The Global Burden of Cardiovascular Mortality due to Sodium

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Disclosures

- Research on the health effects of diet supported by the Bill & Melinda Gates Foundation, Sackler Institute of Nutrition, and US National Institutes of Health.

- Ad hoc honoraria for one-time scientific presentations on diet from Quaker Oats, Pollock Institute, and Bunge.


- Unilever North America Scientific Advisory Board.

Cardiovascular Risk Factors

Mozaffarian, Wilson, & Kannel, Circulation 2008
**Diet & The Heart: Conventional Wisdom**

- Total Fat, Saturated Fat
- Serum Total and LDL Cholesterol
- Coronary Heart Disease

- Ecologic Studies
- Biomarker Studies
- Animal Experiments

**Diet & The Heart: Modern Science**

- Carbohydrates
- Total and saturated fat
- Alcohol and alcoholic beverages
- Dietary fiber
- Vitamins and minerals
- Fish and fats

**Preventing Chronic Diseases: Diet Patterns**

- Various food images

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## Essential Dietary Habits for Health

**EAT:**
- Fish and Seafood
- Whole Grains
- Fruits
- Vegetables
- Nuts
- Vegetable Oils
- Moderate Dairy

**LIMIT:**
- Starches, refined grains, sugars
- Processed Meats
- Sweetened Drinks
- Industrial Trans Fat *
- Salt *

*Mozaffarian, Appel, & Van Horn. Circulation 2011*

## Global Nutrition Transition

- Rapid global epidemiologic and nutrition transition toward noncommunicable diseases (NCDs), including cardiovascular diseases, diabetes, and obesity.
- The “transition” is now largely complete: In nearly all countries, the burdens of NCDs far outweigh infectious and maternal-child diseases.
- 2011 United Nations High Level Summit: Highlighted unhealthy diet and healthy diet as key priorities.

*Prevention and control of noncommunicable diseases. Report of the Secretary-General, United Nations General Assembly, 2011*

*Lim et al., Lancet 2012*

## Quantifying Burdens:
**Comparative Risk Assessment (CRA)**

- **Current Distributions of Exposure**
  - Corrected for missing data, incomparability, and bias
  - By relevant subgroups, including age, sex, country, time

- **Optimal Distributions of Exposure**
  - Exposure distribution at which minimum risk occurs
  - Based on both observed lower risk and observed intakes

- **Etiologic Effects (RRs) of Exposure on Disease**
  - Probable or convincing evidence for causal effects
  - Best unbiased estimates
  - By relevant subgroups (e.g., age, race)

- **Attributable Burdens of Disease**
  - Absolute rates of disease, corrected for bias
  - Mortality, morbidity (DALYs, QALYs)
  - Absolute vs. relative (proportional) burdens
Overall analysis:

Population-attributable fraction = 

\[ \frac{\int_{0}^{m} RR(x)P(x)dx}{\int_{0}^{m} P(x)dx} \]

- \( x \): the exposure level.
- \( (x) \): the usual population exposure distribution.
- \( P'(x) \): the alternate population distribution.
- \( RR(x) \): the relative risk of mortality or morbidity at exposure level x.
- \( m \): maximum exposure level.

Systematic searches of multiple online databases (MEDLINE, EMBASE, etc.)
(Mar 2008 to Jul 2012)

Identification

Potentially relevant identified surveys (n = 536)
Surveys meeting inclusion and exclusion criteria (n = 389)
Surveys not relevant from initial screen (n = 147)
Final surveys used in the analysis and imputation (n = 276)

Surveys without available data or not accepting participation (n = 43)
Additional surveys excluded (n = 56)
- Duplicate reports
- Highly selected population (e.g., pregnant women, hypertensives)
- Data in youth (age ≤ 19 yrs)
- Extensive (3000+) direct contacts with authors, experts, and policy makers
(Mar 2008 to Sep 2010)

Global Data on Salt Consumption

- 143 urinary and 105 dietary surveys covering 1980-2010
- 66 countries
- 460,592 individuals
- 101 surveys from low/mid-income countries, 147 surveys from high-income countries
- 74% of the globe's population represented

Powles et al., BMJ Open 2013
Bayesian Hierarchical Imputation

Bayesian hierarchical imputation model:
- Accounted for both country-level and region-level data and multiple levels of missingness.
- Used country-level data simultaneously as inputs to country and regional estimates.
- Nested intake levels and trends over time in individual countries within regional levels, and in turn within global levels.
- Borrowed information from country, regional, and global levels, depending on extent of data missing or less informative.

Covariates:
- Country-level: Per capita GDP, rural/urban, latitude, rainfall, length of coastline.
- Country-level: FAO Food balance sheets, by country and year.
- Other data as available (e.g., for trans fat).
- Survey-level: Diet assessment method, representativeness, and diet-specific crosswalks (e.g., for urinary vs. dietary sodium).
- Additional variance components.

