Making the Connection: Air Pollution and Physical Activity

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Group Against Smog and Pollution
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Learning Objectives

- Explain physical activity benefits and guidelines
- Discuss public health significance of air pollution exposure while being physically active
- Summarize scientific research examining joint physical activity and air pollution exposure
- Describe an integrated approach for addressing knowledge gaps
PHYSICAL ACTIVITY BENEFITS & GUIDELINES
Physical Activity

- Bodily movement produced by skeletal muscles

- Moderate-intensity
  - Brisk walking, bicycling <10 mph
  - Gardening, ballroom dancing

- Vigorous-intensity
  - Jogging, bicycling >10 mph
  - Swimming laps, jumping rope

- Muscle-strengthening
  - Resistance and weight training
Physical Activity Domains

- Recreational / leisure-time
- Occupational
- Household
- Transportation
Benefits of Physical Activity

- In adults, physical activity lowers risk for:
  - Premature death
  - Coronary heart disease
  - Stroke
  - Hypertension
  - Type 2 diabetes
  - Colon cancer
  - Breast cancer
  - Depression
  - Unhealthy weight gain
  - Injuries from falls

- In children and adolescents, physical activity is associated with improved:
  - Cardiorespiratory fitness
  - Bone health
  - Cardiovascular biomarkers
  - Metabolic health biomarkers
  - Academic achievement
  - Academic behaviors
  - Cognitive skills

Public Health Impacts of Physical Inactivity

- 36% of adults report no leisure-time physical activity
- <50% of adults meet guidelines for aerobic activity
- Inadequate activity responsible for
  - 234,000 deaths per year
  - $117 billion per year in health care expenditures

CDC National Health Interview Survey; Murray CJ et al. 2013 JAMA; Carlson SA et al. 2015 Progress Cardiovascular Dis
Physical Activity Guidelines for Americans (US DHHS)

2008 Physical Activity Guidelines for Americans

Be Active, Healthy, and Happy!

www.health.gov/paguidelines
Physical Activity Guidelines
Adults (18–64 yrs)

- Avoid inactivity. Health benefits are seen with any amount of physical activity.
- Substantial health benefits seen with:
  - 150 min/week of moderate-intensity aerobic activity
  - 75 min/week of vigorous-intensity aerobic activity
  - Activity episodes of 10+ minutes throughout week
- Additional health benefits seen with:
  - 300 min/week of moderate-intensity aerobic activity
  - 150 min/week of vigorous-intensity aerobic activity
- Muscle-strengthening activities 2+ days/week provide additional benefits
Physical Activity Guidelines
Older Adults (65+ yrs)

- Same four principles on previous slide, but additional qualifying guidelines:
  - Guidance for adults who cannot do 150 min/week
  - Use relative intensity to determine level of effort
  - Be aware of chronic conditions and injury risk
  - Recommend balance exercises for persons at risk of falling
Physical Activity Guidelines
Children and Adolescents (6–17 yrs)

- 60+ minutes of physical activity every day
  - Aerobic: Most of 60+ minutes should be moderate- or vigorous-intensity aerobic physical activity, with vigorous-intensity activity 3+ days/week.
  - Muscle-strengthening: 3+ days/week
  - Bone-strengthening: 3+ days/week

- Encourage participation in physical activities that are age appropriate, enjoyable, and offer variety
AIR POLLUTION EXPOSURE AND PHYSICAL ACTIVITY
Global Burden of Disease

Source: Lim SS et al. (2012) Lancet
Physical Activity and Air Pollution Dose

- Concentration: varies across microenvironments
  - Location and time of activity
- Exposure = Concentration x Time
  - Duration of activity
- Dose = Exposure x Ventilation rate
  - Intensity of activity
  - Inhalation dose (faster respiratory rate)
  - Uptake dose (deeper penetration into lungs and reduced nasal filtrations)
- Dose is dependent on age, sex, and body size

Giles and Koehle 2013 Sports Med
Public Health Guidance

- Physical activity guidelines seldom address exposure to air pollution
Exposure to air pollution is associated with several adverse health outcomes, including asthma attacks and abnormal heart rhythms.

People who can modify the location or time of exercise may wish to reduce these risks by exercising away from heavy traffic and industrial sites, especially during rush hour or times when pollution is known to be high.

