International Journal of Epidemiology, 2017, 1551–1563
doi: 10.1093/ije/dyw361
Advance Access Publication Date: 15 February 2017
Original article

Salt and Sodium

Population-level interventions in government jurisdictions for dietary sodium reduction: a Cochrane Review

**Amanda M Barberio,[1]* Nureen Sumar,[2] Kathy Trieu,[3]
Diane L Lorenzetti,[1,4] Valerie Tarasuk,[5] Jacqui Webster,[3]
Norman RC Campbell[1] and Lindsay McLaren[1]**

[1]Department of Community Health Sciences, [2]Department of Family Medicine, Cumming School of Medicine, University of Calgary, Calgary, AB, Canada, [3]Food Policy, George Institute for Global Health, University of Sydney, Camperdown, NSW, Australia, [4]Institute of Health Economics, Edmonton, AB, Canada and [5]Department of Nutritional Science, University of Toronto, Toronto, ON, Canada

*Corresponding author. Department of Community Health Sciences, E-mail: ambarber@ucalgary.ca

Accepted 7 December 2016

Abstract

Background: Worldwide, excessive salt consumption is common and is a leading cause of high blood pressure. Our objectives were to assess the overall and differential impact (by social and economic indicators) of population-level interventions for dietary sodium reduction in government jurisdictions worldwide.

Methods: This is a Cochrane systematic review. We searched nine peer-reviewed databases, seven grey literature resources and contacted national programme leaders. We appraised studies using an adapted version of the Cochrane risk of bias tool. To assess impact, we computed the mean change in salt intake (g/day) from before to after intervention.

Results: Fifteen initiatives met the inclusion criteria and 10 provided sufficient data for quantitative analysis of impact. Of these, five showed a mean decrease in salt intake from before to after intervention including: China, Finland (Kuopio area), France, Ireland and the UK. When the sample was constrained to the seven initiatives that were multicomponent and incorporated activities of a structural nature (e.g. procurement policy), most (4/7) showed a mean decrease in salt intake. A reduction in salt intake was more apparent among men than women. There was insufficient information to assess differential impact by other social and economic axes. Although many initiatives had methodological strengths, all scored as having a high risk of bias reflecting the observational design. Study heterogeneity was high, reflecting different contexts and initiative characteristics.

Conclusions: Population-level dietary sodium reduction initiatives have the potential to reduce dietary salt intake, especially if they are multicomponent and incorporate intervention activities of a structural nature. It is important to consider data infrastructure to permit monitoring of these initiatives.

Key words: Population, intervention, government, policy, equity, salt

Key Messages

- National population-level dietary sodium reduction initiatives have the potential to achieve population-wide reductions in salt intake, especially if they are multicomponent and include activities of a structural nature.
- There was insufficient information available to evaluate differential impacts of interventions by social and economic indicators.
- To permit rigorous study of the impact of these national initiatives, including equity of impact, it is important that countries have sufficient data monitoring infrastructure in place.

Introduction

In almost all countries worldwide, most people consume too much salt.[1] In 2010, estimated global mean salt intake was 10.1 g/day[2] which is twice the World Health Organization (WHO) recommendation of less than 5 g of salt per day.[3] There is strong evidence to suggest a causal relationship between salt intake and high blood pressure, which is a key risk factor for cardiovascular disease.[4–6] Globally, raised blood pressure is estimated to affect 40% of adults and cause 7.5 million deaths, approximately 12.8% of all deaths.[7]

In an attempt to reduce sodium intake, there has been a growing number of national, population-level sodium reduction initiatives.[8,9] Population-level interventions refer to interventions that target whole populations (e.g. jurisdictions) including individuals at high risk as well as individuals with lower risk profiles. This is in contrast to the high-risk strategy where efforts are targeted at individuals with the highest risk. The population-level approach has the potential for significant impact because the societal implications of shifting the entire distribution of risk in a favourable direction is potentially very large.[10] Modelling studies demonstrate that modest reductions in population salt intake could substantially improve health outcomes and yield substantial health care cost savings.[11–14]

When undertaking population-level sodium reduction interventions, it is important to ensure that they do not worsen socioeconomic inequities in health[15–17] by either exacerbating existing inequities in dietary sodium intake or introducing new ones.[18–20] Knowledge of whether, or the degree to which, population-level interventions are equitable in their impact remains limited. Using dietary sodium reduction as a case example, this review provides insight into the broader question of whether and how population-level interventions can achieve both overall and equitable impact.

Building on the foundational work of Rose, we[18,21] distinguished between population-level interventions that are more agentic (target behaviour change among individuals) and those that are more structural (target settings in which behaviours occur). Structural interventions are hypothesized to be more impactful and equitable.[18,21] Using this continuum as a guide (Figure 1), we identified six types of intervention activities that may be part of a population-level dietary reduction initiative in a government jurisdiction: (i) large-scale food product reformulation; (ii) large-scale pricing interventions (e.g. taxation); (iii) food procurement policy in specific settings (e.g. schools); (iv) restrictions on marketing to children; (v) on-package nutrition labelling; and (vi) public information/education campaigns.

