vitamin D status at hyperlocal level. Significant predictors of vitamin D status are:**

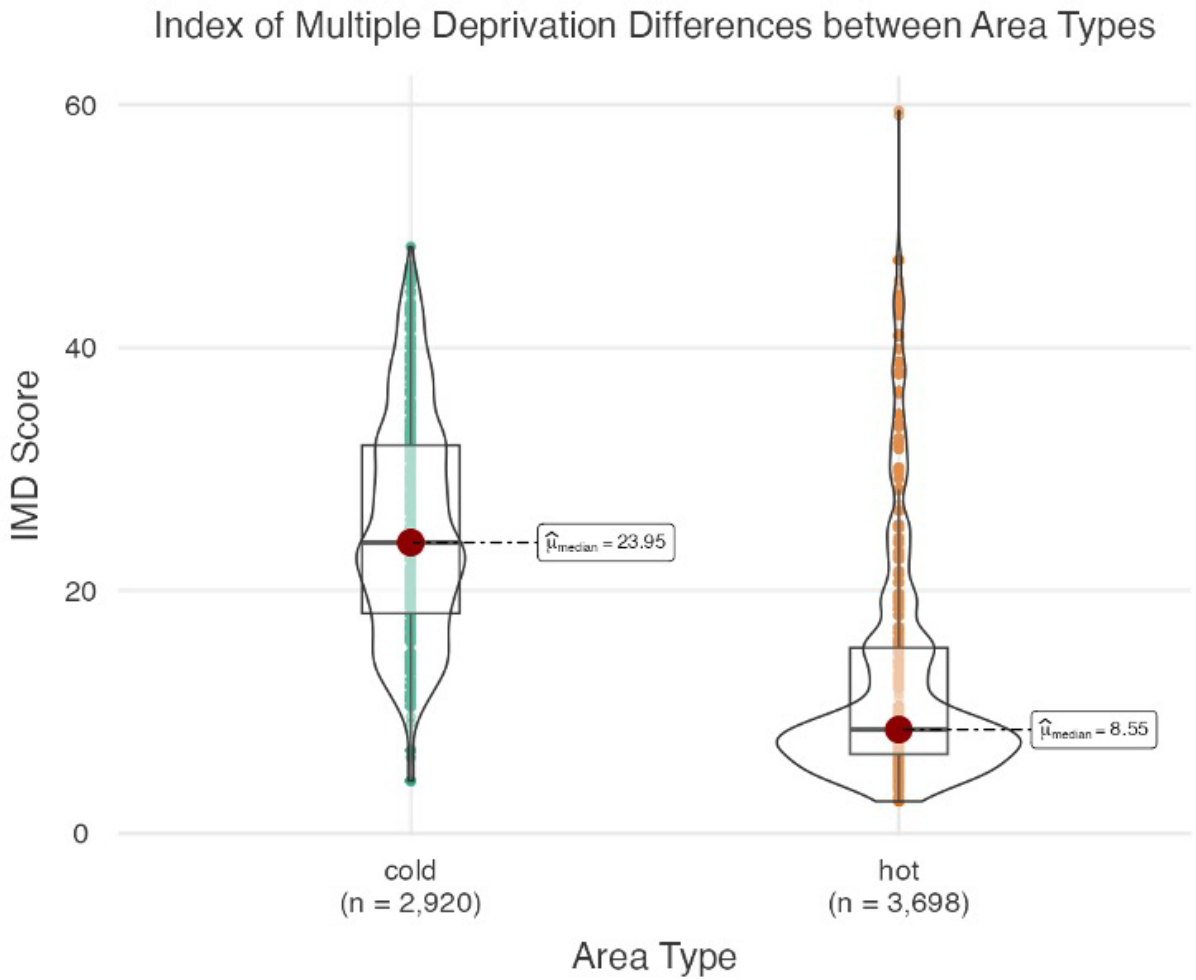
- BMI (Body Mass Index)
- Index of Multiple Deprivation
- Nitrogen Dioxide
- PM10 (Particulate Matter 10 µm)
- PM2.5 (Particulate Matter 2.5 µm)
- PM2.5 Absorbance
- Traffic Intensity on the Nearest Road
- Proximity to Major Roads (Inverse Distance)
- Greenspace Percentage Buffer (300m and 1000m)
- Natural Environment Percentage Buffer (300m and 1000m)
- Distance to Coast
- Population Density
- Average Household Size

