SALT INTAKE
Too Much, Too Little, Or Just Right?

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Federal Child Nutrition Programs, among other requirements, call for a phased reduction in sodium content of meals provided to school children.

In the first phase (Target 1), the prescribed sodium limits are both achievable and reasonable.

SNA’s position is that the requirement for further reduction should be dropped.
BACKGROUND – 2

- I believe the SNA position is correct
- my task is to give you the ammunition you need to argue your position:
  - there is no evidence of a health benefit accruing to further reducing sodium intake
  - on the contrary, there is evidence of possible harm associated with sodium intakes below the target 1 levels
  - targets 2 & 3 cannot be met with diets that are otherwise nutritionally adequate
TIME: March 15, 1982

Salt: A New Villain?
SOME SODIUM INTAKE FACTS

- 2005 IOM recommendations for adults:
  < 1,500 mg/day up to age 50
  < 1,300 mg/day from 50 to 70
  < 1,200 mg/day after age 70

- mean Na intake in U.S. & Europe:
  3,450 mg/day (95% probability range: 2,600–5,000 mg/day)

- this intake has been stable for at least 50 years in forty five 1\textsuperscript{st} world nations
SODIUM INTAKE OVER TIME*

13 population-based studies in the UK
N = 6,343
1984 – 2008

McCarron et al., CJASN 2009

N.B.: 150 mmol is 3450 mg
Benefits and Harms
NUTRIENT RESPONSE CURVE*

- Risk of Deficiency
- Risk of Toxicity

Intake of Nutrient

- EAR
- RDA
- UL

*DRI book; IOM (2006)
BACKGROUND GUIDANCE

- this U-shaped (or J-shaped) distribution of risk is explicitly cited in the IOM’s guidance documents (p. 12)
- and is taken as the basic model for all nutrients in standard textbooks of nutritional epidemiology
NUTRIENT RESPONSE CURVE*

Intake of Nutrient

Risk of Deficiency

Risk of Toxicity

EAR

RDA

UL

Intake of Nutrient

*DRI book; IOM (2006)
RISK AT BOTH EXTREMES

Intake

Risk of Harm

deficiency
toxicity

CU ORC
U-SHAPED? – J-SHAPED?

Risk of Harm

Intake

toxicity

deficiency

Risk of Harm

Intake

deficiency

toxicity
NUTRIENT RESPONSE CURVE*

* DRI book; IOM (2006)
THE SIGMOID RESPONSE

If the intake is low, there is little or no benefit.

What is the benefit?

Maintenance of blood pressure

little or no benefit
THE SIGMOID RESPONSE

The sigmoid response curve shows a non-linear relationship between intake and response, with the "requirement" being the minimum daily intake needed for a response.
ESTIMATED AVERAGE REQUIREMENT

CALCIUM INTAKE

RETENTION

EAR

CALCIUM INTAKE

CU ORC
THE DRI PROCESS

- the RDA is an intake ~2 SD above the EAR
ESTIMATED AVERAGE REQUIREMENT
SODIUM IS UNIQUE AS A NUTRIENT

- for most nutrients, meeting the RDA at a population level means that 97.5% will get more than they actually need
- but with Na, the person unconsciously adjusts intake to match need
  - salt appetite is controlled in the central nervous system
  - salt taste sensors on the tongue “flip” from positive to negative at Na intakes above need
The adverse effect that the IOM sought to minimize was high blood pressure
BLOOD PRESSURE IN NHANES*

- NHANES–I
- 1971–75
- N = 10,372
- ≥ 160 mm Hg taken as hypertension

Population Proportion with Systolic BP 160 mm Hg or higher

Sodium Intake (mg/d)

0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14

0 1000 2000 3000 4000 5000 6000
BLOOD PRESSURE IN NHANES*

- **NHANES-I**
- **N = 10,372**
- **1971–75**
- **≥ 160 mm Hg taken as hypertension**

*rather than a paradox, this is an instance of homeostasis at work*
BLOOD PRESSURE IN NHANES*

- NHANES–I
- N = 10,372
- 1971–75
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higher salt intakes reflect a self-adjusted response to the need to maintain blood pressure
BLOOD PRESSURE IN NHANES*

- NHANES–I
- N = 10,372
- 1971–75
- ≥ 160 mm Hg taken as hypertension

This variation in salt intake is a manifestation of varying sodium need.
THE SODIUM DRIs

- the IOM noted that Na effects arose not from Na, per se, but from NaCl, the form in which ~90% of ingested Na enters the body.
- the IOM stated that there was not enough evidence regarding NaCl effects to establish the usual DRIs, and so proposed, instead, an AI.
THE DRI PROCESS

- an Adequate Intake (AI) is an intake “estimated” when there are not sufficient data to calculate the EAR or RDA
- how is it “estimated”?
- the DRI book says that is to be the average intake observed in a healthy population

“out of thin air”
THE DRI PROCESS

- an Adequate Intake (AI) is an intake “estimated” when there are not sufficient data to calculate the EAR or RDA
- how is it “estimated”?
- the DRI book says that is to be the average intake in a healthy population.