Other Cochrane reviews on dietary sodium reduction have examined the long-term effects of advice to restrict dietary sodium intake on adults participating in randomized controlled trials[22,23] of advice to restrict dietary sodium intake, but none has focused on the impact of sodium reduction initiatives in government jurisdictions nor how equitable they are in their impact. Our objectives were: (i) to assess the impact of population-level interventions for dietary sodium reduction in government jurisdictions worldwide; and (ii) to assess the differential impact of these initiatives by social and economic indicators. This paper is based on a Cochrane review first published in the Cochrane Library.[24]

Methods

Search strategy

We searched the following electronic databases from their start date to 5 January 2015: CENTRAL; Cochrane Public Health Group Specialized Register; MEDLINE; EMBASE; Effective Public Health Practice Project Database; Web of Science; TRoPHI; and LILACS. The detailed search strategy is provided elsewhere.[24] Searches were not restricted by publication date or language. We also searched grey literature websites and resources: OpenGrey, World Health Organization, Public Health Agency of Canada, Centres for Disease Control, Pan American Health Organization,

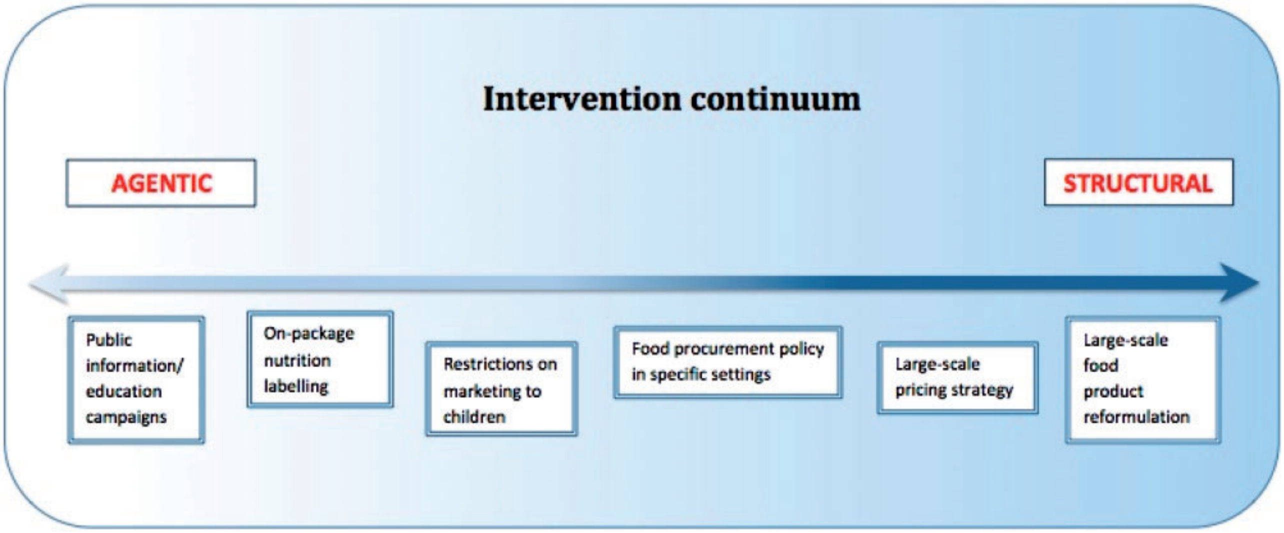


Figure 1. Intervention continuum with six intervention activities that could be incorporated in a population-level dietary sodium reduction initiative.

World Action on Salt and Health and Institute of Medicine. We examined the reference lists of included studies and conducted cited reference searches.

The review was conducted in parallel with a comprehensive review of national sodium reduction efforts under way worldwide,[9] through which we gained additional information from national programme leaders via questionnaires. All 75 countries identified as having a national salt reduction strategy in our companion review[9] were considered for inclusion in the present review. The initiative, or country, was the unit of analysis.

Selection criteria

An initiative was included in the review if: (i) it was population-level in nature (applied to a government jurisdiction); (ii) activities were under way (versus planning stages); (iii) a start date of the initiative could be identified; and (iv) there was at least one pre-intervention data point and at least one post-intervention data point that were comparable in terms of the sample and the method used to determine dietary sodium intake. No study design restrictions were imposed.

The titles and abstracts (when available) of all articles identified through searches were independently screened by two authors. Two authors independently reviewed the full texts of articles that appeared to be suitable for inclusion. Discrepancies were resolved through discussion.

Data extraction and risk of bias assessment

Two review authors collaboratively extracted the following data: study design, participant characteristics, sampling strategy, sample size, response rate, intervention activities, estimates of dietary sodium consumption, axes of inequality, source(s) of funding, conflict of interest and sources of data points. We contacted study authors or country contacts (i.e. national programme leaders of sodium reduction initiatives who coordinated questionnaire completion as noted above) in the case of missing data or uncertainty.

We appraised studies using an adapted version of the Cochrane risk of bias tool that included seven bias domains: sampling, confounding, reliability/validity of outcome measure, blinding of outcome assessment, representativeness of sample, risk of selective outcome reporting, and other sources of bias.[25] Two authors and a research assistant independently assigned a rating of high, low or unclear for each bias domain for each initiative. The rating was based on the worst (highest risk of bias) rating across all available data points. Disagreements between assigned ratings were discussed until a consensus was reached.

