Sodium Reduction
An Annotated Bibliography

Contents

Introduction

This bibliography is intended as a resource to support the design and implementation of national sodium reduction programs, and is useful for policy development, surveillance of population sodium sources and intake, and implementation of sodium reduction efforts. The aim is to provide a brief overview of the scientific basis of key aspects of sodium reduction strategies. This list is not representative of all aspects of sodium reduction and is largely drawn from the scientific literature published in English.

The bibliography is organized into four sections: first, a general overview of the consequences of sodium consumption and strategies for reduction; next, a review of the science behind salt reduction; third, surveillance strategies for measuring sources of sodium and population intake of sodium; and finally, a review of the various strategies recommended for large scale population sodium reduction.

I. Overview of Sodium Reduction

He FJ, MacGregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. Journal of Human Hypertension. 2009 Jun;23(6):363
Salt consumption is likely the major factor for increasing population blood pressure. Multiple studies show that populations with successful reductions in salt consumption also reduced blood pressure as well as other adverse health outcomes, particularly cardiovascular disease. Despite this strong evidence, many countries have not yet developed a salt reduction plan; however, a few countries such as Finland, Japan, and the UK have successfully implemented large-scale salt reduction programs through strategies such as industry engagement for product reformulation and labeling or through public health education.

Frieden TR. Sodium reduction—saving lives by putting choice into consumers' hands. JAMA. 2016 Aug 9;316(6):579-80.
In the United States, high blood pressure is the leading cause of death from heart disease and stroke, and 90% of the population consumes too much sodium. Clear evidence from rigorous studies shows the benefit of sodium reduction on reducing blood pressure. Even small reductions in sodium intake can have great effects on hypertension prevalence, and likely on mortality from cardiovascular disease as well. *"Over a decade, (a reduction of 1200 mg/d) could prevent up to an estimated 500000 deaths and may save an estimated $100 billion in health care costs."* Sodium reduction is unlikely to harm any segment of the population. This article advocates for the immediate implementation of the proposed US guidelines that would set voluntary sodium targets for industry.

Afshin A, Sur PJ, Fay KA, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2019 Apr 4.
The most recent Global Burden of Disease study estimated that global consumption of sodium was 6g per day. High intake of sodium caused approximately 3 million deaths and 70 million disability-adjusted life-years (DALYs) in 2017. High intake of sodium was the leading dietary risk factor for mortality among men and was the leading risk for deaths and DALYs among older adults (≥70 years). It was also found to be the leading dietary risk factor for deaths and DALYs in east Asia and high-income Asia Pacific regions. Countries ranking high-middle and middle on the Socio-Demographic Index (SDI) were at the greatest risk of deaths and DALYs from high intake of sodium. For all countries except those at low SDI, sodium intake was one of the four leading dietary risks.

II. Science of Salt Reduction

2.1 Effect of Sodium on Blood Pressure

Sacks FM, Svetkey LP, Vollmer WM, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. NEJM. 2001 Jan 4;344(1):3-10.

The DASH sodium study randomized participants to be fed three different sodium levels (3,400, 2,300 and 1,150 mg/day) of either the DASH diet (diet rich in fruits, vegetables, and low-fat dairy products, including whole grains, poultry, fish, and nuts) or a typical diet for 30 days at each sodium level. Among participants on a normal diet, those randomized to intermediate and low sodium levels saw a significant reduction in systolic BP of 2.1 mmHg and 6.7mmHg, respectively. Participants randomized to the DASH diet had even greater decreases in blood pressure at the low sodium levels. Compared to the typical diet group with high intake, they achieved systolic BP decreases of 7.1mm Hg (without hypertension) and 11.5 mm Hg (with hypertension). Both diets showed a progressive effect, with greater decreases in BP with further reductions in sodium intake.

He FJ, Li J, MacGregor GA. Effect of longer term modest salt reduction on blood pressure: Cochrane systematic review and meta-analysis of randomised trials. BMJ. 2013 Apr 4;346:f1325.

"A 100 mmol reduction in 24-hour urinary sodium (~6 g/day salt) was associated with a fall in systolic blood pressure of 5.8 mm Hg (2.5 to 9.2, P=0.001) after adjustment for age, ethnic group, and blood pressure status". Additionally, data from both of the two trials that compare multiple salt intake levels over time suggest a dose-response relationship with salt intake and BP, with larger salt reductions resulting in greater BP decreases. Reducing salt intake from the average of the analyzed trials (9.4 g/day) to 5-6 g/day would have significant impacts on lowering blood pressure, but reductions to 3 g/day would provide even greater benefits.

Intersalt: An International Study of Electrolyte Excretion and Blood Pressure. Results for 24-hour urinary sodium and potassium excretion. Intersalt Cooperative Research Group. BMJ. 1988;297:319-28.

Across 52 centers from 32 countries, median urinary sodium excretion values ranged from 4.6 mg/24 h to 5,568.3 mg/24 h. In the four study sites with very low sodium excretion, blood pressure was also found to be low, and there was no significant age-related rise in blood pressure. There was a linear relationship between the median 24-hour urinary sodium excretion and the slope of systolic and diastolic BP with age. After adjustment for body mass index and alcohol intake, all sites demonstrated this same relationship.

Geleijnse JM, Hofman A, Witteman JC, et al. Long-term effects of neonatal sodium restriction on blood pressure. Hypertension. 1997 Apr;29(4):913-7.

Using participants from a 1980 Dutch study that showed that "sodium intake was positive related to BP during the first 6 months of life", this current study demonstrated that sodium intake during infancy may be associated with blood pressure later in life. Fifteen years after the 1980 study, 35% (167) of the original participants were selected for follow up. Compared to the control group (normal sodium intake), the low sodium intake group had 3.6 mm Hg lower systolic blood pressure (−6.6 to −0.5, p=.02) after controlling for confounding factors. Significant differences were not reported between groups for urinary sodium excretion.

2.2 Effect of Sodium on Health Outcomes

Cook NR, Cutler JA, Obarzanek E, et al. Long term effects of dietary sodium reduction on cardiovascular disease outcomes: observational follow-up of the trials of hypertension prevention (TOHP). BMJ. 2007;334(7599), 885.

One of the few trials assessing the impact of sodium intake on CVD, this study used long-term follow-up data from 3,126 prehypertensive adult participants of the trials of hypertension prevention (TOHP) to determine effects on cardiovascular disease outcomes. Participants were randomized to a control group or a sodium reduction intervention group lasting 18 months (TOHP I) or 36-48 months (TOHP II). The intervention groups showed a 30% reduction in cardiovascular disease and a 20% reduction in mortality compared to the control groups.

Adler AJ, Taylor F, Martin N, et al. Reduced dietary salt for the prevention of cardiovascular disease. Cochrane Database of Systematic Reviews. 2014(12).

This review concluded that providing dietary advice to patients to reduce sodium intake had minimal impact, which emphasizes the need for population-wide changes in the options and default quantities of sodium in the commonly consumed foods. Results showed that individual interventions led to small reductions in blood pressure, but it is unclear whether the cost of implementing these interventions is justified. Interventions that do not rely on individual behavior change may prove to be more effective.

Aburto NJ, Ziolkovska A, Hooper L, et al. Effect of lower sodium intake on health: systematic review and meta-analyses. BMJ. 2013 Apr 4;346:f1326.

High-quality evidence from 36 randomized controlled trials shows that sodium reduction results in significant decreases in systolic (-3.39 mm Hg) and diastolic (-1.54 mm Hg) blood pressure in adults (reductions were greater among those with hypertension). Significant reductions were also found among children. Limited evidence from cohort studies showed that increased sodium intake had an increased risk of fatal coronary heart disease events (RR 1.32, 95% CI: 1.13 to 1.53), stroke (RR 1.24, 95% CI: 1.08 to 1.43), and stroke mortality (RR 1.63, 95% CI: 1.27 to 2.10).

2.2.1 Conflicting Science

Webster J, Waqanivalu T, Arcand J, et al. Understanding the science that supports population-wide salt reduction programs. JCH Journal of Clinical Hypertension. 2017 Jun;19(6):569-76.

Despite some limitations in available data, expert scientific groups overseen by governmental or nongovernmental health and scientific organizations agree on the need to reduce population salt intake. Salt reduction could result in millions of lives saved annually, especially cardiovascular deaths caused by hypertension. Although few randomized controlled trials (RCT) have been conducted to directly examine the effects of salt reduction on cardiovascular disease (CVD) due to feasibility and ethical concerns, pooling CVD data from RCTs with long-term follow up "have demonstrated a reduction in cardiovascular events with reduced dietary sodium." A limited number of studies have concluded that low levels of sodium intake are associated with increased mortality; however, the methodologies of these studies are flawed. Strong evidence from higher-quality studies shows that CVD is reduced with lower intakes of dietary sodium. "The recent publication of a few paradoxical studies of questionable scientific merit should not delay implementation of salt reduction initiatives worldwide."

Mente A, O'Donnell M, Rangarajan S, et al. Associations of urinary sodium excretion with cardiovascular events in individuals with and without hypertension: a pooled analysis of data from four studies. The Lancet. 2016 Jul 30;388(10043):465-75.