However, current evidence indicates that the benefits of being active, even in polluted air, outweigh the risk of being inactive.

www.health.gov/paguidelines
Public Health Guidance

- Physical activity guidelines seldom address exposure to air pollution
- Air quality messages recommend reducing the duration or intensity of activity to reduce the negative health impacts of air pollution exposure
<table>
<thead>
<tr>
<th>Descriptors</th>
<th>Level</th>
<th>Cautionary Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0–50</td>
<td>None</td>
</tr>
<tr>
<td>Moderate</td>
<td>51–100</td>
<td>Unusually sensitive people should <strong>consider reducing</strong> prolonged or heavy outdoor exertion</td>
</tr>
</tbody>
</table>
| Unhealthy for Sensitive Groups | 101–150 | The following groups should **reduce prolonged or heavy outdoor exertion:**  
- People with heart or lung disease  
- Children and older adults         |
| Unhealthy                    | 151–200  | The same groups should **avoid all prolonged or heavy outdoor exertion**                                                                       |
| Very Unhealthy               | 201–300  | The same groups should **remain indoors** and keep activity levels low                                                                        |
Public Health Guidance

- Physical activity guidelines seldom address exposure to air pollution
- Air quality messages recommend reducing the duration or intensity of activity to reduce the negative health impacts of air pollution exposure
- Concerns about air pollution exposure could inhibit regular physical activity and associated health benefits
- Challenge: balance competing priorities and communicate clear messages to public
SELECTED SCIENTIFIC STUDIES
Types of Health Studies

- Controlled exposure studies
  - Acute effects of short-term exposures
- Epidemiologic studies
  - Study people in real-world conditions
  - Experimental and observational designs
  - Acute and chronic effects of short- or long-term exposures
- Health Impact Assessment (HIA)
  - Estimate potential health benefits and risks of a proposed policy, program, or project
Health Effects of Exercising in Air Pollution Review (2014)

- Short- and long-term exposure to air pollution prior to or during physical activity can negatively affect
  - Exercise performance
  - Lung function
  - Lung inflammation

- Improved cardiovascular function from regular physical activity might attenuate adverse health effects of air pollution exposure

Giles LV and Koehle MS. 2014 Sports Medicine
Short-term Exposure and Lung Function

- 60 adults with asthma walk for 2 hours along two different routes.
- Larger decline in lung function after walking more polluted route.

McCreanor J, et al. 2007, NEJM
Short-term Exposure and Cognitive Function

- Physical activity known to improve cognitive function
- Serum brain-derived neurotrophic factor (BDNF) is a neurotrophine that enhances brain plasticity
- BDNF increased after cycling in clean air-filtered room, but did not increase after cycling outdoors near a major road

Bos I, et al. 2011 Neuroscience Letters
Short-term Exposure and Lung Function and Blood Pressure

- Case-crossover study design with four scenarios

<table>
<thead>
<tr>
<th>Active / Low pollution</th>
<th>Active / High pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactive / Low pollution</td>
<td>Inactive / High pollution</td>
</tr>
</tbody>
</table>

Comparing Active to Inactive/Rest:

- Physical activity increased pulmonary function in both low and high pollution environments
- Physical activity lowered systolic blood pressure more in the low (vs. high) pollution environment

Long-term Exposure and Asthma Incidence

- Cohort study of 3,535 children 9–16 yrs
- Southern California, 1993–1998
- Playing ≥3 sports increased risk of asthma in high ozone communities, but not in low ozone communities

<table>
<thead>
<tr>
<th>Number of sports played</th>
<th>Low ozone communities</th>
<th>High ozone communities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (incidence)*</td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>0</td>
<td>58 (0.027)</td>
<td>1.0</td>
</tr>
<tr>
<td>1</td>
<td>50 (0.033)</td>
<td>1.3 (0.9–1.9)</td>
</tr>
<tr>
<td>2</td>
<td>20 (0.023)</td>
<td>0.8 (0.5–1.4)</td>
</tr>
<tr>
<td>≥3</td>
<td>9 (0.019)</td>
<td><strong>0.8 (0.4–1.6)</strong></td>
</tr>
</tbody>
</table>

Long-term Exposure and Cardiopulmonary Fitness

- VO$_2$ max was lower overall among children in high pollution areas.
- VO$_2$ max was higher among active (vs. inactive) children only in low pollution area.

### TABLE 5

<table>
<thead>
<tr>
<th>District</th>
<th>Adjusted Mean VO$_2$max</th>
<th>Difference in Mean VO$_2$max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Exercise</td>
<td>No Exercise</td>
</tr>
<tr>
<td>LPD</td>
<td>30.6</td>
<td>28.8</td>
</tr>
<tr>
<td>HPD</td>
<td>29.6</td>
<td>29.0</td>
</tr>
</tbody>
</table>

Yu IT, 2004, J Occup Environ Med
Does Air Pollution Exposure Modify Physical Activity Mortality Benefits?