The quality of the entire body of evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) criteria.[26]

Data analysis

We included estimates of daily average sodium intake obtained using any method (e.g. dietary survey, urine sample). Because different studies reported different estimates (e.g. salt versus sodium; intake versus excretion) we converted all estimates to the common and easily interpretable metric of salt intake in grams per day with standard deviation, when possible. First, if the original source presented estimates of sodium intake, we used the conversion 1 g of salt = 393.4 mg of sodium, to calculate salt intake in grams per day. Second, if the original source presented estimates of 24-h urinary sodium excretion, we used the conversion 1 g of salt = 17.1 mmol of sodium, to calculate salt intake in grams per day. We analysed overall impact by computing the mean change in salt intake (g/day) from before to after intervention.

We intended to examine differential impact by multiple axes of social inequality based on PROGRESS indicators[27] (place of residence, race/ethnicity, occupation, gender, religion, education, social capital and socioeconomic position); however, the data only permitted differential analysis by sex. We intended to examine differences in overall impact by type(s) of intervention activities but were unable to do this, since most of the interventions involved more than one type of intervention activity. Instead, we considered separately the mean difference in salt intake before and after intervention for a subset of initiatives that we identified as multicomponent and including intervention activities of a structural nature.

Heterogeneity (between study variation) was assessed using Cochrane's I^2 statistic.[25] A funnel plot was created to explore potential publication bias. Analyses were performed using RevMan software (version 5.3).

The Conjoint Health Research Ethics Board at the University of Calgary approved this study (ID # E-24264) and the University of Sydney Human Research Ethics Committee approved the questionnaires that were sent to national programme leaders (#14923).

Results

Search results

The database search yielded 15 706 unique records. Of these, 14 995 records were eliminated after an initial title/abstract screening (711 retained). The grey literature search returned 170 documents. Thus a total of 881 full-text documents were assessed for eligibility, of which 828 were excluded. Main reasons for excluding published or grey literature documents were: not empirical research; the study population was not a jurisdiction; they assessed the salt content of foods rather than individuals' intake; or they were simulation/modelling studies (Figure 2). Of the 75 countries identified in our companion review,[9] 45 had estimates of salt intake at two or more time points and were considered for inclusion.

Ultimately, 15 countries (15 national initiatives) met inclusion criteria (Table 1): Austria,[28] Canada,[20] China,[29,30] Denmark,[31] Finland,[32–35] France,[36,37] Ireland,[38–42] Japan,[43–45] The Netherlands,[46] New Zealand,[47,48] Switzerland,[28,49,50] Thailand,[51,52] Turkey,[53] the UK,[19,54–62] and the USA.[63–66] The UK initiative has been evaluated through data collected separately for England only, Scotland only and the UK as a whole; therefore, there may be overlap among the data sets. However, because we considered the UK as only one initiative, and because we did not pool results (see below), this concern about overlap is moot. Key documentation for these countries included: 25 published articles, 15 grey literature documents, 13 country questionnaires and associated correspondence (Figure 2). Of the 45 potentially eligible countries from our companion review,[9] 18 were excluded and an additional 12 countries were classified as 'ongoing' (Table 2).

Initiative characteristics

The 15 included countries are diverse in terms of their setting and initiatives. Most countries ($n = 12$) are 'high income' and three are 'upper-middle income'.[67] Four of the six WHO regions were represented: Europe ($n = 9$); Western Pacific ($n = 3$); the Americas ($n = 2$); and South-East Asia ($n = 1$).

Most initiatives ($n = 12$) had more than one intervention activity under way during the time frame (data points) considered in this review, and most of these ($n = 11$) incorporated intervention activities of a structural nature (e.g. large-scale food product reformulation). The remaining four initiatives (Canada, China, Japan and the USA) involved fewer (1–2) intervention activities of a less structural nature (e.g. public information campaigns).

The start year of the intervention ranged from 1979 (Finland) to 2011 (Austria and Turkey) with only three initiatives beginning before 2000. In some cases, discretion was involved in determining a start date since most initiatives are complex and evolve over time.

Fourteen initiatives were evaluated using an uncontrolled pre-post design and one initiative (China) was evaluated using an open cohort design. The most common measures used to assess dietary salt intake were: various forms of dietary surveys; spot urine samples; and 24-h urine samples. Details on initiative characteristics are presented in Table 1.

Methodological quality and publication bias

We assessed seven bias domains (see Figure 3 for a summary). Although uncontrolled study designs are understandable in this context, such designs make it difficult to rule out alternative explanations for effects observed. Accordingly, all initiatives received a high risk of bias rating on the confounding domain, which resulted in a summary risk of bias rating of 'high' in all cases. In an effort to capture differences in the methodological quality across our included initiatives, we computed the proportion of