A pooled analysis from four prospective studies, including both healthy adults and adults with high risk of diabetes, vascular disease, or hypertension, found a U-shaped association between sodium excretion and cardiovascular events and mortality for individuals with hypertension. High sodium excretion (>7g/day) and low sodium excretion (<3g/day) were both associated with increased risk of cardiovascular disease events or all-cause mortality compared to those with sodium excretion of 4-5 g/day. For those without hypertension, only low sodium excretion (<3 g/day) was associated with a significantly increased risk. 24-hour sodium excretion was estimated based on spot urines.

He FJ, Campbell NR, Ma Y, et al. Errors in estimating usual sodium intake by the Kawasaki formula alter its relationship with mortality: implications for public health. IJE. 2018 Jun 22.

Use of the Kawasaki formula to estimate usual sodium intake can artificially introduce a J-shape curve. Sodium intake from 2,974 pre-hypertensive participants of the Trials of Hypertension Prevention (TOHP) study was assessed using four methods and compared to mortality. When using the gold standard method to measure sodium intake (multiple seven 24-h urinary sodium measurements), a linear relationship with mortality was found. Estimating usual intake by applying the Kawasaki formula (frequently applied to spot urines to estimate usual intake) to the sodium concentration from 3-7 collections, sodium at lower levels was over-estimated and sodium at higher levels was under-estimated. Further, using this method rather than the gold standard method, investigators observed an artifactual J-shaped relationship between sodium intake and mortality.

Olde Engberink RH, van den Hoek TC, van Noordenne ND, et al. Use of a single baseline versus multiyear 24-hour urine collection for estimation of long-term sodium intake and associated cardiovascular and renal risk. Circulation. 2017 Sep 5;136(10):917-26.

Using a single baseline 24-hour urine measurement rather than multiple measurements to estimate usual sodium intake can introduce an artifactual J-shaped relationship between sodium intake and CVD. Single baseline 24-hour sodium measurements as well as (multiple) follow-up 24-hour urine samples provide similar estimates of sodium intake on a population level; however, when used to estimate individual sodium intake, the two methods differ. When using a single baseline measurement, there was no significant association between high sodium intake and increased cardiovascular events/mortality and the curve appeared j-shaped. When using average measurements over 1 to 5 years, there was a significant, linear association.

Cogswell ME, Mugavero K, Bowman BA, Frieden TR. Dietary sodium and cardiovascular disease risk— measurement matters. NEJM. 2016 Aug 11;375(6):580.

This article explores whether low sodium intake causes cardiovascular disease (CVD) by applying Hill's criteria for determining whether an observed association is causal: strength, consistency, specificity, temporality, biologic gradient, plausibility, coherence, experiment, and analogy. Ultimately, a causal association was not identified. Evidence for low sodium intake causing CVD are based on cohort studies which have known weaknesses such as residual confounding. They commonly use flawed sodium intake measurement methods, such as using spot urine samples, using single measurements rather than multiple 24-hour urine samples, and having a short follow-up period between salt reduction intervention and adverse outcomes. Further, they are contradicted by real-world population sodium reduction examples in the United Kingdom, Finland, and Japan as well as other scientific studies showing a progressive dose-response decrease in blood pressure down to as low as 1200 to 1500 mg per day and from the analysis of

long-term follow up trial data showing sodium reduction resulting in decreased CVD events. Finally, in terms of biological plausibility, there is no evidence that reduced sodium intake has any long-term effect on other CVD risks such increased levels of cholesterol, triglycerides, renin, aldosterone, and catecholamine. The authors highlight that "invalid measurement of sodium intake and other methodologic limitations can lead to erroneous conclusions and delay effective public health action to reduce blood pressure and save lives".

Cobb LK, Anderson CA, Elliott P, et al. Methodological issues in cohort studies that relate sodium intake to cardiovascular disease outcomes: a science advisory from the American Heart Association. Circulation. 2014 Jan 1.

"Methodological issues may account for the inconsistent findings in currently available observational studies." In a review of the quality of 26 cohort studies relating sodium intake to CVD, all but one study (Trials of Hypertension Prevention (TOHP)) had methodological issues that could potentially alter the direction of association (systematic error=22; reverse causality=16). Studies that reported an inverse or J-shaped were slightly most likely to contain an error with a potential to alter the direction of the association compared to studies with a positive association. The TOHP study, which did not find a J- or U-shape relationship utilized a more rigorous protocol including 3 to 7 24-hour urine samples and excluded participants with incomplete collections. Errors with the potential to lead to a false null result, such as random error in estimating sodium intake or having insufficient power, were present in 23 studies. Overall, studies had an average of 3-4 methodological problems, and study was quality was often difficult to assess due to insufficient information provided.

2.2.2 Country Examples

Karppanen H, Mervaala E. Sodium intake and hypertension. Progress in Cardiovascular Diseases. 2006 Sep 1;49(2):59-75.

This article summarizes the scientific evidence relating high population salt intake with high prevalence of hypertension, using Finland as a case study. As average salt intake decreased by one third over 25-30 years in Finland, there was a simultaneous decrease of more than 10mm Hg in average population blood pressure (systolic and diastolic), a 75% to 80% decrease in both stroke and coronary heart disease mortality among those less than 65, and a 5- to 6-year increase in life expectancy. The article also describes salt-labeling legislation, such as the "high salt content" warning labels. This legislation encouraged product reformulation, resulting in reduced average salt content in the most important food categories. A sodium-reduced, potassium-, and magnesium-enriched salt alternative was also available and promoted. Methods for successful population level salt reduction are summarized.

He FJ, Pombo-Rodrigues S, MacGregor GA. Salt reduction in England from 2003 to 2011: its relationship to blood pressure, stroke and ischaemic heart disease mortality. BMJ Open. 2014 Apr 1;4(4):e004549.

A nationwide salt reduction program was introduced in the UK in 2003, and by 2011, a 15% reduction in population salt intake was observed. During this same period, a significant decrease in BP of 2.7 /1.1 mm Hg (p<0.001 for systolic and diastolic BP) was observed after adjusting for major factors known to be associated with BP. Decreased BP appears to be at least partially attributable to population salt reduction. Mueller NT, Noya-Alarcon O, Contreras M, et al. Association of age with blood pressure across the lifespan in isolated yanomami and yekwana villages. JAMA cardiology. 2018 Dec 1;3(12):1247-9.

This study among the Venezuelan Yanomami community (hunter-gatherer-gardeners with very low salt exposure) and the nearby Yekwana community (who have intermittent exposure to processed foods and salt) found that only the Yekwana experience an age-related rise in blood pressure. While both communities start out with similar blood pressures in early childhood, between-group differences in blood

pressure increase with age rising to a 15.9 mm Hg difference by age 50 (the age-SBP slope was significantly steeper for Yekwana individuals). Overall, the Yanomami had significantly lower systolic and diastolic blood pressure than the Yekwana (SBP: 95.4 mmHg vs. 104.0 mmHg, P<0.001; DBP: 62.9 mm Hg vs. 66.1 mmHg; P = 0.03).

2.3 Sodium and Potassium

Perez V, Chang ET. Sodium-to-potassium ratio and blood pressure, hypertension, and related factors. Advances in Nutrition. 2014 Nov 3;5(6):712-41.

Both reduced sodium intake and increased potassium intake have been reported to reduce blood pressure. This systematic review concluded that "the sodium-to-potassium ratio (Na-K ratio) is more strongly associated with blood pressure outcomes than either sodium or potassium alone in hypertensive populations".

2.4 Modeling Impact and Cost-effectiveness of Sodium Reduction

World Health Organization. Saving lives, spending less: a strategic response to noncommunicable diseases. World Health Organization; 2018.

Reducing unhealthy diets through reducing salt intake is considered a "Best Buy intervention" by the WHO. Recommended interventions to reduce salt intake include reformulation of food products, establishing a supportive environment in public institutions by providing low-salt options, education through behavior change communication and mass-media campaigns, and front-of-pack labelling. Investment in salt reduction activities offers the highest return among all Best Buy interventions, an estimated US$12.82 return on every US$1 invested.

Kontis V, Mathers CD, Rehm J, et al. Contribution of six risk factors to achieving the 25× 25 non-communicable disease mortality reduction target: a modelling study. The Lancet. 2014 Aug 2;384(9941):427-37.

Following the 2013 World Health Assembly, global commitments were made to reach a 25% relative reduction in premature mortality from non-communicable diseases (NCDs) by 2025. This study estimates that achieving the targets for six risk factors, including a 30% reduction in salt intake (others include tobacco and alcohol use, obesity, and raised blood pressure and glucose), would result in a decreased probability (-22% in men, -19% in women) of dying from any of the four major NCDs (cardiovascular diseases, chronic respiratory diseases, cancers, and diabetes).

Webb M, Fahimi S, Singh GM, et al. Cost effectiveness of a government supported policy strategy to decrease sodium intake: global analysis across 183 nations. BMJ. 2017 Jan 10;356:i6699.

