**Supplemental Material**

**Joint associations between neighborhood walkability, greenness, and particulate air pollution on cardiovascular mortality among adults with a history of stroke or acute myocardial infarction**

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**eAppendix 1**

**Results**

*Three-way Interactions of PM2.5, Walkability, and SES*

Among those living in neighborhoods with the highest percentage of people with less than a high school education (low SES neighborhood), the difference in PM2.5 associated CVD mortality risk between living in a low walkable neighborhood (reference) [HR=1.18 (95% CI: 1.05-1.34)] versus living in a high walkable neighborhood [HR=1.28 (95% CI: 1.06-1.55)] was 10%. In comparison, among those living in neighborhoods with the lowest percentage of people with less than a high school education (high SES neighborhood), the difference in risk between living in a low walkable neighborhood [HR=1.18 (95% CI: 1.05-1.34)] versus living in a high walkable neighborhood [HR=1.19 (1.00-1.41)] was only 1%.

**eAppendix 2**

**Discussion**

*Three-way interactions of PM2.5, Walkability, and SES*

We previously reported a two-way interaction between PM2.5 and neighborhood education, where we found stronger effects of long-term PM2.5 on CVD mortality among those living in low SES neighborhoods (interaction-term p-value for trend=0.029).1 Our three-way interaction analysis extends our previous work to incorporate combined effects of low SES and highly walkable neighborhoods. Individuals in low SES groups tend to have a higher prevalence of CVD risk factors such as obesity and HTN,2 and we accounted for these comorbidities in our model. Lower SES groups may often be “captive walkers” (relying on walking for transportation)3, 4 or respond more to their residential environment because of lack of means to travel elsewhere3, therefore this population may be exceedingly exposed to air pollution in a highly walkable (and often more polluted) neighborhood. In addition, perceptions of the built environment (perceived neighborhood walkability, green space quality, aesthetics, or utility) can also be further influenced by SES, where people of low SES have been shown to perceive their surroundings differently than those of high SES.5, 6

**eTable 1.** Independent association of greenness (NDVI at 250m and 500m buffers) with CVD mortality

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Greenness** | **Model** | **Covariates** | **Greenness,** **NDVI < 0.3** **HRa (95% CI)** | **Greenness,** **NDVI ≥ 0.3****HRa (95% CI)** |
| NDVI 250m | 1 | Ageb, sex, study start year | 0.95 (0.91-0.99) | 0.83 (0.74-0.93) |
|  | 2 | Model 1 + race, comorbidities, BMI, smoking, CVD history, revascularization, medication use  | 0.96 (0.92-1.00) | 0.85 (0.76-0.96) |
|  | 3 | Model 2 + SES | 1.00 (0.96-1.04) | 0.88 (0.78-0.99) |
|  | 4 | Model 3 + PM2.5 | 0.99 (0.95-1.03) | 0.93 (0.83-1.05) |
|  | 5 | Model 4 + walkability | 1.00 (0.95-1.05) | 0.94 (0.83-1.06) |
| NDVI 500m | 1 | Ageb, sex, study start year | 0.95 (0.91-0.99) | 0.83 (0.74-0.93) |
|  | 2 | Model 1 + race, comorbidities, BMI, smoking, CVD history, revascularization, medication use  | 0.96 (0.92-1.00) | 0.85 (0.76-0.95) |
|  | 3 | Model 2 + SES | 1.00 (0.96-1.04) | 0.88 (0.78-0.98) |
|  | 4 | Model 3 + PM2.5 | 0.99 (0.95-1.04) | 0.93 (0.83-1.05) |
|  | 5 | Model 4 + walkability | 1.00 (0.96-1.05) | 0.94 (0.83-1.06) |

aHazard ratios per 0.1 increase in NDVI; N=83,408 and 8,799 CVD mortality events

bAdjusted for age using Cox models with age as strata

**eTable 2.** Joint effects of A) greenness and PM2.5 (N=83,408), B) walkability and PM2.5 (N=83,560), and C) greenness and walkability (N=83,408) on CVD mortality risk, in models adjusted for age, sex, study start year, race, comorbidities, BMI, smoking, CVD history, revascularization, medication use, and SES.