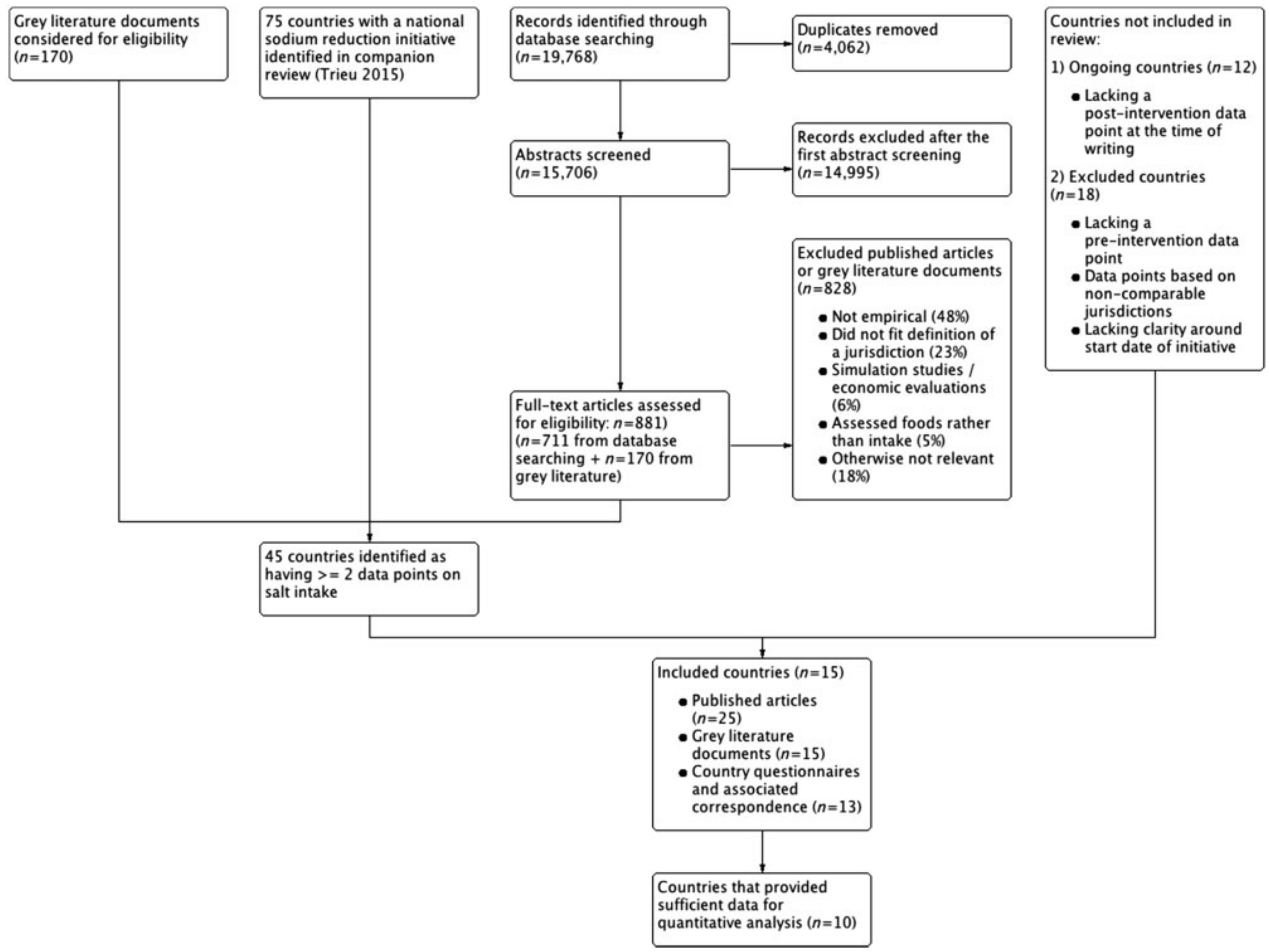


Figure 2. Study flow chart.

bias domains scored as 'high' or 'unclear' for each intervention (out of 7). Based on that metric, the initiatives in our sample from highest to lowest methodological quality are: France, Finland, UK-England, UK-Scotland (1/7); Canada, China, Ireland, and UK-whole, USA (2/7); Denmark (3/7); Austria, The Netherlands, Switzerland (4/7); and Japan, New Zealand, Thailand and Turkey (5/7).

Based on the GRADE criteria, our overall quality of evidence rating for the one outcome measure in this review (salt intake in g/day) is 'very low'. There was substantial between-study variation based on the I^2 measures ($> 90\%$ in all cases), reflecting different contexts and initiative characteristics, and therefore we do not present any pooled results. A funnel plot (not shown) did not show evidence of a publication bias, which is consistent with our comprehensive search and inclusion of grey literature.

Effects of initiatives

Ten of the 15 included initiatives provided sufficient data for quantitative analysis of overall impact (Table 3). Please note that for the UK, our assessment of overall impact was based on the predominant effect across the three sources of data (UK-England, UK-whole and UK-Scotland). The total sample size for the 15 initiatives exceeds 260 000 participants. Of those 10 initiatives (64 798 participants), five showed a mean decrease in salt intake from before to after intervention, including, China, Finland (Kuopio area), France, Ireland and the UK (UK-England and UK-whole). These decreases ranged from −1.15 g/day [95% confidence interval (CI): −1.69, −0.61] in Finland to −0.35 g/day (95% CI: −0.52, −0.18) in Ireland. A mean increase in salt intake from before to after intervention was observed for two initiatives [Canada: 1.66 g/day (95% CI: 1.56, 1.76); and Switzerland: 0.80g/day (95% CI: 0.19, 1.41)]. Five initiatives (Denmark, Japan, New Zealand, Thailand and Turkey) were omitted because they lacked variance estimates to accompany means, which could not be resolved using other reported data or contacting authors.