In a global modeling study across 183 countries, the cost effectiveness of a 10-year government "soft regulation" policy consisting of combined targeted industry agreements and public education to reduce population sodium consumption by 10% was approximately I$204 per DALY saved with a population weighted mean cost of I$1.13 per capita. Nearly 5.8 million DALYs/year related to CVD would be averted. Cost effectiveness estimates widely ranged by country; however, in all but one country the interventions were cost effective as per the WHO benchmark (<3×GDP per capita).

2.4.1 Country examples

Zhang J, Guo X, Lu Z, et al. Cardiovascular Diseases Deaths Attributable to High Sodium Intake in Shandong Province, China. JAHA. 2019 Jan 8;8(1):e010737.

Using 24-hour urinary sodium data from the 2011 SMASH study, authors estimated the annual number of CVD-related deaths in Shandong province attributable to high sodium intake and modelled the number

of lives potentially saved through a 30% reduction in sodium intake. High sodium intake (>2000mg/day) was estimated to account for an estimated 16,000 CVD-related deaths in 2011 among those aged 25-69 (or nearly 20% of total CVD deaths) in Shandong. With a 30% reduction in sodium intake, Shandong province could potentially avert 8,800 sodium attributed CVD deaths, and with the SMASH sodium reduction goal of 4g/day, 6,700 sodium attributed deaths could be averted.

Rubinstein A, Martí SG, Souto A, et al. Generalized cost-effectiveness analysis of a package of interventions to reduce cardiovascular disease in Buenos Aires, Argentina. Cost Effectiveness and Resource Allocation. 2009 May 6;7(1):1.
A cost-effectiveness comparison of six individual and two population-based interventions to decrease CVD in Argentina found that population-based interventions were most cost effective, specifically, reducing salt in bread (ARS $151/DALY averted) and public health education through mass media (including promotion of a low-salt diet) (ARS $547/DALY averted).

Watkins DA, Olson ZD, Verguet S, et al. Cardiovascular disease and impoverishment averted due to a salt reduction policy in South Africa: an extended cost-effectiveness analysis. Health Policy and Planning. 2015 Apr 3;31(1):75-82.
Authors conducted a cost-effectiveness analysis to assess the South African Government policy to lower population salt intake to 5g per person/day by regulating salt in processed foods and conducting media campaigns. The policy would avert approximately 5,600 deaths and 23,000 cases of CVD yearly (11% of CVD deaths). It would also save US$ 4.06 million in household out-of-pocket expenditures on CVD, save US$51.25 million in government healthcare subsidies, reduce catastrophic spending, and prevent nearly 2,000 cases of poverty annually. Reformulating food products could cause food prices to rise, but the increase would at worst only be slightly more than the out of pocket expenditures averted.

Mason H, Shoaibi A, Ghandour R, et al. A cost effectiveness analysis of salt reduction policies to reduce coronary heart disease in four Eastern Mediterranean countries. PloS One. 2014 Jan 7;9(1):e84445.
A study of the cost-effectiveness of three salt reduction policies (health promotion campaign, labelling, and mandatory reformulation of salt content in processed food) in Tunisia, Syria, Palestine, and Turkey found that compared to no policy, the number of life years gained increased in all countries with all policies (separately and in combination). The majority of policies were cost saving as well. Policies including all 3 interventions resulted in the highest estimated cost savings, ranging from $6 million in Palestine to $1.3 billion in Turkey. Life years gained (LYG) under the same scenario included 6,455 LYG in Tunisia; 31,674 LYG in Syria; 2,682 LYG in Palestine and 378,439 LYG in Turkey.

2.5 Taste, Sensory, Acceptability of Reduced Sodium Diet
Bobowski N. Shifting human salty taste preference: potential opportunities and challenges in reducing dietary salt intake of Americans. Chemosensory Perception. 2015 Sep 1;8(3):112-6.
Dietary salt preference largely stems from one's individual salt intake habits. Those who consume high sodium levels prefer the taste of high salt. This review paper highlights findings such as the impact of early exposure to salty foods in determining salt preference later in life, the ability for salt preference to change over time after limiting exposure, and the tendency not to overcompensate for low-sodium foods by adding salt at the table. Gaps in the research are also discussed, such as whether children's salt preference can be shifted and why humans desire and consume salt in the absence of biological need.

Beauchamp GK, Bertino M, Engelman K. Failure to compensate decreased dietary sodium with increased table salt usage. JAMA. 1987;258(22):3275-8.

When sodium was reduced by nearly 50% in foods served to study participants, participants only added 20% back with a salt shaker at the table. Throughout the study, participants did not report any changes in taste perception.

Jaenke R, Barzi F, McMahon E, et al. Consumer acceptance of reformulated food products: A systematic review and meta-analysis of salt-reduced foods. Critical Reviews in Food Science and Nutrition. 2017 Nov 2;57(16):3357-72.

"[S]alt can be reduced in breads and processed meats by up to 37% and 67%, respectively, without a decrease in consumer acceptability." For cheese products, meta-analysis showed decreasing levels of acceptance with increasing levels of salt reduction. Acceptance was lower in studies with salt reduction above 60%. Results varied for other products. Acceptability of products using low-sodium salts or flavor compensation were also studied. Replacing up to 50% of salt with potassium chloride in meat products or up to 30% in cheese was not found to impact acceptability.

2.6 Sodium and Iodine

Because many populations primarily consume iodine through salt fortification, there is concern that reduction of salt intake will lead to inadequate consumption of iodine. Iodine fortification has been a major and successful public health initiative over the past 2-3 decades. Thus, it is important that progress in this area is not hindered but complemented by salt reduction strategies.

Campbell NR, Dary O, Cappuccio FP, et al. Need for coordinated programs to improve global health by optimizing salt and iodine intake. Revista Panamericana de Salud Pública. 2012;32:281-6.

Iodine fortification and salt reduction programs should be integrated in order to optimize intake of both nutrients. Integrated surveillance of both salt and iodine intake will be more efficient and effective than uncoordinated efforts. Public messaging to both use fortified salt and to reduce salt consumption should be coordinated and not conflicting or confusing. International agencies, national governments, health professionals, and NGOs must take action to ensure programs are integrated and lessons and resources are shared and leveraged across countries.

Verkaik-Kloosterman J, van Veer P, Ocké MC. Reduction of salt: will iodine intake remain adequate in The Netherlands?. British Journal of Nutrition. 2010 Dec;104(11):1712-8.

This modeling study in a Dutch population found that salt reductions of 12, 25 or 50% in industrially processed foods decreased mean salt intake by 7, 15 and 30% compared with current intake, and mean iodine intake by 6, 12 or 25%. Iodine intake levels remained adequate at all salt reduction levels for most the population. Reducing both discretionary salt and salt in industrial foods by 50%, led to a slight increase (1-11%) in inadequate iodine intakes for age groups above 3 years. For children aged 1-3 years, all scenarios led to inadequate iodine levels, affecting between 10% (12% industrial reduction) to 35% of the population (50% reduction industrial + discretionary). However, if industry meets the target of using iodized salt in 50% of industrially processed foods, there would be "adequate iodine intakes for virtually the whole population, including young children" for all scenarios.

Charlton K, Ware LJ, Baumgartner J, Cockeran M, Schutte AE, Naidoo N, Kowal P. How will South Africa's mandatory salt reduction policy affect its salt iodisation programme? A cross-sectional analysis from the WHO-SAGE Wave 2 Salt & Tobacco study. BMJ Open. 2018 Mar 1;8(3):e020404.

In this cohort study of older South Africans, salt intake (measured by 24-hour urine) was positively associated with 24-hour iodine excretion (p<0.001). Those in the lowest salt intake category (<5g/day) did

not meet iodine requirements (95 µg/day). Salt reduction programs may need to be accompanied by further iodine fortification efforts, and intake of both nutrients should be monitored simultaneously.

He FJ, Ma Y, Feng X, Zhang W, et al. Effect of salt reduction on iodine status assessed by 24 hour urinary iodine excretion in children and their families in northern China: a substudy of a cluster randomised controlled trial. BMJ Open. 2016 Sep 1;6(9):e011168.

In an RCT, a ~3.5-month school-based educational salt reduction program in northern China led to a significant decrease in salt intake of 1.9 g/day in children and 2.9 g/day in adults. Although iodine intake also decreased (19.3% in children and 11.4% in adults), iodine intake remained adequate.

III. Surveillance

3.1 Measuring Dietary Sodium Intake

3.1.1 Spot urine vs. 24-hour urine for population values

Spot urine samples are much easier to collect and require far fewer resources than the gold standard, 24-hour urine method. This section looks at evidence examining how spot urine samples perform compared to 24-hour urine in determining population sodium intake.

Brown IJ, Dyer AR, Chan Q, et al. INTERSALT Co-Operative Research Group. Estimating 24-hour urinary sodium excretion from casual urinary sodium concentrations in Western populations: the INTERSALT study. AJE. 2013 May 14;177(11):1180-92.