|  |
| --- |
| **Greenness and PM2.5****HR (95% CI)** |
|  | **Low PM2.5** | **Moderate PM2.5** | **High PM2.5** |
| **Low Greenness** | 1.05 (0.87-1.27) | 1.12 (1.02-1.22) | 1.30 (1.11-1.52) |
| **Moderate Greenness** | 1.08 (0.97-1.21) | 1.11 (1.03-1.21) | 1.18 (1.07-1.30) |
| **High Greenness** | *1.0 (reference)* | 1.06 (0.95-1.18) | 1.14 (0.97-1.33) |
| **Walkability and PM2.5****HR (95% CI)** |
|  | **Low PM2.5** | **Moderate PM2.5** | **High PM2.5** |
| **Low Walkability** | 1.04 (0.88-1.22) | 1.10 (0.94-1.29) | 1.10 (0.89-1.35) |
| **Moderate Walkability** | 1.09 (0.94-1.28) | 1.12 (0.97-1.29) | 1.22 (1.05-1.43) |
| **High Walkability** | *1.0 (reference)* | 1.13 (0.98-1.31) | 1.22 (1.04-1.43) |
| **Walkability and Greenness****HR (95% CI)** |
|  | **Low Greenness** | **Moderate Greenness** | **High greenness** |
| **Low Walkability** | 1.24 (0.95-1.63) | 1.10 (0.93-1.29) | 1.06 (0.90-1.24) |
| **Moderate Walkability** | 1.18 (1.01-1.39) | 1.15 (0.99-1.33) | 1.11 (0.95-1.30) |
| **High Walkability** | 1.14 (0.98-1.33) | 1.20 (1.03-1.40) | *1.0 (reference)* |

**eTable 3**. Linear association of PM2.5 and CVD mortality by walkability quartile, controlling for greenness

|  |  |
| --- | --- |
|  | **PM2.5 Exposure****HR (95% CI)** |
| **Overall** |  1.18 (1.06-1.32) |
| **By Walkability Quartile** |   |
| **Q1 (Least Walkable)** | 1.17 (1.04-1.33) |
| **Q2** | 1.19 (1.07-1.32) |
| **Q3** | 1.24 (1.10-1.39) |
| **Q1 (Most Walkable)** | 1.24 (1.07-1.44) |

Model adjusted for age, sex, race/ethnicity, study start year, comorbidities (hypertension, hyperlipidemia, diabetes), BMI, smoking, CVD history, revascularization, medications (statins, hypertensive medication), SES (neighborhood education, Medicaid insurance), NDVI 1km. HRs per 10 µg/m3 increase in 1-year mean PM2.5. Interaction between PM2.5 and continuous walkability variable: p-value=0.02

**eTable4.** Number of subjects (N) per category for joint effects of A) greenness and PM2.5 (N=83,408), B) walkability and PM2.5 (N=83,560), and C) greenness and walkability (N=83,408) on CVD mortality risk

|  |  |  |
| --- | --- | --- |
| 1. **Greenness and PM2.5**
 | **N** | **Percent of cohort (N=83,408)** |
| **High** greenness | **Low** PM2.5 | 7,219 | 8.7 |
| **Moderate** greenness | **Low** PM2.5 | 6,287 | 7.5 |
| **Low** greenness | **Low** PM2.5 | 1,598 | 1.9 |
| **High** greenness | **Moderate** PM2.5 | 5,124 | 6.1 |
| **Moderate** greenness | **Moderate** PM2.5 | 30,304 | 36.3 |
| **Low** greenness | **Moderate** PM2.5 | 18,957 | 22.7 |
| **High** greenness | **High** PM2.5 | 1,593 | 1.9 |
| **Moderate** greenness | **High** PM2.5 | 10,488 | 12.6 |
| **Low** greenness | **High** PM2.5 | 1,838 | 2.2 |
| 1. **Walkability and PM2.5**
 | **N** | **Percent of cohort (N=83,560)** |
| **High** walkability | **Low** PM2.5 | 2,516 | 3.0 |
| **Moderate** walkability | **Low** PM2.5 | 7,043 | 8.4 |
| **Low** walkability | **Low** PM2.5 | 5,668 | 6.8 |
| **High** walkability | **Moderate** PM2.5 | 20,663 | 24.7 |
| **Moderate** walkability | **Moderate** PM2.5 | 27,608 | 33.0 |
| **Low** walkability | **Moderate** PM2.5 | 6,140 | 7.4 |
| **High** walkability | **High** PM2.5 | 5,400 | 6.5 |
| **Moderate** walkability | **High** PM2.5 | 6,875 | 8.2 |
| **Low** walkability | **High** PM2.5 | 1,647 | 2.0 |
| 1. **Greenness and Walkability**
 | **N** | **Percent of cohort (N=83,408)** |
| **High** greenness  | **High** walkability | 1,827 | 2.2 |
| **Moderate** greenness | **High** walkability | 13,182 | 15.8 |
| **Low** greenness  | **High** walkability | 13,558 | 16.3 |
| **High** greenness | **Moderate** walkability | 5,814 | 7.0 |
| **Moderate** greenness | **Moderate** walkability | 27,544 | 33.0 |
| **Low** greenness | **Moderate** walkability | 8,133 | 9.8 |
| **High** greenness | **Low** walkability | 6,295 | 7.6 |
| **Moderate** greenness | **Low** walkability | 6,353 | 7.6 |
| **Low** greenness | **Low** walkability | 702 | 0.8 |