When we constrained our sample to the seven initiatives (34 227 participants) that were multicomponent and incorporated intervention activities of a structural nature

Table 1. Characteristics of the 15 included initiatives

Country	World Bank country classification	World Health Organization region	Start date of initiative	Intervention activities	Study design	Main method used to determine dietary salt intake
Austria	High-income	Europe	2011	1. Food product reformulation 2. Food procurement policy in specific settings 3. Public information/ education campaign	Uncontrolled pre-post	24-h dietary recall
Canada	High-income	The Americas	1982	1. Public information/ education campaign	Uncontrolled pre-post	24-h dietary recall
China	Upper-middle-income	Western Pacific	2006	1. Public information/ education campaign	Open cohort	24-h dietary recall
Denmark	High-income	Europe	2008	1. Food product reformulation 2. Food procurement policy in specific settings 3. On-package nutrition information 4. Public information/ education campaign	Uncontrolled pre-post	Spot urine
Finland (Kuopio area)	High-income	Europe	1979	1. Food product reformulation 2. Food procurement policy in specific settings 3. On-package nutrition information 4. Public information/ education campaign	Uncontrolled pre-post	24-h urine
France	High-income	Europe	2001	1. Food product reformulation 2. Food procurement policy in specific settings 3. Public information/ education campaign	Uncontrolled pre-post	7-day food record
Ireland	High-income	Europe	2003	1. Food product reformulation 2. On-package nutrition information 3. Public information/ education campaign	Uncontrolled pre-post	Food frequency questionnaire
Japan	High-income	Western Pacific	2001	1. Public information/ education campaign	Uncontrolled pre-post	Nutritional intake survey
The Netherlands	High-income	Europe	2007	1. Food product reformulation 2. Food procurement policy in specific settings 3. On-package nutrition information 4. Public information/ education campaign	Uncontrolled pre-post	24-h urine
New Zealand	High-income	Western Pacific	2005	1. Food product reformulation	Uncontrolled pre-post	Total diet study

(continued)

Table 1. Continued

Country	World Bank country classification	World Health Organization region	Start date of initiative	Intervention activities	Study design	Main method used to determine dietary salt intake
				2. On-package nutrition information 3. Public information/ education campaign		
Switzerland	High-income	Europe	2008	1. Food product reformulation 2. Food procurement policy in specific settings 3. Public information/ education campaign	Uncontrolled pre-post	24-h urine
Thailand	Upper-middle-income	South-East Asia	2006	1. Food product reformulation 2. Food procurement policy in specific settings 3. On-package nutrition information 4. Public information/ education campaign	Uncontrolled pre-post	Dietary survey
Turkey	Upper-middle-income	Europe	2011	1. Food product reformulation 2. Food procurement policy in specific settings 3. Public information/ education campaign	Uncontrolled pre-post	24-h urine
UK-England[a] UK-whole[a,b] UK-Scotland[a]	High-income	Europe	2003	1. Food product reformulation 2. Food procurement policy in specific settings 3. Restrictions on marketing to children 4. On-package nutrition information 5. Public information/ education campaign	Uncontrolled pre-post	Spot urine 24-h urine Spot urine
USA	High-income	The Americas	Late 1980s to early 1990s	1. On-package nutrition information 2. Public information/ education campaign	Uncontrolled pre-post	Estimated 24-h urine from spot urine

[a] The UK is considered as one initiative but was evaluated using data for England only, Scotland only and the UK as a whole.

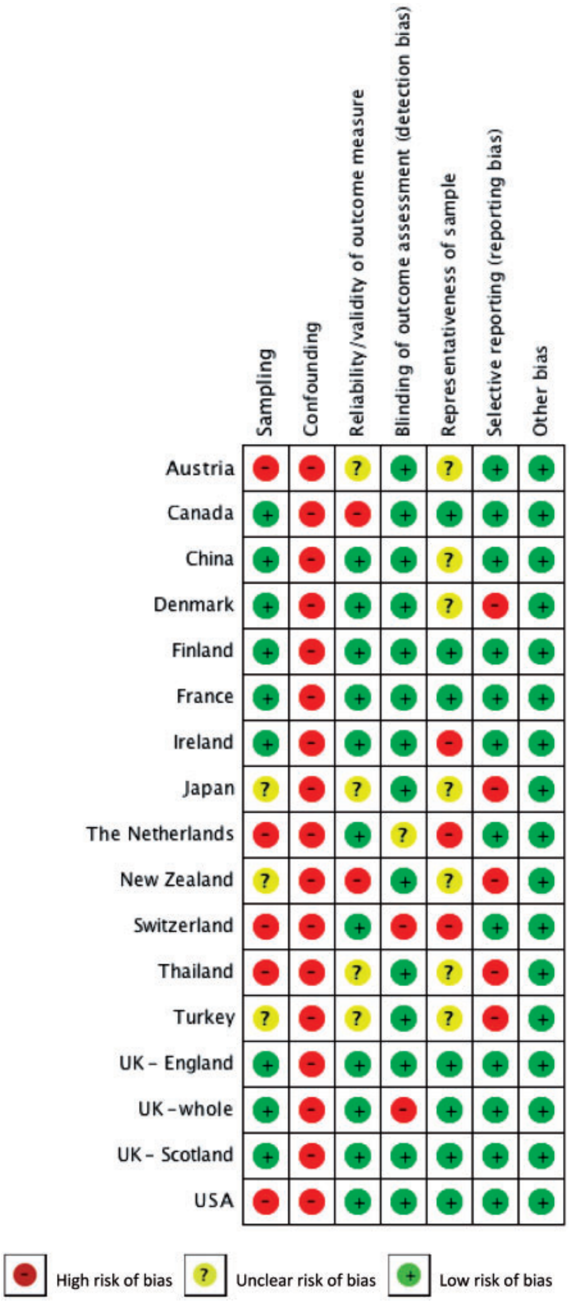
[b] Please note that our post-intervention dataset included Northern Ireland. We used the label 'UK-whole' to convey what was common across the two data points.