Spot urine concentrations and 24-hour urinary sodium excretion collected by the Intersalt study (1885-1987 in 32 North American and European countries) were compared to determine the utility of estimating 24-hour urinary sodium excretion using spot urine specimens. The correlation (Pearson r) between observed and estimated 24-hour sodium excretion was 0.50 for individual men and 0.51 for individual women, and .79 for men at the population-level and 0.71 for women at the population-level. Bias was minimal (-1.8 mmol men; 2.2 mmol women) at the population level. Using spot urine estimations, the percent of people with sodium intake above the recommended levels was slightly higher than with observed 24-hour sodium excretion. Spot urine specimens may be able to provide useful estimates of population but not individual sodium intake.

Huang L, Crino M, Wu JH, et al. Mean population salt intake estimated from 24-h urine samples and spot urine samples: a systematic review and meta-analysis. IJE. 2016 Jan 21;45(1):239-50.

This study (a review of 29 studies estimating daily salt intake based on both spot and 24-hour urine) provides evidence that spot urine samples can be used to provide estimates of mean population salt intake; however, because spot urine systematically overestimated lower levels of salt intake and underestimated higher levels compared to 24-hour urine, spot urine samples should not be used to detect changes in average population salt consumption over time. For estimating mean population salt intake as above or below a 5g/day threshold, spot urine had a sensitivity of 97% and specificity of 100% (assuming 24-hour urine to be gold standard).

Petersen KS, Wu JH, Webster J, et al. Estimating mean change in population salt intake using spot urine samples. IJE. 2016 Oct 18;46(5):1542-50.

Paired spot urine samples (drawn from the same population at two time points and analyzed as paired data) may be more useful for detecting change over time in population salt intake than un-paired samples. Approximately 1,000 participants in Australia in 2011 and 2014 provided 24-hour and spot urine samples. Using 24-hour urines, a significant decrease of 0.48 g/day of salt intake was seen. Although estimates

using spot urine samples were not significantly different than those from the 24-hour urine data, only the estimates using paired samples also detected a significant change in sodium intake. This did not vary based on estimation equation. However, when analyzed by geographical location, "spot urine samples did not consistently detect the change in salt intake shown by the 24-h urine collections," regardless of whether they were paired. Though paired spot urine may be a useful alternative to 24-hour for detecting changes in mean population salt intake, more evidence is needed before the success of salt reduction interventions can be reliably monitored without 24-hour urine collections.

Campbell NR, He FJ, Tan M, et al. The International Consortium for Quality Research on Dietary Sodium/Salt (TRUE) position statement on the use of 24-hour, spot, and short duration (< 24 hours) timed urine collections to assess dietary sodium intake. JCH. 2019 May 14.

Based on a review of multiple systematic reviews and analyses, the International Consortium for Quality Research on Dietary Sodium/Salt (TRUE) concludes that the recommended method for assessing population dietary sodium intake is to collect "single complete 24-hour urine samples, collected over a series of days from a representative population sample" and for individual level estimations, "at least 3 non-consecutive complete 24-hour urine collections collected over a series of days that reflect the usual short-term variations in dietary pattern." Generally, spot urine samples systematically underestimate changes in dietary sodium intake at the population level. To understand the role of single spot or short duration timed urine collections in assessing population average sodium intake will require more research. Single spot or short duration timed urine collections are not recommended for individual sodium intake estimation.

3.1.2 24-hour urine vs. 24-hour dietary recall

McLean RM, Farmer VL, Nettleton A, et al, TRUE Consortium (International Consortium for Quality Research on Dietary Sodium/Salt). 24-hour Diet recall and Diet records compared with 24-hour urinary excretion to predict an individual's sodium consumption: A Systematic Review. JCH. 2018 Oct 9.

Thirty studies assessing individual sodium consumption compare estimates from 24-hour dietary recall or diet records vs. gold standard 24-urine collections. Results showed a wide variation between the methods. Correlations coefficients comparing diet recall to 24-hour urine ranged from 0.16 to 0.72. Comparing food diaries to the gold standard, correlations ranged from 0.11 to 0.49. The two studies that reported results of Bland-Altman limits of agreement analyses both found 24-hour diet recall did not accurately estimate intakes from 24-hour urines. Diet records or dietary recall alone may be useful to determine intake of certain nutrients, food groups, or dietary patterns, but is prone to error when used to determine individual sodium consumption or the relationships between individual sodium intake and health outcomes. Studies that rely solely on dietary assessment as a measure of individual sodium intake "must be viewed carefully and skeptically".

3.2. Population Sodium Intake

Powles J, Fahimi S, Micha R, et al., Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE. Global, regional and national sodium intakes in 1990 and 2010: a systematic analysis of 24 h urinary sodium excretion and dietary surveys worldwide. BMJ Open. 2013 Dec 1;3(12):e003733.

Using 24-hour urine-based and diet-based surveys from 66 countries (61% high-income regions, 40% low- or mid-income regions), authors estimated a mean level of global sodium consumption of 3.95g per day (or 10.06g/day of salt) as of 2010 (regional mean levels ranged from 2.18 to 5.51g sodium per day), with 99.2% of adults worldwide exceeding recommended level of 2.0g/day and 88.3% exceeding the recommended level by more than 1.0g/day. Men had slightly higher intake than women (4.14g/day vs 3.7g/day). Variation by age was small. Highest intakes were found in Asia (East Asia: 4.8g/day, Asia Pacific

(high income): 5.0g/day, and Central Asia 5.51g/day. Next highest were Eastern Europe (4.18g/day), Central Europe (3.92g/day), and the Middle East and North Africa (3.92g/day). Lowest intakes were found in Sub-Saharan Africa, Latin America and the Caribbean and Oceania, although data was limited in these areas. A statistically non-significant increase in sodium intake globally was found using 24-hour urine data between 1990 and 2010.

Batcagan-Abueg AP, Lee JJ, Chan P, et al. Salt intakes and salt reduction initiatives in Southeast Asia: a review. Asia Pacific Journal of Clinical Nutrition. 2013 Nov 1;22(4):683-97.

A review of sodium consumption studies (19 total) in Southeast Asia (Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam) found that "insufficient evidence exists regarding salt intakes in Southeast Asia". Three countries (Malaysia, Philippines, Singapore) had national nutrition survey data, while data from the remaining countries came from smaller sub-national studies, except Vietnam where sodium consumption estimates were not available. Evidence suggests that sodium intake exceeds the recommended 2g/day in most countries, and men generally have higher intakes than women. The majority of intakes were between 1.2g – 4.5g/day. Thailand, Singapore, and the Philippines generally reported the highest intakes. Only two countries had data on children: Indonesian schoolchildren exceeded recommended limits (range of 2.12 – 3.58g/day) and two studies among Thai pre-school children showed inconsistent findings (range of 0.54-1.45g/day). Studies showed a large contribution of sodium comes from added salt and condiments/sauces. The most common sodium reduction interventions identified were consumer-focused, including dietary guidelines, promotion of diet/lifestyle changes, and public awareness campaigns. Fewer focused on food production or the environment.

3.3 Dietary Sources of Sodium

L'Abbé M, Legetic B, Legowski B, et al. A review of methods to determine the main sources of salt in the diet. WHO/PAHO Regional Expert Group for Cardiovascular Disease Prevention through Population-wide Dietary Salt Reduction. 2010.

Knowing the main sources of dietary salt in a country is essential for the development of effective salt reduction interventions. To determine baseline data on the major contributors to salt intake, authors recommend determining the level of discretionary salt in the household by a combination of direct and indirect methods (e.g., qualitative surveys or interviews, household food disappearance studies, "subtraction" methods), determining food consumption patterns through established survey instruments (if they exist) or by 24-hour recalls or food frequency questionnaires, and identifying the proportional importance of discretionary sources versus commercially prepared foods. They emphasize the importance of directing resources toward maintaining national or international food composition databases, either from primary or secondary sources.

3.3.1 Country Examples

Anderson CA, Appel LJ, Okuda N, et al. Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 years: the INTERMAP study. JADA 2010 May 1;110(5):736-45.

Using data from the INTERMAP study, major dietary sources of sodium among 4,680 adults aged 40-59 in China, Japan, the United Kingdom, and the United States were identified and compared. Sources of sodium were assessed from four multi-pass, in-depth 24-hour dietary recalls completed by each participant. In Japan, major sources of sodium included soy sauce (20%), soups (16.4%), processed fish or seafood (15%), and salted (pickled) vegetables and fruits (9.8%). In China, the main source was salt added during home cooking and at the table (75.8%), with 50% higher discretionary salt use in the north of China. In the United Kingdom, processed foods contributed to 95% of the sodium intake, with processed breads,

cereals, and grains (34.6%) and processed red meats, poultry, and eggs (20.4%) being the highest contributors. Similarly, the major sources of salt in the United States came from processed foods (underestimated at 71%) with processed breads, cereals, and grains (19.5%) and processed red meats, poultry, and eggs (12.0%) being the highest contributors, as well as 11.7% from seasonings, sauces, dressings, etc. and 8.2% from dairy products.

