NATURAL ENVIRONMENTS AND HEALTH: THE RELATIONSHIP BETWEEN GREENNESS AND MORTALITY

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Natural Environments and Health

Outline
- Background on Contextual Factors and Health
- Background on Greenness
- Greenness and Mortality
- Greenness and Depression
- Future Directions
The Places in Which We Live/Work/Play Influence Our Health
Contextual Measures

- Urban Sprawl
- Neighborhood Walkability
- Food Environments
- Neighborhood Socioeconomic Status
- Outdoor Light at Night
- Noise
- Natural Environments
Contextual Measures

- Urban Sprawl
- Neighborhood Walkability
- Food Environments
- Neighborhood Socioeconomic Status
- Outdoor Light at Night
- Noise
- Natural Environments
Biophilia hypothesis suggests that human beings have evolved to have an affinity for nature, plants, and living things.

Ulrich’s psychoevolutionary theory posits that exposure to nature may have a direct restorative effect on cognition, and may decrease stress.
Access to green spaces may also provide opportunities for social interactions and increase social cohesion.
Natural environments provide locations for both routine and recreational physical activity.
Vegetation may buffer exposure to air pollution, removing ozone, particulate matter, NO$_2$, SO$_2$, and carbon monoxide from the air.

Vegetation may also reduce exposure to harmful noise, as well as alleviate thermal discomfort during heat stress.
Higher levels of greenness have been linked in observational and experimental studies to:
- Increased physical activity
- Lower obesity
- Improved mental health
- Higher birth weights
- Lower cardiovascular disease risk
- Lower overall mortality
Research

Exposure to Greenness and Mortality in a Nationwide Prospective Cohort Study of Women

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Background

- Few studies have examined the effect of greenness on mortality risk

- Aim: To examine the relationship between surrounding residential greenness and all-cause mortality in the Nurses’ Health Study from 2000-2008

Nurses’ Health Study (NHS)
- Began in 1976 with 121,701 female nurses aged 30-55

Biennial questionnaires with disease and mortality follow-up

Biennial residential mailing addresses geocoded over follow-up

Location of NHS residential addresses over follow-up

Exposure

- Normalized Difference Vegetation Index (NDVI)
  - Satellite data on vegetation quantity at 250m resolution
  - Mean NDVI value surrounding nurses’ residential addresses
  - Time-varying measures for each season from 2000-2008

MODIS NDVI Data for July 2000

Outcome

- All-Cause Mortality from 2000-2008
  - Deaths usually reported by families
  - Deaths among non-respondents were identified by searching the National Death Index
Results: Main Effects

- Hazard ratios are adjusted for calendar time, age, race, smoking, individual SES, Census tract median home value and income
- \(N=108,630\) with 8,604 deaths over 627,008 person-years of follow-up 2000-2008

<table>
<thead>
<tr>
<th>Quintile</th>
<th>Cumulative Average Greenness (Fully Adjusted HR (95% CI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quintile 1</td>
<td>Ref</td>
</tr>
<tr>
<td>Quintile 2</td>
<td>0.92 (0.86, 0.98)</td>
</tr>
<tr>
<td>Quintile 3</td>
<td>0.90 (0.84, 0.96)</td>
</tr>
<tr>
<td>Quintile 4</td>
<td>0.94 (0.88, 1.00)</td>
</tr>
<tr>
<td>Quintile 5</td>
<td>0.88 (0.82, 0.94)</td>
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<tr>
<td>P for Trend</td>
<td>0.002</td>
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*James et al. Environ Health Perspect 2016 124:1344–1352*
**Results: Main Effects**

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<th>Cumulative Average Greenness</th>
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*12% lower mortality rate in the highest greenness quintile versus the lowest*

- Hazard ratios are adjusted for calendar time, age, race, smoking, individual SES, Census tract median home value and income
- N=108,630 with 8,604 deaths over 627,008 person-years of follow-up 2000-2008

*James et al. Environ Health Perspect 2016 124:1344–1352*
Results: Cause-Specific Mortality Findings

<table>
<thead>
<tr>
<th>Quintile</th>
<th>Cumulative Average Greenness</th>
<th>Cancer Mortality (3,363 Cases)</th>
<th>Respiratory Mortality (766 Cases)</th>
</tr>
</thead>
<tbody>
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<td>Quintile 1</td>
<td>Ref</td>
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</tr>
<tr>
<td>Quintile 2</td>
<td>0.93 (0.84, 1.03)</td>
<td>0.84 (0.69, 1.04)</td>
<td></td>
</tr>
<tr>
<td>Quintile 3</td>
<td>0.90 (0.81, 1.00)</td>
<td>0.86 (0.69, 1.06)</td>
<td></td>
</tr>
<tr>
<td>Quintile 4</td>
<td>0.93 (0.83, 1.03)</td>
<td>0.75 (0.60, 0.94)</td>
<td></td>
</tr>
<tr>
<td>Quintile 5</td>
<td>0.87 (0.78, 0.97)</td>
<td>0.66 (0.52, 0.84)</td>
<td></td>
</tr>
<tr>
<td>P for Trend</td>
<td>0.024</td>
<td>&lt;0.001</td>
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- Hazard ratios are adjusted for calendar time, age, race, smoking, individual SES, Census tract median home value and income