**eTable 5.** Joint effects of A) greenness and PM2.5, B) walkability and PM2.5, and C) greenness and walkability on CVD mortality risk, in models excluding individuals living in areas with <1,000 people per square mile (N=72,207) and adjusted for age, sex, study start year, race, comorbidities, BMI, smoking, CVD history, revascularization, medication use, and SES.

|  |
| --- |
| **Greenness and PM2.5****HR (95% CI)** |
|  | **Low PM2.5** | **Moderate PM2.5** | **High PM2.5** |
| **Low Greenness** | 1.05 (0.85-1.30) | 1.11 (0.99-1.26) | 1.31 (1.09-1.57) |
| **Moderate Greenness** | 1.09 (0.95-1.26) | 1.10 (0.98-1.24) | 1.20 (1.06-1.37) |
| **High Greenness** | *1.0 (reference)* | 1.02 (0.88-1.18) | 1.11 (0.92-1.34) |
| **Walkability and PM2.5****HR (95% CI)** |
|  | **Low PM2.5** | **Moderate PM2.5** | **High PM2.5** |
| **Low Walkability** | 1.05 (0.86-1.27) | 1.06 (0.89-1.26) | 1.09 (0.83-1.42) |
| **Moderate Walkability** | 1.06 (0.90-1.26) | 1.08 (0.93-1.26) | 1.21 (1.03-1.42) |
| **High Walkability** | *1.0 (reference)* | 1.10 (0.95-1.28) | 1.19 (1.00-1.40) |
| **Walkability and Greenness****HR (95% CI)** |
|  | **Low Greenness** | **Moderate Greenness** | **High Greenness** |
| **Low Walkability** | 1.26 (0.94-1.68) | 1.12 (0.94-1.33) | 1.05 (0.87-1.28) |
| **Moderate Walkability** | 1.19 (1.01-1.40) | 1.15 (0.99-1.34) | 1.11 (0.93-1.31) |
| **High Walkability** | 1.14 (0.98-1.34) | 1.21 (1.04-1.42) | *1.0 (reference)* |

**eTable 6.** Linear association ofPM2.5 and CVD mortality within walkability and neighborhood education quartiles

|  |  |  |
| --- | --- | --- |
| **Neighborhood Education** | **Overall PM2.5 HR** | **PM2.5 HRs by Walkability Quartile** |
| **Walk Q1 (Low walkability)** | **Walk Q2** | **Walk Q3** | **Walk Q4 (High walkability)** |
| **Education Q1****(High SES)** | 1.16 (1.03-1.30) | 1.18 (1.05-1.34) | 1.19 (1.05-1.36) | 1.21 (1.05-1.39) | 1.19 (1.00-1.41) |
| **Education Q2** | 1.17 (1.04-1.30) | 1.18 (1.05-1.34) | 1.18 (0.99-1.39) | 1.18 (1.00-1.39) | 1.19 (1.00-1.43) |
| **Education Q3** | 1.22 (1.10-1.36) | 1.18 (1.05-1.34) | 1.22 (1.03-1.45) | 1.25 (1.05-1.48) | 1.21 (1.01-1.44) |
| **Education Q4****(Low SES)** | 1.25 (1.10-1.41) | 1.18 (1.05-1.34) | 1.17 (0.98-1.40) | 1.21 (1.01-1.46) | 1.28 (1.06-1.55) |

Model adjusted for age, sex, race/ethnicity, study start year, comorbidities (hypertension, hyperlipidemia, diabetes), BMI, smoking, CVD history, revascularization, medications (statins, hypertensive medication), SES (neighborhood education, Medicaid insurance). All hazard ratios per 10 µg/m3 increase in 1-year mean PM2.5. Three-way interaction term not statistically significant (interaction-term p-value=0.846).

**eFigure 1. Kaiser Permanente Northern California (KPNC) study region (Alameda, Amador, Butte, Calaveras, Colusa, Contra Costa, El Dorado, Fresno, Glenn, Kings, Lake, Madera, Marin, Mariposa, Mendocino, Merced, Monterey, Napa, Nevada, Placer, Sacramento, San Benito, San Francisco, San Joaquin, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, Stanislaus, Sutter, Tulare, Tuolumne, Yolo, and Yuba counties) and Census block groups within Alameda county. Total of 7,796 block groups and average 11 subjects per block group.**

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**eFigure 2.** Distributions of NDVI 1km, walkability, and PM2.5 exposures



**eFigure 3.** Independent association of greenness with CVD mortality modeled as a piecewise linear spline, in models adjusted for age, sex, study start year, race, comorbidities, BMI, smoking, CVD history, revascularization, medication use, and SES (N=83,408)



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