Bayesian Hierarchical Imputation

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**BP Effects of Sodium: Dose-Response**

Based on semi-parametric restricted cubic spline analysis of 107 RCTs (N=6,970)

Mozaffarian D et al, submitted

- **P linearity = 0.001**
- **P nonlinearity 0.58**

![BP Effects of Sodium: Dose-Response](image)

**BP Effects of Sodium: Interaction by Age**

Based on inverse variance meta-regression of 107 RCTs (N=6,970)

Mozaffarian D et al, submitted

**BP Effects of Sodium: Joint Interaction by Age, Race, and Hypertension**

- For a white, normotensive, 50-year old, 2.3 g/d lower sodium reduced systolic BP by 3.74 mm Hg (95%CI: 2.29, 5.18).
- **Age**: per 1 year (until age 70): 0.105 mm Hg (95%CI: 0.047, 0.164) lesser or greater reduction.
- **Hypertensive**: 1.87 mm Hg greater reduction (95%CI: 0.12, 3.63).
- **Black race**: 2.49 mm Hg greater reduction (95%CI: 0.13, 4.85).

Based on inverse variance meta-regression of 107 RCTs (N=6,970)

Mozaffarian D et al, submitted
Dose-Response Effects of BP on CVD

Mean intakes associated with better health:
- 614 mg/d: Lower systolic BP and lower age-BP slopes in ecologic studies.
- 1245 mg/d: Lower incidence of gastric cancer in meta-analysis of prospective cohorts.
- 1500 mg/d: Reduced BP in randomized controlled trials.
- 1880 mg/d: Lower incidence of CHD mortality in meta-analysis of prospective cohorts.

Highest reported national mean intakes, non-energy adjusted:
- 2245 mg/d: Lower incidence of total stroke in meta-analysis of prospective cohorts.
- 1800 mg/d: Lower incidence of stroke mortality in meta-analysis of prospective cohorts.
- 2400 mg/d: Lower incidence of CHD mortality in meta-analysis of prospective cohorts.

Global Data on BP Levels and CVD Deaths

National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5.4 million participants.

Danaei et al. Lancet 2011


Lopez et al. Lancet 2012
Results

- In 2010, 1.65 million (95% UI: 1.10, 2.22) global CVD deaths per year were attributable to sodium intakes >2 g/d.
- Corresponds to 1 in 10 (9.5%) of all CVD deaths.
- In the US: 301 deaths per million per year, or 1 in 16 (6.3%) of all CVD deaths, and 1 in 8 (13.1%) before age 70.

Absolute CVD Mortality Attributable to Sodium (>2 g/d) in 2010
Proportional CVD Mortality Attributable to Sodium (>2 g/d) in 2010

Absolute CVD Mortality Attributable to Sodium in 2010

Proportion of CVD Deaths Attributable to Sodium in 2010
Summary

• In 2010, 1.65 million (95% UI: 1.10, 2.22) global CVD deaths/year attributable to sodium >2 g/d, or 1 in 10 (9.5%) of all CVD deaths.
• 42% from CHD, 41% from stroke, and 17% from other CVD
• 4 in 5 (84%) sodium-related CVD deaths in low & mid-income nations.
• 2 in 5 (40.1%) premature, i.e. age ≤ 69 years.
• “Silk Road” countries had highest absolute CVD mortality due to sodium.
• Proportional mortality was more evenly distributed across the globe.
• Sensitivity analyses: Changing the definition of optimal intake from 2000 to 1000 mg/d increased the attributable global deaths by ~40%, to 2.30 million (95% UI: 1.55, 3.07).

Changing Behavior

• Individual level approaches
• Health care system strategies
• Population strategies

Evidence-Based Policy Interventions to Improve Diet

<table>
<thead>
<tr>
<th>Media and Education</th>
<th>Sustained, focused media campaigns, especially combined with multi-component strategies, focused on specific foods or drinks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labeling and Information</td>
<td>Mandated nutrition facts, front-of-pack labels/icons, or menu labeling to influence industry behavior and product formulations.</td>
</tr>
<tr>
<td>Schools</td>
<td>Multicomponent diet and activity program including classes, teacher training, supportive policies, environmental changes, family components.</td>
</tr>
<tr>
<td>Workplaces</td>
<td>Comprehensive worksite wellness programs for diet, activity, tobacco.</td>
</tr>
<tr>
<td>Economic Incentives</td>
<td>Subsidy strategies to lower prices of more healthful foods and beverages.</td>
</tr>
<tr>
<td>Economic Incentives</td>
<td>Tax strategies to increase prices of less healthful foods and beverages.</td>
</tr>
<tr>
<td>Bans and Mandates</td>
<td>Restrictions on ads/marketing of less healthy foods/drinks to children on television, and near schools and public places, and on packages.</td>
</tr>
<tr>
<td>Bans and Mandates</td>
<td>Direct bans (e.g., sodium, trans fat) or mandates (e.g., vegetable oils).</td>
</tr>
</tbody>
</table>

Artinian et al., AHA Scientific Statement, Circulation 2010
Mozaffarian et al., AHA Scientific Statement, Circulation 2012
Mozaffarian et al, AHA Scientific Statement, Circulation 2012
Conclusions

• Poor lifestyle is the leading cause of preventable diseases in nearly all nations. Resultant morbidity and mortality, adverse impacts on disparities, and economic costs are staggering.