Elorriaga N, Gutierrez L, Romero IB, et al. Collecting Evidence to Inform Salt Reduction Policies in Argentina: Identifying Sources of Sodium Intake in Adults from a Population-Based Sample. Nutrients. 2017 Aug 31;9(9):964.

Prior to implementing new legislation limiting the sodium content in select processed foods in Argentina, a 34-item Food Frequency Questionnaire was administered to 2,217 adults to estimate sodium intake from select foods, use of available low-salt alternatives, and the frequency of discretionary salt use. Average salt intake from selected processed foods was 4.7g/day (higher among men and those with lower education). "Soups and other convenience foods" were found to be the highest source of sodium (36.1%), followed by "Bread, crackers and cookies" (24.9%), "Meat products" (18.7%), and "Cheeses" (15.0%). Categories of foods with regulated maximum limits accounted for 47.6% of the total sodium intake from processed foods. Discretionary salt use was high, with 83.2% reporting always or often using use salt at the table or during cooking.

Blanco-Metzler A, Moreira Claro R, et al. Baseline and Estimated Trends of Sodium Availability and Food Sources in the Costa Rican Population during 2004–2005 and 2012–2013. Nutrients. 2017 Sep 15;9(9):1020.

Between 2004-2005 and 2012-2013, there was a statistically significant increasing trend in the amount of sodium available for consumption ($p < 0.0001$) based on food and beverage acquisition records from the Costa Rica Household Budget Surveys. The availability of sodium per person per day increased from 3.9g to 4.6g. Table salt was the main source of dietary sodium (60.2%) in both 2004-2005 and 2012-2013, with participants using an estimated 2.4-2.8g/day. The next major source of sodium was processed foods (15.4% in 2004-2005, 14.2% in 2012-2013), followed by condiments (9.3% in 2004-2005, 13.2% in 2012-2013), and ready to eat meals (9.8% in 2004-2005, 7.2% in 2012-2013). Intake of processed foods and sodium-based condiments increased over the time period, while ready to eat meals and natural foods containing sodium decreased over time.

Johnson C, Santos JA, Sparks E, et al. Sources of Dietary Salt in North and South India Estimated from 24 Hour Dietary Recall. Nutrients. 2019 Feb;11(2):318.

In both North and South India, added (discretionary) salt was the main source of sodium in the diet (87.71% in South India and 83.45% in North India). Additional sources in the south included meat, poultry, and eggs (6.3%), dairy and dairy products (2.6%), and fish and seafood (1.6%); in the north, additional sources included dairy and dairy products (6.4%), bread and bakery products (3.3%), and fruits and vegetables (2.1%). No significant differences were found within regions for salt intake based on sex, age, or education level. In South India, urban areas consumed more salt from added salt than rural areas (90% vs. 86%); however, in North India, rural areas consumed more (86% vs. 81%). Data was collected based on two 24-hour dietary recalls from 1,283 participants selected from rural, urban, and slum areas in North and South India.

IV. Interventions

4.1 Overall Summary of Interventions

Cobb LK, Appel LJ, Anderson CA. Strategies to reduce dietary sodium intake. Current Treatment Options in Cardiovascular Medicine. 2012 Aug 1;14(4):425-34.

The six major strategies to reduce sodium intake in the general population include: 1) Public education campaigns, 2) Individual dietary counseling given by healthcare providers, 3) Food labeling (especially front-of-pack labels, such as high-salt warning labels, low-salt promotion labels, and traffic-light symbols), 4) Coordinated voluntary reductions, 5) Procurement policies (setting specific sodium standards for food purchased either by government and/or private institutions), and 6) Regulation of sodium levels in food, both restaurant and packaged food. Regulations, one of the most difficult to implement, are "likely the most effective strategy to reduce sodium intake in a long-term, sustainable way". Further, "a multi-factorial effort that includes several component strategies will have the greatest impact".

Trieu K, Neal B, Hawkes C, et al. Salt reduction initiatives around the world–a systematic review of progress towards the global target. PloS One. 2015 Jul 22;10(7):e0130247.

Between 2010 and 2014, the number of countries with national salt reduction strategies more than doubled (to 75 countries) with another nine planned. Most are in high- or upper-middle income countries, with only 11 in lower-middle income countries and one in a low-income country. Most strategies incorporate multiple components, including industry reformulation (61 countries), setting sodium targets for one or more food categories (39), consumer education (71), front-of-pack labeling (31), interventions in public institution settings (54), and salt taxation (3). Consumer education was the most common approach in all regions except the Americas, where industry engagement was most common. 33 countries have taken some sort of legislative action on salt reduction (mandatory salt targets, taxation, front of pack labeling, or standards for salt as part of procurement policies in public institutions). As of 2014, 12 countries reported reductions in population salt intake, 19 reported reductions in salt levels in foods, and 7 reported improvements in consumer knowledge, attitudes or behaviors relating to salt.

Barberio AM, Sumar N, Trieu K, et al. Population-level interventions in government jurisdictions for dietary sodium reduction: A Cochrane Review. International journal of epidemiology. 2017 Feb 15;46(5):1551-405.

This Cochrane review assessed the impact of population-level sodium reduction interventions in 10 countries with adequate data for assessment. Five of these ten countries showed a mean decrease in salt intake from before to after intervention (China, Finland (Kuopio area), France, Ireland, UK), ranging from -1.15g/day in Finland to -0.35g/day in Ireland. Two initiatives resulted in a mean increase in salt intake (Canada, Switzerland). Of the seven multicomponent interventions that were structural in nature (targeting environments rather than directly targeting behavior change, e.g. reformulation or procurement policies), four showed a mean decrease in salt intake. The overall quality of evidence rating was "very low". Only 10 of the 75 countries with sodium reduction initiatives originally identified provided sufficient data for quantitative analysis, which demonstrates the frequent lack of plans to monitor sodium reduction initiatives or a limited data infrastructure in general.

Hyseni L, Elliot-Green A, Lloyd-Williams F, et al. Systematic review of dietary salt reduction policies: Evidence for an effectiveness hierarchy? PloS One. 2017 May 18;12(5):e0177535.

This systematic review including 70 studies shows that comprehensive, multi-component strategies that use "upstream, structural" policy-based population approaches (e.g., mandatory reformulation) generally achieve the largest reductions in population-wide salt consumption. When assessed separately, "mandatory reformulation alone could achieve a reduction of approximately 1.45g/day (three separate

studies), followed by voluntary reformulation (-0.8g/day), school interventions (-0.7g/day), short term dietary advice (-0.6g/day) and nutrition labelling (-0.4g/day), but each with a wide range". Smaller reductions were seen for taxation, community-based counseling, health education media campaigns, and worksite interventions.

4.1.1 Country/Regional Examples

Laatikainen T, Nissinen A, Kastarinen M, Jula A, Tuomilehto J. Blood pressure, sodium intake, and hypertension control: lessons from the North Karelia Project. Global heart. 2016 Jun 1;11(2):191-9.

This article describes the North Karelia Project, an intensive hypertension prevention and control program started in 1972 in North Karelia, Finland. In the late 1970s, sodium reduction efforts were scaled up to address the extremely high intake of sodium in the population, which eventually resulted in decreased average salt intake as well as significant reductions in blood pressure between 1982 and 1997. Interventions included: 1) health education targeted to the whole population, 2) education of patients including nutrition counselling, 3) training of personnel on the association between salt intake and blood pressure and on food preparation, and 4) environmental changes including introduction of low-sodium salt, reducing salt content in school meals and at other institutions, and working with industry to reformulate products with less salt.

Shao S, Hua Y, Yang Y, et al. Salt reduction in China: a state-of-the-art review. Risk Management and Healthcare Policy. 2017;10:17.

Most of the Chinese population far exceed recommended daily salt consumption, with levels ranging from 7.6g/day in Fujian and Guangdong provinces to 15.2g/day for adults in Beijing. Western China generally has a higher intake (12.5 g/day) than eastern China (8.6 g/day). Salt intake has declined since the 1990s. Most salt is reported to be from cooking at home. Interventions conducted in China to reduce salt consumption include: 1) Policies: required labeling of salt content, regulating low-sodium salt, 2) National initiatives: multisector health education campaigns, 3) Regional initiatives: salt restriction tools/spoons, promotion of low-sodium salt, subsidies for manufacturers of low salt products, product placement in supermarkets, and 4) Research on low-sodium salt. Authors recommend alignment of government, industry, academic, and consumer stakeholders through a Salt Reduction Task Force to spearhead, coordinate, and monitor nation-wide salt reduction efforts. Targeted messaging, setting salt targets for industry, food labeling, scaling up salt restriction tools and salt substitutes were also recommended.

Pillay A, Trieu K, Santos JA, et al. Assessment of a salt reduction intervention on adult population salt intake in Fiji. Nutrients. 2017 Dec 12;9(12):1350.

Fiji implemented a 20-month national salt reduction intervention between 2014-2015 including strategic health communication (through a health educator training program and a public awareness campaign); a hospital program (education and reducing salt in meals); and engagement of food manufacturers and food retailers to voluntarily lower the salt content of foods, use reduced salt products, and remove salt shakers from tables. To assess the impact, 24-h urine samples were taken before and after the 20-month intervention. Sodium intake decreased from 11.7g/day to 10.3g/day, which was not statistically significant (p=0.115).