<table>
<thead>
<tr>
<th>Physical activity</th>
<th>Main model</th>
<th>Interaction model, fully adjusted&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Moderate/low NO&lt;sub&gt;2&lt;/sub&gt; (&lt;leq 19.0 μg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>High NO&lt;sub&gt;2&lt;/sub&gt; (&lt;geq 19.0 μg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>p-Value&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude&lt;sup&gt;a&lt;/sup&gt; model</td>
<td>Fully adjusted model</td>
<td>Moderate/low NO&lt;sub&gt;2&lt;/sub&gt; (&lt;leq 19.0 μg/m&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>High NO&lt;sub&gt;2&lt;/sub&gt; (&lt;geq 19.0 μg/m&lt;sup&gt;3&lt;/sup&gt;)</td>
<td></td>
</tr>
<tr>
<td>Total mortality (n = 5,534)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports</td>
<td>0.62 (0.59, 0.65)</td>
<td>0.78 (0.73, 0.82)</td>
<td><strong>0.79 (0.74, 0.85)</strong></td>
<td><strong>0.75 (0.67, 0.83)</strong></td>
<td>0.14</td>
</tr>
<tr>
<td>Cycling</td>
<td>0.77 (0.73, 0.81)</td>
<td>0.83 (0.78, 0.88)</td>
<td><strong>0.83 (0.77, 0.88)</strong></td>
<td><strong>0.83 (0.75, 0.92)</strong></td>
<td>0.81</td>
</tr>
<tr>
<td>Gardening</td>
<td>0.72 (0.68, 0.77)</td>
<td>0.84 (0.79, 0.89)</td>
<td><strong>0.85 (0.78, 0.92)</strong></td>
<td><strong>0.83 (0.75, 0.91)</strong></td>
<td>0.77</td>
</tr>
<tr>
<td>Walking</td>
<td>0.91 (0.83, 1.00)</td>
<td>0.97 (0.88, 1.06)</td>
<td><strong>0.96 (0.86, 1.08)</strong></td>
<td><strong>0.95 (0.80, 1.14)</strong></td>
<td>0.79</td>
</tr>
<tr>
<td>Respiratory mortality (n = 354)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports</td>
<td>0.40 (0.31, 0.50)</td>
<td>0.60 (0.47, 0.77)</td>
<td>0.65 (0.49, 0.88)</td>
<td>0.50 (0.32, 0.77)</td>
<td>0.70</td>
</tr>
<tr>
<td>Cycling</td>
<td>0.54 (0.43, 0.67)</td>
<td>0.62 (0.50, 0.77)</td>
<td><strong>0.55 (0.42, 0.72)</strong></td>
<td><strong>0.77 (0.54, 1.11)</strong></td>
<td>0.09</td>
</tr>
<tr>
<td>Gardening</td>
<td>0.50 (0.40, 0.63)</td>
<td>0.63 (0.50, 0.79)</td>
<td><strong>0.55 (0.41, 0.73)</strong></td>
<td><strong>0.81 (0.55, 1.18)</strong></td>
<td>0.02</td>
</tr>
<tr>
<td>Walking</td>
<td>0.63 (0.46, 0.86)</td>
<td>0.71 (0.51, 0.97)</td>
<td>0.67 (0.46, 0.97)</td>
<td>0.89 (0.47, 1.67)</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Does Physical Activity Modify Acute Air Pollution Mortality Risks?

- 24,000 Chinese adults (>30 yrs) who died in 1998
- Air pollution associated with mortality only in “No exercise” group (but not in “Exercise” group)
- Never vs. Low, Moderate, and High exercise
  - Non-linear trend
  - Low and moderate exercise reduce risk
  - No additional protection in high exercise group

Wong CM, et al. 2007 Prev Med
### Active Transportation and All-Cause Mortality

- Active commuting reduces all-cause mortality
  - Includes deaths from air pollution and traffic crashes

<table>
<thead>
<tr>
<th>Study/Location</th>
<th>Relative risk associated with bicycling for transportation</th>
<th>Average PM$_{10}$ ($\mu$g/m$^3$)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersen (2000) Copenhagen Heart Study</td>
<td>0.70</td>
<td>23</td>
</tr>
<tr>
<td>Matthews (2007) Shanghai Women’s Health Study</td>
<td>0.66</td>
<td>87</td>
</tr>
</tbody>
</table>

Hamer M & Chida Y 2008 Prev Med; * World Bank Air pollution in cities database
Role of the Built Environment

- Neighborhood walkability and air pollution concentrations correlated (Vancouver, Canada)
- Compare ischemic heart disease mortality in So. Cal neighborhoods
- High-walkable:
  - 7 deaths from increased physical activity
  + 6 more deaths from increased air pollution (+ 9 PM$_{2.5}$ – 3 O$_3$)

Marshall JD, et al., 2009 Environ Health Perspect; Hankey S et al. 2012 Environ Health Perspect
Environmental and Health Equity

- “Win-win” neighborhoods (low pollution and high walkability) located in higher income areas (Vancouver)

- In high-minority neighborhoods, physically active children living near parks had higher dose of traffic-related pollution (compared to similar children in low-minority neighborhoods) (California)