adults ≤ 50: 1500 mg/d
ages 50–70: 1300 mg/d
ages 70 & up: 1200 mg/d
THE SODIUM DRIs

- the adverse effect with increasing salt intake, which the AI seeks to minimize, is elevated blood pressure
- the IOM, in effect, ignored adverse effects at low intakes, *i.e.*, the panel used a linear model rather than a U–shaped model
- this explains why the BP data and the health outcomes data disagree
RISK AT BOTH EXTREMES

BP is the proxy for toxicity risk.
RISK AT BOTH EXTREMES

presumption: any decrease in intake decreases risk or severity of cardiovascular disease at all salt intakes

real risk reduction up here

is applied down here

BP is the proxy

Risk of Harm

Intake
“You can say without any shadow of doubt” that the authorities pushing the eat-less-salt message had “made a commitment to salt education that goes way beyond the scientific facts.”

Drummond Rennie, M.D.
Editor, *JAMA*
STARTING INTAKE MATTERS

Health outcomes are the proxy for Risk of Harm.

Intake →

CU ORC
STARTING INTAKE MATTERS

This behavior applies to most or all nutrients. Does it apply as well to Na?
CVD EVENTS*

*Worksite Hypertension Study; Alderman, M. 1995 Hypertension 25:1144–52
CV MORTALITY & MORBIDITY

CVD Mortality

All CVD Events

24-Hour urinary sodium excretion tertile
- Low
- Medium
- High

No. at risk by Tertile

Low 1220 1190 997 709 457 429 1220 1190 997 709 457 429
Medium 1250 1225 968 609 416 389 1250 1225 968 609 416 389
High 1211 1189 906 430 291 272 1211 1189 906 430 291 272

*Stolarz-Skrzypek et al., JAMA 2011 [pooled data from two large European studies]
TYPE I DIABETES & MORTALITY*

Current (AI) Recommendation

"Normal" Range

2800–5000 mg/d

Figure 1—The association between 24-h urinary sodium excretion and all-cause mortality

*Thomas et al., Diabetes Care 2011
RISK vs. INTAKE

- composite of CV death, stroke, MI, & CHF
- 14 cohort studies
- N = 154,282
- O’Donnell et al., Eur Heart Journal 2012

![Graph showing the relationship between Urine Na (g/d) and Hazard Ratio (95% CI) with data points at 0, 2, 4, 6, 8, 10, and 12 g/d. The hazard ratio decreases as urine sodium increases, reaching a minimum around 6 g/d, then increases again.]
RISK vs. INTAKE

- combined CV death, stroke, MI, & CHF

![Graph showing the relationship between Urine Na (g/d) and Hazard Ratio (95% CI). The lowest risk is indicated.]
CHF RISK vs. Na INTAKE

- EPIC–Norfolk Study
- n = 19,857
- mean follow-up: 12.9 yrs
- Pfister et al. (2014) Eur J Heart Failure
CVD RISK vs. Na INTAKE

- O’Donnell et al. NEJM 2014

Graph showing the relationship between Sodium Excretion (g/day) and Odds Ratio.
FURTHER PROBLEMS

- besides using a linear model instead of a U–shaped one, the IOM failed to factor in the crucial roles of Ca and K intakes, as revealed in the classic DASH studies
DASH–I*

- three–way trial of dietary intervention
  - standard American diet
  - diet high in fruits and vegetables
  - diet high in fruits & vegetables plus low–fat milk (~730 mg extra Ca)

- Na intake held constant at ~3000 mg across all three diets

*Appel et al., NEJM 1997; 336:1117-24
DASH-I: Hypertensive Cohort*

*Appel et al., NEJM 1997; 336:1117-24
DASH-I: Conclusions

- BP reduction was as large as produced by standard anti-hypertensive mono-therapy regimens
- if applied at a population level, the full DASH diet would reduce incidence of
  - stroke by 27%
  - MIs by 15%

N.B.: Na reduction was not a part of the “full” DASH regimen
DASH–II

- Control: standard diet, but with three levels of Na intake
- DASH: high fruit, vegetable, and dairy diet, also with three levels of Na intake
Na, BP, & THE DASH DIET*

Sodium Intake Level (mg/d)
3300 2400 1500

Mean Systolic BP (mm Hg)
140
135
130
125
120

Sodium Intake Level (mg/d)

Control
DASH

DASH – “OFFICIAL” CONCLUSIONS

- emphasis remained on *reducing* fat and sodium
- role of *increasing* Ca & K intakes minimized or ignored entirely
the possibly harmful effects of high Na intake are magnified when the diet is inadequate in Ca and K

high Ca & K intakes mitigate the possible harm of high Na intakes
BP AS A PROXY FOR RISK

- 5-yr cohort study
- 398,419 hypertensive pts. at Kaiser SoCal
- risk of death &/or ESRD
- Sim et al., J Am Coll Cardiol 2014; 64:588–97
Sodium is a “poster child” for the larger nutrient problem
THE NUTRIENT PROBLEM

- the field lacks a consensus on how to define “normal” or “adequate”
- that leaves the field virtually without a target to aim at
- and forces reliance upon empirical evidence that, say, intake $A$ is “better” by some measurable endpoint than intake $B$
- the evidence must be in the form of RCTs
OTHER BENCHMARKS