Enkhtungalag B, Batjargal J, Chimedsuren O, et al. Developing a national salt reduction strategy for Mongolia. Cardiovascular Diagnosis and Therapy. 2015 Jun;5(3):229.

In 2010, Mongolia initiated action to develop a national salt reduction strategy. An inter-sectoral working group was established with government officials and industry representatives to raise awareness and invite collaborations. Baseline data on salt intake and sources were obtained, showing a mean salt intake

of 11.06g/day and a high intake of salt from salty tea (30%), meals (23%), and other processed foods (47%). Pilot salt reduction initiatives were launched from 2011-2014, resulting in improved consumer awareness, reductions in salt intake among factory workers, and voluntary reductions among bakeries, the meat industry, and others. These activities were used to inform the national salt reduction strategy in 2014, which aims to "create a social, economic and legal environment to support the reduction of population salt intake by 30% by 2025". Implementation of this strategy is planned for 2015-2025 and aims to 1) advance the legal environment for salt reduction; 2) improve partnerships, and 3) create an enabling environment to support consumers to make the right choices.

4.2 Industry Reformulation

Webster J, Trieu K, Dunford E, Hawkes C. Target salt 2025: a global overview of national programs to encourage the food industry to reduce salt in foods. Nutrients. 2014 Aug 21;6(8):3274-87.
Fifty-nine countries have engaged the food industry to reduce salt in foods (another 12 plan to engage industry). 35 countries established voluntary salt targets, nine established mandatory targets, and 23 reported holding industry meetings. Most countries with mandatory targets had targets for bread only. Only two (South Africa and Argentina) had mandatory targets for a range of products. Of the countries engaging industry, 44 reported having established monitoring mechanisms for packaged food, with most using at least chemical analysis of food, and 17 countries documented reductions to salt levels in at least one product. Efforts to engage industry were largely found in the Americas, Europe, and the Western Pacific, with fewer in Africa, Eastern Mediterranean, or South East Asia.

Downs SM, Christoforou A, Snowdon W, et al.. Setting targets for salt levels in foods: A five-step approach for low-and middle-income countries. Food Policy. 2015 Aug 1;55:101-8.
"The aim of this paper is to propose a step-by-step approach to setting and implementing targets for salt levels in foods for LMICs, which can then be used for voluntary or mandatory policy interventions." The five main steps are: 1) identifying the main sources of salt in the diet, 2) selecting foods for salt targets, 3) setting target levels in foods, 4) identifying strategies for engagement with stakeholders and 5) establishing mechanisms for monitoring. Multiple implementation strategies for each step exist, and a hierarchy of "the most to least desirable based on validity and methodological strength" is provided for each step. Salt targets can be used not only for directly regulating the sodium content in processed foods, but also to implement labeling, food procurement, and taxation policies.

4.2.1 Country Examples

Curtis CJ, Clapp J, Niederman SA, Ng SW, Angell SY. US food industry progress during the National Salt Reduction Initiative: 2009–2014. AJPH. 2016 Oct;106(10):1815-9.
The National Salt Reduction Initiative (NSRI) is a U.S.-based coalition initiated in 2009 aimed at "reducing population sodium intake by 20%, through a reduction in sodium in US packaged and restaurant foods by 25% by 2014". The NSRI set target levels in 61 packaged food categories for 2012 and 2014. "In 2009, when the targets were established, no categories met NSRI 2012 or 2014 targets. In 2014, 16 (26%) categories met 2012 targets and 2 (3%) met 2014 targets." By 2014, 45% of food products had achieved the 2012 targets. From 2009 to 2014, the sales-weighted mean sodium density declined significantly by 6.8%, with reductions seen in 43% of food categories. No change was reported in restaurant food.

He FJ, Brinsden HC, MacGregor GA. Salt reduction in the United Kingdom: a successful experiment in public health. Journal of Human Hypertension. 2014 Jun;28(6):345.
"(T)he United Kingdom now has the lowest known salt intake of any developed country as measured by 24-h urinary sodium" (as of 2014). The nine key components of the salt reduction program in the United

Kingdom, were: (1) setting up an action group; (2) determining salt intake and sources of salt; (3) setting a target for population salt intake and developing a salt reduction strategy; (4) setting progressively lower salt targets for industry with a clear time frame; (5) working with the industry to reformulate food with less salt; (6) engaging and recruiting of ministerial support; (7) clear nutritional labelling; (8) consumer awareness campaign; and (9) monitoring progress. The salt reduction program in the UK achieved a 15% reduction in average salt intake, from 9.5g/day in 2003 to 8.1g in 2011 (P<0.05). Product surveys show that the salt content in processed foods decreased during the program, including a 20% decrease in bread and 45% in ready meals. Between 2003-2007, the percentage of adults who add salt at the table decreased from 32.5% to 23.2%, and sales of table/cooking salt decreased by approximately 20%. The program was shown to be very cost-effective (£1.5 billion saved per year) and led to approximately 6,000 fewer deaths from cardiovascular disease per year by 2008.

Arcand J, Blanco-Metzler A, Benavides Aguilar K, et al. Sodium Levels in Packaged Foods Sold in 14 Latin American and Caribbean Countries: A Food Label Analysis. Nutrients. 2019 Feb;11(2):369.
In 2015, the Salt Smart Consortium released a set of sodium reduction targets for 12 categories of packaged foods throughout Latin America and the Caribbean. Targets included a regional target (maximum) level and a more aggressive lower target level (used as the goal). Overall, 82% of packaged foods in the 14 countries surveyed met the regional target level, and 47% met the lower target level. In all countries, at least of 77% of products met at least the regional target. The proportion of foods meeting the sodium targets varied, both across countries and food categories. Food categories meeting the targets most frequently included uncooked noodles and pasta, flavored cookies and crackers, seasonings, mayonnaise, and cured and preserved meats (all above 91%). Categories with the lowest proportion meeting the targets include wet and dry soups, bouillon cubes/powders, breaded meat and poultry, and cakes.

Hofman KJ, Lee R. Intersectoral case study: Successful sodium regulation in South Africa. World Health Organization Regional Office for Africa. 2013.
In 2016, South Africa began to implement mandatory regulation of sodium used in processed foods for several industries. Sodium limits were set for foods with the highest sodium, particularly bread, which contributes about 25–40% of an average South African's daily intake of sodium, as well as for butter and margarine, savory snacks, processed meats, and soup mixes. Limits are to be phased in over a three-year period, with the first deadline in June 2016 and stricter limits in June 2019. Methods for enforcement and testing sodium levels for compliance were included in the legislation. Challenges to the process of developing this legislation, include industry pressure, concerns related to enforcement, and concerns about an expected increase in bread prices due to the reformulation costs. Regulations were made possible by intersectoral collaboration among government, academia, and industry; strong government commitment to regulating sodium; a consultation process with nutrition and hypertension-related academics, representatives of the food industry, and non-governmental organizations; and adequate consideration given to understanding industry concerns and providing "an inclusive and respectful approach".

Alhamad N, Almalt E, Alamir N, Subhakaran M. An overview of salt intake reduction efforts in the Gulf Cooperation Council countries. Cardiovascular Diagnosis and Therapy. 2015 Jun;5(3):172.
There has been variable progress in salt reduction efforts across countries in the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates). Intake remains high, with people in most countries consuming more than 12g/day. Efforts to reduce the salt content of bread, the major source of sodium, have been initiated in all countries. At the time of this study, only Qatar and Kuwait had made substantial progress, with a 10-20% salt reduction in bread. Challenges include "lack of political

commitment, inexperience and shortage of qualified human resources". Other regional efforts include surveillance (Kuwait, Oman, Bahrain), food labeling (Bahrain), engaging the private sector on health education (Kuwait), and reducing salt in other processed foods such as cheese and processed meats (Kuwait, Oman).

4.3 Front of Pack Labeling and Marketing

Kanter R, Vanderlee L, Vandevijvere S. Front-of-package nutrition labelling policy: global progress and future directions. PHN. 2018 Jun;21(8):1399-408.
In 2004, the WHO first proposed front-of-pack nutrition labeling (FOPL) to improve diet and health. Since then, the number of initiatives has steadily increased. A variety of labeling schemes exist around the world, varying in presentation and type of public health nutrition message and nutrient focus. Most schemes include sodium, fats, and total sugars. Existing programs usually fall into one of the following systems: health logos (e.g. Keyhole logo in Nordic countries, Choices Programme logo), traffic lights (UK, Ecuador), summary indicator FOPL (e.g. Health Star Ratings and the France A to E ratings), and warning labels (Chile's black warning labels, Finland excess sodium label). Although there is increasing political and societal acceptability of FOPL and widespread agreement that interpretive labels influence consumer understanding and behavior more, further evidence is needed for 1) the relative effectiveness of the various types of interpretive FOPL systems and the impact on consumer behavior and industry reformulation, 2) best practices for label characteristics, such as size, color, and placement, 3) understanding who benefits from FOPL and impact on health inequalities, 4) research examining FOPL in real-world settings as opposed to online environments, 5) decisions regarding voluntary vs. mandatory systems.