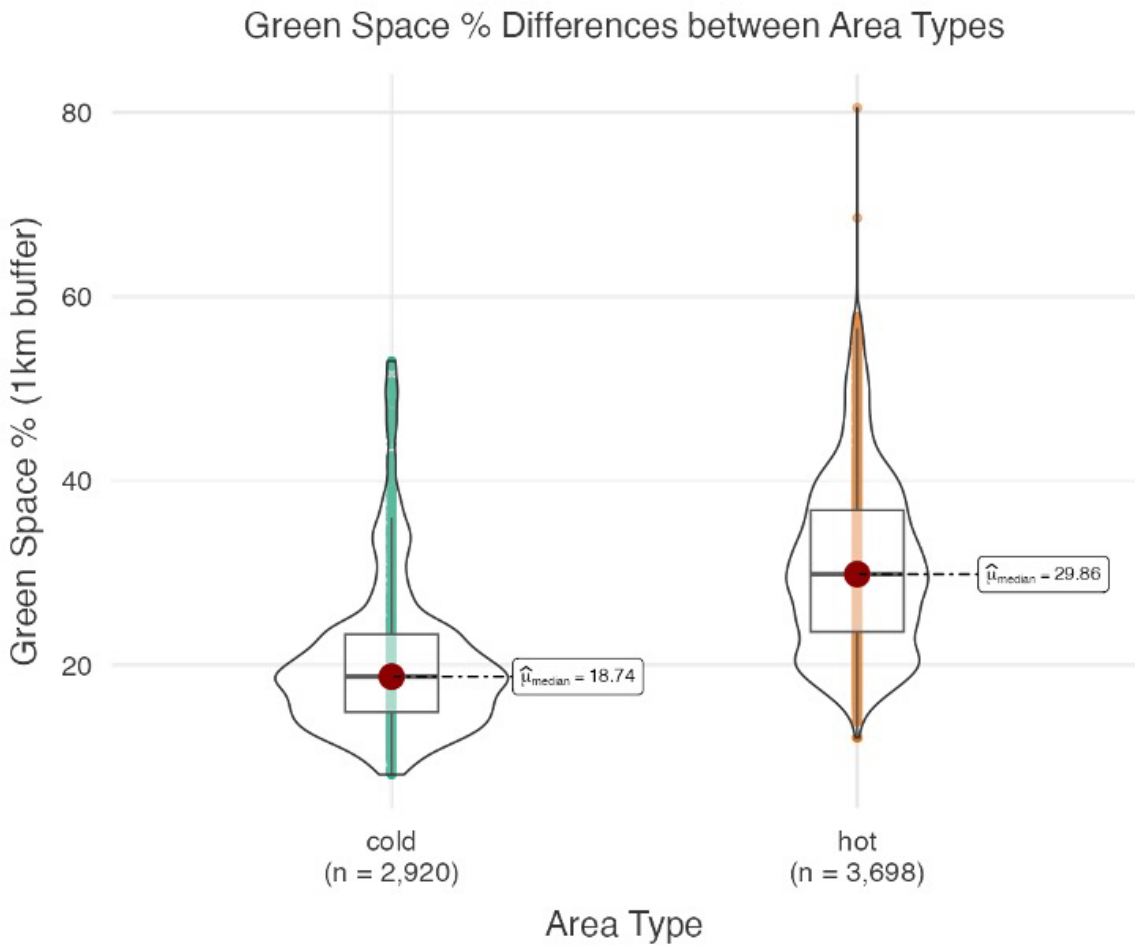
# ‘Hot’ & ‘Cold’ spot analysis




Local Spatial Autocorrelation Analysis was carried out to pinpoint the locations of clustering. ‘Hot spots’ indicate regions with higher vitamin D levels, conversely, ‘Cold spots’ reveal areas with lower levels.

# Results of ‘Hot’ & ‘Cold’ spot analysis




The two violin plots are examples of how variables differ between hot and cold spots. IMD was significantly lower in hot spots (left), highlighting the role of socio-economic status in influencing vitamin D levels, with more deprived areas showing lower vitamin D levels. Greenspace was significantly higher in hot spots relative to cold spots (right), highlighting the importance of access to greenspace.

# Conclusions and Future Work

- Our GWR model is the first to identify heterogeneity in the relationship between air pollution and VD status across London and suggests this can be explained by the hyperlocal built environment.
- This study highlights the complex interplay of environmental, demographic, and socio-economic factors influencing vitamin D levels in London. Public health interventions should consider these factors, particularly targeting areas with high pollution and low greenspace, to address vitamin D deficiency.
- Further research is needed to explore the causal mechanisms and develop targeted strategies for improving vitamin D levels in vulnerable populations.

**Questions for future work include:**

- Does vitamin D deficiency exacerbate health inequalities amongst ethnically minoritised groups?
- Which environmental interventions can significantly improve vitamin D levels, particularly amongst ethnically minoritised groups?
    - e.g air pollution reduction strategies, building structure and materials, green canopy cover, vegetation types...



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