*James et al. Environ Health Perspect 2016 124:1344–1352*
Results: All-Cause Mortality Analyses Stratified by Self-Reported Physical Activity

P for interaction: 0.03

Greenness

- Total Physical Activity (MET-hrs per Week)
- Air Pollution Exposure (Modeled PM$_{2.5}$)

Social Engagement (Participate in Groups >1 / Week)

Mental Health (Doctor-Diagnosed Depression or Antidepressant Use)

Mortality

Greenness

Total Physical Activity (MET-hrs per Week)
Proportion Explained: 2.1% (0.2%, 19.3%)

Air Pollution Exposure (Modeled PM$_{2.5}$)

Social Engagement (Participate in Groups >1 / Week)

Mental Health (Doctor-Diagnosed Depression or Antidepressant Use)

Mortality
Greenness

Total Physical Activity (MET-hrs per Week)
Proportion Explained: 2.1% (0.2%, 19.3%)

Air Pollution Exposure (Modeled PM$_{2.5}$)
Proportion Explained: 4.4% (2.4%, 7.7%)

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Mental Health (Doctor-Diagnosed Depression or Antidepressant Use)

Mortality

Greenness

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Proportion Explained: 2.1% (0.2%, 19.3%)

Air Pollution Exposure (Modeled PM$_{2.5}$)
Proportion Explained: 4.4% (2.4%, 7.7%)

Social Engagement (Participate in Groups >1 / Week)
Proportion Explained: 19.1% (10.0%, 33.3%)

Mental Health (Doctor-Diagnosed Depression or Antidepressant Use)

Mortality
**Greenness**

1. **Total Physical Activity (MET-hrs per Week)**
   - Proportion Explained: 2.1% (0.2%, 19.3%)

2. **Air Pollution Exposure (Modeled PM$_{2.5}$)**
   - Proportion Explained: 4.4% (2.4%, 7.7%)

3. **Social Engagement (Participate in Groups >1 / Week)**
   - Proportion Explained: 19.1% (10.0%, 33.3%)

4. **Mental Health (Doctor-Diagnosed Depression or Antidepressant Use)**
   - Proportion Explained: 30.6% (15.5%, 44.6%)

**Mortality**

*James et al. Environmental Health Perspectives. 2016.*
Conclusions

- Higher levels of greenness associated with a decreased rates of all-cause mortality in this cohort of female nurses, after accounting for numerous potential confounders.
- Evidence of mediation by mental health, social engagement, air pollution, and physical activity.
Strengths and Limitations

- Large nationwide prospective cohort study
- Adds evidence to mechanisms with mediation analyses

- Female nurses, primarily white
  - Limited generalizability
- No qualitative description of vegetation
- No information on how participants interact with nature
Outcome: Depression

- First self-reported **physician-diagnosed depression or use of antidepressants** from biennial questionnaire:

  - “Have you ever had any of these physician-diagnosed illnesses?—Depression, Dr. Dx”

  - “Regular medication (mark if used regularly in past 2 years): Prozac, Zoloft, Paxil, Celexa, other antidepressants (e.g. Elavil, Tofranil, Pamelor)”
Effect Modification

- Effect of greenness was consistent across individual and area-level characteristics
  - Marital status
  - Individual SES
  - Area SES
  - Urbanicity
  - $\text{PM}_{2.5}$ level
Questions Moving Forward

- Generalizability
- Uncertainty over the relevant geographic context to measure greenness
- Is the Normalized Difference Vegetation Index around each participant’s home the relevant exposure?
Developed by US EPA

Data generated from digital image processing, air photo interpretation and classification of aerial photography from USDA

Automated feature extraction used to classify six common land cover classes:
- Impervious Surface, Soil-Barren, Grass-Herbaceous, Tree-Forest, Agriculture, and Water

Data available for 3 visible and 1 near infrared spectral bands, one meter pixel size, nation-wide, 50 cities planned
For 12 cities, created moving windows to estimate percentages of the following measures within a 50m buffer:

- **Green Space**: Grass-Herbaceous, Tree-Forest, Agriculture
- **Tree Cover**: Tree-Forest
- **Water**: Water

**Distance to Park:**

- GIS sources and other state, county, and local parks and recreation information
mHealth: Activity Space

- mHealth: Smartphones and consumer wearable devices
  - Efficient, objective, low-cost measurement of location-based behavior

- Unprecedented perspectives on exposure and behavior

- Break the current dichotomy between small precise studies and large studies with error
Acknowledgments

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- Rachel Banay, MPH
- Jaime Hart, ScD
- Carla Bezold, MPH

- NIEHS R01 ES017017
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- NHLBI T32 HL 098048