Shangguan S, Afshin A, Shulkin M, et al. A Meta-Analysis of Food Labeling Effects on Consumer Diet Behaviors and Industry Practices. AJPM. 2018 Dec 17.
This meta-analysis of 60 studies from 11 countries found that labeling, including labels on packages, menus, and other point-of-purchase (on shelf, vending machines, posters) labeling, significantly decreased consumer intakes of energy by 6.6%, total fat by 10.6%, and other unhealthy dietary options by 13.0% (although not for sodium or saturated fat). Vegetable consumption increased by 13.5%. In studies evaluating traffic light systems, labeling increased the selections of healthier green and amber options and reduced selection of red options. Labeling seems to encourage some industry reformulation, with results from six studies showing a significant decrease in product contents of sodium by 8.9% and artificial trans-fat by 64.3%, but no change in saturated fat or total energy. "This study did not identify consistent differential effects according to label type, placement, intervention duration, or mandatory versus voluntary labeling."

4.3.1 Comparing Types of Labels

Becker MW, Bello NM, Sundar RP, et al. Front of pack labels enhance attention to nutrition information in novel and commercial brands. Food Policy. 2015 Oct 1;56:76-86.
Experiments tracking participants' allocation of attention to various iterations of front of pack label (FOPL) designs and traditional Nutrition Facts Panel (NFP) designs found that participants were more likely to detect changes to the labels with FOPL designs than NFP, meaning that the FOPL designs "garner attention more readily" than NFPs. Changes were detected even faster when FOPL designs used colors; using facial icons (smiling/frowning faces) did not have an impact on the participants' attention.

Arrúa A, Machín L, Curutchet MR, et al. Warnings as a directive front-of-pack nutrition labelling scheme: comparison with the Guideline Daily Amount and traffic-light systems. PHN. 2017 Sep;20(13):2308-17.
This comparison study of front-of-pack warning labels versus Guideline Daily Amounts (GDA) and traffic-light system labels found that warning labels were most effective at improving customers' ability to identify unhealthful products. Warning labels required the least amount of time to correctly identify whether a product was high in sodium or other key nutrients compared to the traffic light system and GDA. An additional perceived healthfulness experiment showed that "products with high energy, saturated fat, sugar and/or sodium content that featured warnings on the label received significantly lower healthfulness scores than those featuring the GDA or the traffic-light system." Both warning and traffic-light systems better allowed customers to correctly identify the most healthful product when comparing options than the GDA system.

4.3.2 Country Examples
Food and Agriculture Organization of the United Nations, Pan American Health Organization, World Health Organization. Approval of a New Food Act in Chile: Process Summary. 2016.
In 2012, Chile passed the Nutritional Composition of Food and Food Advertising law in Chile, which, among other aspects, mandated a front-of-pack warning labelling system for all packaged foods. To implement the system, Chile established maximum limits for sodium, calories, saturated fats, and sugar per 100 grams or 100 milliliters. A black "high in" warning label is required on the front of the package for each ingredient which exceeds the maximum limit. These maximum limits were phased in gradually over a 36-month period. These limits are also used to restrict the marketing of foods "high in" certain ingredients to children under 14 and restricts sales of these foods in schools. An advertising campaign was conducted to educate consumers on the labels and advertising restrictions, and early studies show good acceptance and a high level of understanding of the labels. This paper cites the strong political will of authorities from the Ministry of Health and some members of parliament, as well as support from universities and international organization as factors to the successful passage of this law.

4.4 Knowledge and Behavior Change
Trieu K, McMahon E, Santos JA, et al. Review of behaviour change interventions to reduce population salt intake. International Journal of Behavioral Nutrition and Physical Activity. 2017 Dec;14(1):17.
Overall, 19 of the 22 studies looking at the effectiveness of population-level behavior change interventions on salt reduction reported significantly reduced estimated daily salt intake or improved self-reported salt-lowering behaviors. Of the 22 studies, 14 were health education interventions, 4 were public awareness campaigns, and 4 were multicomponent education interventions (both health education and awareness campaigns). "Of the 12 studies whose outcome was salt intake, 10 demonstrated significant reductions ranging from 0.9 g/d to 4.4 g/d." The 3 studies showing no significant improvements were all health-education-only programs (as opposed to public awareness campaigns and multi-component interventions). Of the 10 studies classified as higher-quality studies (those with low risk of bias, e.g. selection bias, reporting bias), only 5 found significant effects on salt intake or behaviors based on the more objective outcome assessment method. Results of the study indicate that there is not yet a proven best method of reducing discretionary salt intake.

4.4.1 Country Examples
Do HT, Santos JA, Trieu K, et al. Effectiveness of a Communication for Behavioral Impact (COMBI) intervention to reduce salt intake in a Vietnamese Province based on estimations from spot urine samples. JCH. 2016 Nov;18(11):1135-42.

In Vietnam, about 80% of salt intake comes from table salt or salty condiments used at home. Therefore, a behavior change approach was taken to reduce population salt intake in one Vietnamese city using the Communication for Behavioral Impact (COMBI) framework. The intervention led to significant decreases in mean salt excretion both from spot and 24-hour urine samples (-0.43g/day and -1.99g/day, respectively). Significant improvements were seen for knowledge and behavioral outcomes, including increased awareness that high salt intake can cause hypertension, heart attack, and stroke and reported reductions to adding salt or sauces in the home or consuming processed foods or dishes high in salt. Mean SBP and DBP decreased significantly (5.93 mm Hg and 3.83 mm Hg, respectively), awareness of hypertensive status improved among those with hypertension (+16.3%), and fewer hypertensive subjects reported not being managed or treated (-14.2%).

Land MA, Wu JH, Selwyn A, et al. Effects of a community-based salt reduction program in a regional Australian population. BMC Public Health. 2016 Dec;16(1):388.
A multi-faceted, community-based salt reduction intervention following the Communication for Behavioral Impact (COMBI) framework was implemented in Australia from 2010 to 2014. It led to significant reductions in mean salt intake of 0.8 g/day as measured by 24-hour urine. Key messages included using the FoodSwitch app, swapping table salt for a salt substitute, using spices instead of salt, and avoiding processed foods. In addition to the 24-hour urine results, significant improvements were found for most knowledge and behavioral indicators, including understanding the importance of lowering salt and using spices for flavoring or the sodium reduced, potassium-rich salt substitute which was provided.

Wentzel-Viljoen E, Steyn K, et al. Evaluation of a mass-media campaign to increase the awareness of the need to reduce discretionary salt use in the South African population. Nutrients. 2017 Nov 12;9(11):1238.
For about 9 months during 2014-2015, a mass media campaign was implemented in South Africa to reduce discretionary salt intake and increase public knowledge on the dangers of high salt intake. Baseline and follow-up surveys were conducted to assess the change in knowledge, attitudes and behavior. 77.8% of the follow-up survey respondents reported having seen the SaltWatch media campaign messages. Knowledge regarding high salt intake and its health outcomes improved significantly. At follow up, "significantly more participants reported that they were taking steps to control salt intake (38% at baseline vs. 59.5% at follow up), especially for reductions in salt used in cooking and at the table, as well as higher use of herbs and spices. No significant changes were found in other behaviors, including avoiding processed foods, looking at salt/sodium labels on food, buying low-salt or low-sodium alternatives, or avoiding eating out. Data was not collected on changes in salt intake.

He FJ, Wu Y, Feng XX, et al. School based education programme to reduce salt intake in children and their families (School-EduSalt): cluster randomised controlled trial. BMJ. 2015 Mar 18;350:h770.
A school-based education program on salt intake in Northern China reduced salt intake by 2.6 grams per day, a 26% reduction (−1.9 g/day in children and −2.9 g/day in adults). The intervention included health education lessons on salt reduction with interactive activities, and students were asked to take the messages home to their families, along with educational materials for the parents. The impact was assessed through a cluster-randomized control trial in 28 primary schools. Although systolic and diastolic blood pressure increased among both the control and intervention groups of adults and children by the end of the trial, the increase was less among the intervention group, with a mean effect of −1.8 mm Hg.

4.5 Changing the Environment

Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. Creating healthy food and eating environments: policy and environmental approaches. Annu. Rev. Public Health. 2008 Apr 21;29:253-72.

Improving the "environmental context and conditions in which people live and make choices" is crucial in improving individual- and population-level dietary behaviors. Promising interventions and policies exist for improving behaviors in a variety of environmental contexts. For example, setting nutrition standards for foods available in schools, increasing fresh fruit-and-vegetable programs in schools, establishing worksite programs to increase availability and decrease the price of healthy food, point-of-purchase promotion and targeted food placement in worksite cafeterias as well as supermarkets, preventing "food deserts" where healthy food is unavailable, smaller portion sizes, and nutrition information at restaurants. Disparities in access to and affordability of healthy food often negatively affect low-income and rural populations. Policies and programs should ensure that healthy options are available, identifiable, and affordable to people of all income levels and all geographic locations. Macro-level agricultural policies, government regulations that affect food pricing, and marketing restrictions should all be aligned with national nutrition goals to ensure healthy food is the default choice.