(Table 3), four showed a mean decrease in salt intake from before to after intervention, ranging from Finland to Ireland (see above). One initiative (Switzerland) showed a mean increase in intake from before to after intervention (see above). The other two initiatives (Austria and The Netherlands) did not show a change in salt intake.

Nine initiatives provided data that permitted quantitative analysis of impact by sex. For women, three initiatives showed a mean decrease in salt intake [China: −0.76 g/day, (95% CI: −1.07, −0.45), Finland: −0.90 g/day (95% CI: −1.57, −0.23), France: −0.28 g/day (95% CI: −0.47, −0.09)], and two initiatives showed a mean increase in salt intake [Canada: 2.41 g/day (95% CI: 2.30, 2.52), the USA 0.76 g/day (95% CI: 0.09, 1.43)]. The remaining four countries (Austria, The Netherlands, Switzerland, and the UK (UK-whole and UK-Scotland)) did not show a mean change

Table 2. Countries with population-level dietary sodium reduction initiatives that were classified as 'excluded' and as 'ongoing'

	Rationale	Countries
Excluded initiatives (*n* = 18)	Lacking a pre-intervention data point	Argentina, Australia, Barbados, Indonesia, Italy, Portugal, Slovakia
	Existing data points based on non-comparable jurisdictions	Croatia, Malaysia, Poland, Slovenia, Sri Lanka, Vietnam
	Lack of clarity around the start date of the initiative	Bangladesh, Iceland, Israel, Singapore, Uruguay
Ongoing initiatives (*n* = 12)	Lacking a post-intervention data point at the time of writing	Belgium, Brazil, Bulgaria, Chile, Costa Rica, Fiji, Hungary, Lithuania, Mongolia, Norway, Republic of South Korea, Sweden



	Sampling	Confounding	Reliability/validity of outcome measure	Blinding of outcome assessment (detection bias)	Representativeness of sample	Selective reporting (reporting bias)	Other bias
Austria	-	-	?	+	?	+	+
Canada	+	-	-	+	+	+	+
China	+	-	+	+	?	+	+
Denmark	+	-	+	+	?	-	+
Finland	+	-	+	+	+	+	+
France	+	-	+	+	+	+	+
Ireland	+	-	+	+	-	+	+
Japan	?	-	?	+	?	-	+
The Netherlands	-	-	+	?	-	+	+
New Zealand	?	-	-	+	?	-	+
Switzerland	-	-	+	-	-	+	+
Thailand	-	-	?	+	?	-	+
Turkey	?	-	?	+	?	-	+
UK - England	+	-	+	+	+	+	+
UK -whole	+	-	+	-	+	+	+
UK - Scotland	+	-	+	+	+	+	+
USA	-	-	+	+	+	+	+

- High risk of bias
? Unclear risk of bias
+ Low risk of bias

Figure 3. Summary of risk of bias assessment based on an adapted version of the Cochrane risk of bias tool.

in salt intake from before cessation to after cessation of the intervention (Table 4). For men, five initiatives showed a mean decrease in salt intake, ranging from the UK-whole [−1.32 g/day (95% CI: −1.90, −0.74)] to France [-0.57 g/day (95% CI: −0.88, −0.26)]. One initiative showed a mean increase in salt intake [Canada 0.87 g/day (95% CI: 0.70, 1.04)] and the remaining three countries (the Netherlands, Switzerland and the USA] did not show a mean change in salt intake from before cessation to after cessation of the intervention (Table 5).

There was insufficient information to assess differential impact by other social and economic axes. Some studies reported estimates by social and economic indicators at one or more time points (see summary in the full review[24]). However, the different methods and meanings of these indicators across studies precluded a quantitative assessment of differential impact.

Discussion

The findings of this review provide some evidence that population-level sodium reduction initiatives have the potential to reduce salt intake, particularly if those initiatives are multicomponent and incorporate intervention activities of a structural nature (e.g. food product reformulation and food procurement policy). This finding is consistent with Rose's population strategy of prevention[10] and highlights the importance of distinguishing between population-level interventions of a more structural nature (target settings in which behaviours occur) versus those of a more agentic nature (target behaviour change among individuals).[18] Additionally, our results suggest that the impact of national sodium reduction initiatives in terms of salt intake may be stronger among men than women. This finding could reflect in part the observation that globally, men consume more salt than women.[2]

There was insufficient information to determine differential impacts of these initiatives by other axes of

Table 3. Mean change in salt intake (g/day) from before to after intervention overall, and by the subset of multicomponent initiatives that incorporate structural activities