• Our findings provide robust quantitative estimates of the global, regional, national, and age and sex specific burdens of CVD due to excess sodium consumption.

• Excess sodium is a major contributor to CVD in high, middle, and low income nations, in men and women, and in middle-aged and older adults.

• These results inform priorities for prevention programs, including the need for strong public health policy to reduce sodium at global, regional, national, and community levels.

• Clinicians, scientists, public health officials, policy makers, communities, advocacy groups, and industry must engage in and form alliances to translate these findings into action.

Global sodium consumption among adults age 20+ in 2010

Global Burden of Diseases
Nutrition and Chronic Diseases Expert Group (NutriCoDE)

Core Team - Harvard School of Public Health:
• Dariush Mozaffarian, Ronal Hisch, Shahab Khatibzadeh, Mayurese Rao, Gita Singh, Peilin Shi.

Sodium:
• John Powles, Saeed Fahimi, Institute of Public Health, Cambridge UK.

General Support:
• Majid Ezzati, Imperial College London UK; Ibrahim Elmadfa, U. of Vienna, Austria.

Cancer Etiologic Effects:
• Tim Byers, U. of Colorado; Edward Giovannucci, Harvard School of Public Health; Stephanie Smith-Warner, Harvard School of Public Health.

Exposure Imputation:
• Stephen Lim, Kathryn Andrews, Rebecca Engell, Institute for Health Metrics and Evaluation, Seattle.

Global Corresponding Members:
• 100 corresponding members provided unpublished data from 126 dietary surveys in 117 countries.
Evidence-Based Individual Behavior Change

• Shared, specific, proximal goals. (Class 1A)

• Planned regular follow-up (individual visits, group visits, electronic follow-up). (Class 1A)

• Self-monitoring (e.g., food diary). (Class 1A)

• Verbal, written, or electronic feedback. (Class 1A)

• Long-term support (family, friends, peers). (Class 1A)

Arkoian et al., Circulation 2010

Key Diet Priorities: Focus on the Positive

<table>
<thead>
<tr>
<th>Food</th>
<th>Servings per Day</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>4 to 5 servings</td>
<td>1 cup of low-fat vegetables;</td>
</tr>
<tr>
<td></td>
<td>per day</td>
<td>1 cup of raw vegetables;</td>
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<tr>
<td></td>
<td></td>
<td>1 cup of cooked vegetables;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 cup of mixed vegetables.</td>
</tr>
<tr>
<td>Pasta</td>
<td>4 to 5 servings</td>
<td>1 cup of whole-wheat pasta;</td>
</tr>
<tr>
<td></td>
<td>per day</td>
<td>1 cup of brown rice;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 cup of lentil soup;</td>
</tr>
<tr>
<td>Whole grains</td>
<td>3 or more servings per day</td>
<td>1 slice of whole-grain bread;</td>
</tr>
<tr>
<td></td>
<td>per week</td>
<td>1 cup of low-fat, unflavored</td>
</tr>
<tr>
<td></td>
<td></td>
<td>oatmeal, or cereal.</td>
</tr>
<tr>
<td>Fish and shellfish</td>
<td>2 or more servings per week</td>
<td>1 or 2 portions (the portion size of 1 deck of cards)</td>
</tr>
<tr>
<td>Nuts and seeds</td>
<td>4 to 5 servings</td>
<td>1/2 to 1 tablespoon of seeds</td>
</tr>
<tr>
<td></td>
<td>per week</td>
<td>per week.</td>
</tr>
<tr>
<td>Dairy products</td>
<td>2 to 3 servings</td>
<td>1 cup of milk or yogurt;</td>
</tr>
<tr>
<td></td>
<td>per day</td>
<td>1 ounce of cheese or cream.</td>
</tr>
<tr>
<td>Vegetables oils</td>
<td>2 to 4 servings</td>
<td>1 teaspoon oil, 1 tablespoon vegetable spread</td>
</tr>
</tbody>
</table>
### Health Care Systems Strategies

- **Multiple educational techniques**, e.g. live and media presentations, to improve provider knowledge on key lifestyle targets and behavior change approaches.
- **Efficient EMR assessment and monitoring** of diet, physical activity, adiposity, and smoking.
- **Regular scheduling strategies** for individual and/or group visits to receive education and behavioral support.
- **Structured systems for individualized feedback**, using clinic and phone approaches, on patients’ behavior change efforts.
- **Quality benchmarks and reimbursement guidelines** focused on health behaviors, including diet and physical activity.

Montali et al., Circulation 2012

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### U.S. Declines in Blood Cholesterol: 1988 to 2010

![Graph showing U.S. declines in blood cholesterol from 1988 to 2010](image)

Carroll et al., JAMA 2012

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### Drug Treatments vs. Population Approaches

![Graph comparing individual patient drug treatments versus population changes, non-drug related.](image)

Ford et al, NEJM 2007