- there are several alternative benchmarks that have been proposed
- the one that seems best for Na is the intake that minimizes the need for the physiological compensation that occurs when intake is low
A BETTER BENCHMARK

- such compensation, for Na, is the activation of the RAAS mechanism, which becomes operative at Na intakes at or below ~3000 mg/d for an adult
RAAS – A RESCUE MECHANISM

angiotensinogen → angiotensin I → angiotensin II

↑ sympathetic activity
↑ NaCl reabsorption & water retention
↑ aldosterone secretion
↑ arteriolar constriction & rise in BP
↑ ADH secretion from pituitary

↓ renin

↓ renal blood flow
Note that the body’s response in RAAS is arteriolar constriction & rise in BP

We attempt to lower BP by Na restriction, and the body fights back by increasing BP

↑ sympathetic activity
↑ NaCl reabsorption & water retention
↑ aldosterone secretion
↑ ADH secretion from pituitary
Na INTAKE & RAAS RESPONSES*

these compensatory ("rescue") mechanisms begin to be deployed at Na intakes below ~3200 mg/d

*Brunner et al., NEJM (1972) 286:441–49
MI RISK & RENIN LEVELS*

*Alderman, M.
NEJM 1991;
Am J Hypertension 1997
A BETTER BENCHMARK

- such compensation, for Na, is the activation of the RAAS mechanism, which becomes operative at Na intakes at or below ~3000 mg/d for an adult
- using that criterion, Na intakes < 3000 mg would be “deficient”
- in other words, without compensation individuals would have hypotension and/or hypovolemia
DIAGRAMMATIC RELATIONSHIP

Na intake (g/d)

Systolic BP (mm Hg)

compensation required

optimal

CU ORC
increased risk of hypertension
compensation fails
FINAL THOUGHTS

- compensatory mechanisms are important for survival and are “normal”.
- the question: do we want an intake that requires our bodies to make continuous compensatory adjustments?
- or would we prefer to reserve the need of those adjustments for emergencies or for abnormal situations?
Nutritional Feasibility
A final question:
Do we want nutritionally adequate diets?
If so, is a Na intake of $\leq 1500$ mg/d compatible with adequacy of other nutrients?
Food pattern modeling shows that the 2010 Dietary Guidelines for sodium and potassium cannot be met simultaneously.

“Modeling analyses showed that the 2010 Dietary Guidelines for sodium were incompatible with potassium guidelines and with nutritionally adequate diets.”

*Maillot, Monsivais, & Drewnowski
Nutr. Res. 2013
“Modeling analyses showed that the 2010 Dietary Guidelines for sodium were incompatible with potassium guidelines and with nutritionally adequate diets. . . Feasibility studies should precede . . . the issuing of dietary guidelines to the public.”

*Maillot, Monsivais, & Drewnowski
Nutr. Res. 2013
On May 14, 2013, the IOM issued new guidelines for American salt intakes. Recent studies had provided compelling evidence that salt intake in the range recommended by the IOM in 2005 could actually increase heart-related illness and death. So, in a dramatic reversal, the 2013 recommendation acknowledged that there was no evidence that reducing intake below 2300 mg per day was beneficial.

Target 2 & 3 levels are below 2300 mg/d
ISSUE SETTLED?

3 June 2013

The Honorable Kathleen Sebelius,
Secretary of Health and Human Services
Hubert H. Humphrey Building
200 Independence Avenue, SW
Washington, DC 20001

Dear Madame Secretary:

The Institute of Medicine recently released a report, *Sodium Intake in Populations: Assessment of Evidence* (May 2013). Following the release of the report, some press coverage misstated the conclusions of the report.

I am writing to stress key points in the committee’s report. First, the evidence linking sodium intake to health outcomes supports current efforts by the Centers for Disease Control and Prevention (CDC) and other authoritative bodies to reduce sodium intake in the U.S. population below the current average adult intake of 3,400 mg per day. Second, the evidence reviewed on health outcomes does not currently support reductions in dietary sodium in the general population to levels as low as 1,500 mg per day, although health benefits would be less than pro-

Sincerely,

Harvey V. Fineberg, M.D., Ph.D.
President, IOM

THE NATIONAL ACADEMIES

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The salt controversy is the “number one perfect example of why science is a destabilizing force in public policy.”

Sanford Miller, M.D.
Former Deputy FDA Commissioner, Foods
Science, 8/14/98
SALT & TASTE

- split pea soup
- partial sensory profile with NO added seasoning
- Gillette, June 1985 Food Technology pp 47–56
SALT & TASTE

- split pea soup
- partial sensory profile comparing 0.3% salt (▽) with no added seasoning (○)
- Gillette, June 1985 Food Technology pp. 47–56
SUMMARY

- target 2 & 3 Na intake levels are:
  - unphysiological
  - possibly harmful, and
  - effectively unfeasible
- they should not be implemented
SOME RESOURCES

- Heaney RP. Sodium: How, and How Not, to Set a Nutrient Intake Recommendation; Am J Hypertension 2013
Thank you . . .
Questions?