Country	Year of post-intervention data point	Post-intervention salt intake: mean, SD, *n*	Year of pre-intervention data point	Pre-intervention salt intake: mean, SD, *n*	Effect estimate: salt intake: mean (95% CI)
Austria[a]	2012	8.15 g/day, SD = 2.99 380	2008	8.3 g/day, SD = 3.53 2123	−0.15 g/day (−0.49, 0.19)
Canada	2004	7.77 g/day, SD = 1.54 10499	1970–72	6.11 g/day, SD = 3.46 4540	1.66 g/day (1.56, 1.76)[c]
China	2009	11.49 g/day, SD = 6.6 6932	2006	12.7 g/day, SD = 7.11 6826	−0.76 g/day (−0.99, −0.53)[b]
Finland (Kuopio area)[a]	1987	10.63 g/day, SD = 4.1 400	1979	11.78 g/day, SD = 4.72 670	−1.15 g/day (−1.69, −0.61)[b]
France[a]	2006–07	7.54 g/day, SD = 2.34 1922	1998–99	8.0 g/day, SD = 2.58 1345	−0.46 g/day (−0.63, −0.29)[b]
Ireland[a]	2007	7.85 g/day, SD = 3.7 9172	2002	8.2 g/day, SD = 5.9 5992	−0.35 g/day (−0.52, −0.18)[b]
The Netherlands[a]	2010	8.58 g/day, SD = 3.36 342	2006	8.58 g/day, SD = 3.19 317	0 g/day (−0.50, 0.50)
Switzerland[a]	2011	9.2 g/day, SD = 3.8 1448	1984	8.4 g/day, SD = 3.6 147	0.80 g/day (0.19, 1.41)[c]
UK-England[a]	2007	5.46 g/day, SD = 1.12 4269	2003	6.32 g/day, SD = 1.18 1668	−0.86 g/day (−0.93, −0.79)[b]
UK-whole[a]	2008	8.64 g/day, SD = 4.39 692	2000–1	9.53 g/day, SD = 4.48 1147	−0.89 g/day (−1.31, −0.47)[b]
UK-Scotland[a]	2009	6.8 g/day, SD = 4.95 1045	2003	6.8 g/day, SD = 5.19 1148	0 g/day (−0.42, 0.42)
USA	2010	8.64 g/day, SD = 5.08 525	1988–94	8.34 g/day, SD = 4.83 1249	0.30 g/day (−0.21, 0.81)

[a] Initiatives that are multicomponent and incorporate intervention activities of a structural nature.

[b] Decrease in mean salt intake (g/day) from before to after intervention.

[c] Increase in mean salt intake (g/day) from before to after intervention.

stratification. Based on our qualitative synthesis of findings from the few countries that incorporated analysis of differential impact, some studies showed that inequities did not necessarily increase (worsen) in the context of a national sodium reduction initiative.[59] However, more studies that consistently incorporate differential impact analysis are needed to confirm this.

Based on the tools used (adapted version of Cochrane's risk of bias and the GRADE criteria),[25,26] all the initiatives included in this review were considered to have a high risk of bias and the overall quality of evidence rating was very low. However, these assessments of quality of evidence need to be interpreted with consideration of the complex nature of the intervention (national initiatives in government jurisdictions) and the corresponding use of uncontrolled study designs.[68] Computing the proportion of bias domains on which each initiative had a high or unclear risk of bias allowed us to capture some variation in the methodological quality of our included initiatives. Notably, based on that metric, none of the four lowest-quality initiatives were included our quantitative synthesis.

Whereas our companion review identified 75 countries worldwide that had national sodium reduction initiatives,[9] the present review only included 15 of these countries, 10 of which provided sufficient data for quantitative analysis. In many cases, these exclusions reflected limited data infrastructure. For example, seven countries lacked a pre-intervention (baseline) data point and were excluded due to the impossibility of going backwards and generating pre-intervention data (Table 2). Going forward, it is important that countries develop a plan to monitor the impact of sodium reduction initiatives, including equity of impact, which employs high-quality methods.

Our review has limitations. First, despite our best efforts to accurately characterize the intervention activities for each initiative, some uncertainty remains. For instance, a country contact speaking to national efforts may have been unaware of activities that were occurring in smaller jurisdictions (e.g. provinces, states, cities). Second, since dietary salt intake was the only outcome considered in this review, it is unknown whether, or the extent to which, national sodium reduction initiatives impact on other

Table 4. Mean change in salt intake (g/day) from before to after intervention for women only

Country	Year of post-intervention data point	Post-intervention salt intake: mean, SD, *n*	Year of pre-intervention data point	Pre-intervention salt intake: mean, SD, *n*	Effect estimate: salt intake: mean (95% CI)
Austria	2012	7.6 g/day, SD = 3.11 232	2008	7.6 g/day, SD = 2.81 1345	0 g/day (−0.43, 0.43)
Canada	2004	7.41 g/day, SD = 1.44 5612	1970–72	5.0 g/day, SD = 2.71 2566	2.41 g/day (2.30, 2.52)[b]
China	2009	11.43 g/day, SD = 6.35 3605	2006	12.19 g/day, SD = 6.86 3584	−0.76 g/day (−1.07, −0.45)[a]
Finland (North Karelia and Kuopio area)	1987	9.5 g/day, SD = 3.78 220	1979	10.4 g/day, SD = 4.15 327	−0.90 g/day (−1.57, −0.23)[a]
France	2006–07	6.65 g/day, SD = 1.88 1082	1998–99	6.93 g/day, SD = 2.16 732	−0.28 g/day (−0.47, −0.09)[a]
The Netherlands	2010	7.42 g/day, SD = 2.49 188	2006	7.89 g/day, SD = 2.96 180	−0.47 g/day (−1.03, 0.09)
Switzerland	2011	7.8 g/day, SD = 3.3 742	1984	7.3 g/day, SD = 2.9 95	0.5 g/day (−0.13, 1.13)
UK-England	2007	4.12 g/day, SD = 2.47 2343	2003	4.73 g/day, SD = 3.12 933	−0.61 g/day (−0.83, −0.39)[a]
UK-whole	2008	7.66 g/day, SD = 4.77 398	2000–01	8.1 g/day, SD = 3.88 891	−0.44 g/day (−0.97, 0.09)
UK-Scotland	2009	5.7 g/day, SD = 4.37 598	2003	6.1 g/day, SD = 3.87 640	−0.4 g/day (−0.86, 0.06)
USA	2010	7.55 g/day, SD = 3.84 267	1988–94	6.79 g/day, SD = 6.18 604	0.76 g/day (0.09, 1.43)[b]