Niebylski ML, Lu T, Campbell NR, et al. Healthy food procurement policies and their impact. International journal of environmental research and public health. 2014 Mar 3;11(3):2608-27.

"Healthy food procurement programs found in this review were nearly always effective at increasing availability of healthier food and decreasing that of less healthy food; contributing to the increased purchases of healthier foods and lower purchases of food high in fat, sodium and sugar". A systematic review evaluated the impact of such policies on healthy eating and health outcomes and included procurement policies implemented in schools (19 studies), worksites (6 studies), remote communities (3 studies), and 6 studies in other settings including hospitals, care homes, correctional facilities, government institutions. No policy intervention identified was unsuccessful. Two studies which included health outcomes found improvement in blood pressure and BMI. Many procurement policies were strengthened by allied interventions such as educational programs or subsidies for healthy foods. Additionally, procurement policies may lead to reformulation of products to be healthier, although more research is needed in this area.

4.5.1 Country Examples

Lederer A, Curtis CJ, Silver LD, Angell SY. Toward a healthier city: nutrition standards for New York City government. AJPM. 2014 Apr 1;46(4):423-8.

In 2008, New York City Mayor Bloomberg signed an Executive Order which led to the development of the NYC Standards for Meals/Snacks Purchased and Served, a policy requiring all city agencies to follow the standards (including limits for sodium) for all food that is purchased, prepared, and/or served by the agency, covering more than 260 million meals and snacks per year. The standards were developed by a Food Procurement Workgroup, with representation from all relevant city agencies and the NYC Health Department serving as technical advisor. Elements which led to successful implementation of the standards included support from a high-level central authority, providing extensive technical assistance to agencies, incorporating the standards into all city agency contracts which involved food, and developing regular progress reports detailing agencies' compliance with the standards.

4.5.2 Venues
4.5.2.1 Schools

Ellison RC, Capper AL, Stephenson WP, et al. Effects on blood pressure of a decrease in sodium use in institutional food preparation: the Exeter-Andover Project. Journal of Clinical Epidemiology. 1989 Jan 1;42(3):201-8.

A six-month boarding school intervention to reduce sodium intake through changes to food purchasing and preparation led to a 15-20% reduction in sodium intake at the two participating schools. No information or directives were given to students throughout the intervention. The two schools each served as an intervention and control site during alternating years. Students selected for monitoring were asked to keep a 24-hour food diary once a week at scheduled intervals during the intervention and measured their blood pressure at the beginning and end of the school year. After adjusting for sex and initial blood pressure, "the net effect on both systolic and diastolic blood pressure produced by the 24 weeks of dietary intervention is estimated at approximately -1.0 mmHg for males and -2.5 mmHg for females".

Spence S, Delve J, Stamp E, et al. The impact of food and nutrient-based standards on primary school children's lunch and total dietary intake: a natural experimental evaluation of government policy in England. Plos One. 2013 Oct 30;8(10):e78298.

In 2006, food- and nutrient-based standards were mandated for primary schools in England. A study at 12 primary schools found that "Implementation of school food policy standards was associated with significant improvements in the nutritional content of school lunches." Post-implementation, mean daily intake of sodium fell by 67 mg per day. Children who ate the school lunch consumed less sodium (-128 mg) than children eating a packed lunch. Additional improvements were seen post-implementation in reduced energy, absolute intakes of fat, saturated fat, and non-milk extrinsic sugars in packed and school lunches. Children who ate school lunches had "a lower percent energy derived from fat and saturated fat, but more carbohydrate, protein, non-starch polysaccharides, vitamin C and folate in their total diet than children who ate a packed lunch".

World Food Programme. Smart School Meals: Nutrition-sensitive national programmes in Latin America and the Caribbean. 2017. Rome: WFP.

Nearly all countries in the Latin America and the Caribbean region implement school meals programs; however, "despite undisputed achievements and progress, the nutritional potential of school meals is often underutilized". Many of these programs could be strengthened by incorporating specific nutrition criteria to limit unhealthy nutrients such as salt, fats, and sugar.

4.5.2.2 Hospitals

Moran A, Lederer A, Curtis CJ. Use of nutrition standards to improve nutritional quality of hospital patient meals: findings from New York City's Healthy Hospital Food Initiative. Journal of the Academy of Nutrition and Dietetics. 2015 Nov 1;115(11):1847-54.

The New York City Health Department implemented the Healthy Hospital Food Initiative (HHFI) from 2010-2014, which included nutrient-based food procurement standards and standards for patient meals. A study comparing the nutritional composition of regular-diet patient meals in 8 hospitals before and after the initiative found that "Median sodium content decreased 19%, from 2,636mg to 2,149mg per day." Additionally, fiber increased by 25%, the percentage of calories from fat decreased by 24% and from saturated fat by 21%, and daily dessert offerings decreased 92%. At follow-up, nutrition content across all hospital menus improved and either met or exceeded the minimum HHFI standards.

Ministry of Health, Population and Public Health. Sodium reduction in health-care facilities – B.C.'s experience. 2016. Healthy Living and Health Promotion, Ministry of Health, Population and Public Health, Victoria, Canada.

The British Columbia health authority developed and implemented provincial sodium guidelines and procurement policies for food service operations in BC government health care facilities between 2011 and 2016. The initiative was carried out in three phases: 1) developing sodium guidelines and procurement policies (5 months), 2) stakeholder engagement and implementation (3 years), and 3) final push to reach the target of 2300mg per day/meal (adults) and 1818-2300 mg (pediatric) (1 year). Results showed that by 2016, adult meals had 28% less sodium than at baseline (3372mg to 2372mg), although the final reduction target of 2300mg was not met. Due to various implementation, the date for reaching the target levels was extended to 2021, and sodium targets were lowered to 2,300 – 2,700 mg during the interim.

4.6 Salt Substitutes

Hernandez AV, Emonds EE, Chen BA, et al. Effect of low-sodium salt substitutes on blood pressure, detected hypertension, stroke and mortality. Heart. 2019 Jan 19:heartjnl-2018.

Meta-analysis of 21 randomized controlled trials showed that low-sodium salts significantly lowered both systolic and diastolic blood pressure when compared to regular salt (by 7.8 and 4.0 mm Hg respectively. No conclusions could be made on the effects of salt substitutes on stroke or cardiovascular-related mortality due to the scarcity of data. Low-sodium salt substitutes ranged from 0% to 97% NaCl content. Urinary sodium excretion decreased by −35.82 mmol/day on average, and increases were found for urinary potassium excretion. No other significant intervention effects were found for blood glucose, total cholesterol, triglycerides and BMI. Outcomes were not statistically different for any outcomes across hypertensive, mixed, and normotensive populations.

Chang HY, Hu YW, Yue CS, et al. Effect of potassium-enriched salt on cardiovascular mortality and medical expenses of elderly men. AJCN. 2006 Jun 1;83(6):1289-96.

"Potassium-enriched salt reduced the CVD mortality hazard ratio to ~60% that of the control group" in a randomized control trial of the effects of potassium-enriched salt (49% sodium chloride, 49% potassium chloride) on CVD outcomes in a veteran retirement home in Taiwan. Residents in the experimental group had a longer life expectancy (0.2-0.9 years longer) and significantly lower expenditures on CVD-related inpatient care. Residents were assigned to receive meals from kitchens randomized to either an experimental (potassium salt) group or control (regular salt) group and were followed for 31 months on average. Residents with high serum creatinine concentrations were excluded.

Li N, Yan LL, Niu W, et al. The effects of a community-based sodium reduction program in rural China–a cluster-randomized trial. PloS One. 2016 Dec 9;11(12):e0166620.

A cluster-randomized trial in 120 villages in rural northern China measured the effects of providing access to a low-sodium, potassium-based salt substitute along with health education on sodium reduction. Of the 60 villages receiving the intervention, half also received a price subsidy for the low-sodium salt. At the end of the trial, "mean urinary sodium excretion in intervention compared with control villages was 5.5% lower (-14mmol/day, 95% confidence interval -26 to -1; p = 0.03), potassium excretion was 16% higher (+7mmol/day, +4 to +10; p<0.001), and sodium to potassium ratio 15% lower (-0.9, -1.2 to -0.5; p<0.001)." Use of low-sodium salts was twice as high among intervention sites receiving the price subsidy than intervention sites not receiving the subsidy; the estimated effect on urinary sodium was not statistically significant, possibly due to lower sample size. Knowledge relating to salt and salt substitute improved in the intervention group.

Appendix I: Sodium Conversion Values

Salt		Sodium	
Grams	**Teaspoons**	**mgs**	**mmols**
6	1	2300*	100*
5	NA	2000*	87
0.0585	NA	23	1
2.5*	NA	1000	43.5
1	NA	394	17.1

*approximate