Health Impact Assessment (HIA) Systematic Review

- Review of 30 HIAs on mode shift to active transportation

- Health impacts assessed
  - Physical activity
  - Traffic incidents/crashes
  - Air pollution exposure to traveler
  - Air pollution exposure to general population

- Benefits of increased activity strongly outweighed risks of traffic incidents and air pollution exposure
  - Median benefit : risk ratio = 9 (range: -2 to 360)

Health Impact Assessment (HIA) Systematic Review

N. Mueller et al. / Preventive Medicine 76 (2015) 103–114
Knowledge Gaps

- Integrated public health guidance
  - Mixture of pollutants / combined toxicity
  - Effect modification
  - Role of confounders (e.g., noise, stress)
  - Susceptible populations
- Land use and transportation planning
  - Street-scale built environment features
  - Neighborhood built environment features
  - Health equity and environmental justice
INTEGRATED RESEARCH APPROACH
Figure 1. Research approaches for studying air pollution and physical activity

**Typical research approach**

- **Air pollution exposure**
  - Control for covariates
  - Acute and chronic health effects
  - Air pollution policy

- **Physical activity level**
  - Control for covariates
  - Acute and chronic health effects
  - Physical activity policy

**New integrated research approach**

- **Joint air pollution and physical activity exposure**
  - Effect modification
  - At-risk populations
  - Role of built environment
  - Equity considerations
  - Aggregate acute and chronic health effects
  - Integrated air pollution and physical activity policies

- **Physical activity level**
Effect Modification

- Goal: Improve understanding of modifying effects of short- and long-term exposures on acute and chronic health outcomes and of underlying biological mechanisms

1. Does exposure to air pollution attenuate long-term health benefits of physical activity? If so, to what extent?
2. To what extent are physically fit persons less susceptible to acute and chronic health effects of air pollution exposure?
3. Does short-term joint physical activity and air pollution exposure have positive or negative health effects? Does the effect differ across health outcomes?
At-risk Populations

- Goal: Identify at-risk populations to inform the development and targeting of public health guidelines
  1. Are some population subgroups more or less susceptible to health effects associated with joint exposure?
  2. Does the trade-off between benefits vs. risks differ across population subgroups?
Goal: Identify design strategies and policies that promote increased physical activity in lower pollution environments

1. What design features make for “win-win” neighborhoods?
2. How can bicycle/pedestrian infrastructure encourage physical activity and reduce air pollution exposure?
3. Where should schools and athletic facilities be sited to enhance health benefits of physical activity?
**Equity Considerations**

- **Goal:** Promote policies that mitigate inequalities in both air pollution exposure and physical activity opportunities

1. What populations are more likely to have decreased physical activity opportunities and elevated air pollution levels?
2. How can we provide equal access to win-win neighborhoods?
3. How can we ensure physical activity infrastructure is located in less polluted environments, especially in disadvantaged areas?
RECOMMENDATIONS AND NEXT STEPS
General Recommendations on Air Pollution and Physical Activity

- As much as possible, avoid traffic on busy roads and during rush hour.
- In the summer, exercise in the morning to minimize ozone exposure.
- At-risk individuals (e.g., pre-existing cardiovascular or respiratory disease) should consult their physician prior to starting an exercise program.
- Follow local air quality forecasts and plan workouts around them.

Giles LV & Koehle MS 2014 Sports Med; HHS Physical Activity Guidelines for Americans, 2008;
Considerations for Future Guidance on Air Pollution and Physical Activity

- Address all types of physical activity
- Address air pollution in microenvironments
  - Proximity to major roads, urban/rural settings
  - Time of day, seasonality
- Balance acute and chronic health effects to multiple organ systems
- Provide local air pollution data to help inform individual’s physical activity decisions
“Shortest path” route

From Address: 105 Commercial, Vancouver
To Address: Van Dusen Botanical Gardens, Vancouver
Route Type: Designated + Alternate Cycling Roads
Preference: Shortest Path Route
“Least traffic pollution” route

http://www.cyclevancouver.ubc.ca/cv.aspx
Considerations for Future Guidance on Air Pollution and Physical Activity

- Address all types of physical activity
- Address air pollution in microenvironments
  - Proximity to major roads, urban/rural settings
  - Time of day, seasonality
- Balance acute and chronic health effects to multiple organ systems
- Provide local air pollution data to help inform individual’s physical activity decisions

- Encourage physical activity and time outdoors!
Let’s Change the Paradigm

It’s a green day. Go for it.

Today GOOD

It’s a green day. Go for it.

Today GOOD

MahoniningValleyAir.org
Everyone has a role to play to increase walking and make our communities more walkable

- Transportation, land-use, and community design
- Parks, recreation, and fitness
- Education
- Business and industry
- Volunteer and nonprofit organizations
- Health care and public health
- Media
- Families and individuals