[a] Decrease in mean salt intake (g/day) from before to after post intervention.
[b] Increase in mean salt intake (g/day) from before to after intervention.

outcomes such as blood pressure; this is important for future reviews to consider. Third, though our companion review identified national sodium reduction initiatives in countries at all levels of economic development and in all WHO regions, this review did not include any initiatives in lower-middle or low-income countries, nor in the African or Eastern Mediterranean regions. Thus, the generalizability of our findings to those countries and regions remains unknown. Fourth, it is possible that for some initiatives, not enough time has yet passed for a reduction in dietary sodium intake to be detected.[24,49,50] In future reviews, it will be important to examine the impact of differential initiative duration, as data permit. Finally, a pooled analysis was not appropriate due to the high level of heterogeneity across the studies. Although less heterogeneity is desirable from a research point of view, it is not necessarily a reasonable or desirable goal for population-level initiatives. These initiatives are embedded within their unique social, cultural, economic and political contexts, and the initiative and its impact are inextricably related to those dimensions of context. We recommend that, in circumstances where it is not possible or appropriate to employ traditional methods of quantitative synthesis for these reasons, researchers and the systematic review community focus on developing alternative thoughtful and rigorous ways to synthesize and interpret these initiatives and their findings.

An important strength of this review is the comprehensive systematic search of the peer-reviewed and grey literature as well as the additional information gained directly from country contacts that would otherwise have been missed, since much of it is not available in published form. Many of the initiatives, especially those included in the quantitative synthesis, had methodological strengths including large, nationally representative samples and rigorous measurement of dietary sodium intake.

Conclusion

In summary, across the 10 studies included in the quantitative synthesis, five showed a reduction in dietary salt intake from pre-intervention to post-intervention levels. However, when we focused on the seven multicomponent initiatives, a reduction in salt intake was more apparent, with four of seven countries showing a decrease. A pooled analysis was not appropriate because of high levels of heterogeneity across studies. These findings suggest that while national population-level dietary sodium reduction initiatives in general have the potential to achieve population-wide reductions

Table 5. Mean change in salt intake (g/day) from before to after intervention for men only

Country	Year of post-intervention data point	Post-intervention salt intake: mean, SD, *n*	Year of pre-intervention data point	Pre-intervention salt intake: mean, SD, *n*	Effect estimate: salt intake: mean (95% CI)
Austria	2012	8.7 g/day, SD = 2.79 148	2008	9.4 g/day, SD = 3.56 778	−0.7 g/day (−1.21, −0.19)[a]
Canada	2004	8.19 g/day, SD = 1.65 4837	1970–72	7.32 g/day, SD = 3.8 1924	0.87 g/day (0.70, 1.04)[b]
China	2009	12.45 g/day, SD = 6.86 3327	2006	13.21 g/day, SD = 7.37 3242	−0.76 g/day (−1.10, −0.42)[a]
Finland (North Karelia and Kuopio area)	1987	12 g/day, SD = 4.45 180	1979	13.1 g/day, SD = 5.2 343	−1.1 g/day (−1.95, −0.25)[a]
France	2006–07	8.69 g/day, SD = 2.83 840	1998–99	9.26 g/day, SD = 3.01 613	−0.57 g/day (−0.88, −0.26)[a]
Netherlands	2010	10.09 g/day, SD = 3.65 154	2006	9.51 g/day, SD = 3.19 137	0.58 g/day (−0.21, 1.37)
Switzerland	2011	10.6 g/day, SD = 4.2 706	1984	10.4 g/day, SD = 3.9 52	0.20 g/day (−0.90, 1.30)
UK – England	2007	5.16 g/day, SD = 3.36 1926	2003	g/day, SD = 3.46 735	−0.94 g/day (−1.23, −0.65)[a]
UK – whole	2008	9.68 g/day, SD = 4.1 294	2000–01	6.1 g/day, SD = 5.02 833	−1.32 g/day (−1.90, −0.74)[a]
UK – Scotland	2009	7.3 g/day, SD = 3.78 447	2003	11 g/day, SD = 5.17 508	−0.30 g/day (−0.87, 0.27)
United States	2010	10.02 g/day, SD = 6.25 258	1988–94	7.6 g/day, SD = 7.81 645	−0.02 g/day (−0.99, 0.95)

[a] Decrease in mean salt intake (g/day) from before to after intervention.
[b] Increase in mean salt intake (g/day) from before to after intervention.

in salt intake, those that are multicomponent and incorporate intervention activities of a structural nature are likely to be the most impactful. Unfortunately, a substantial proportion of existing national sodium reduction initiatives had to be excluded because they lacked comparable pre-intervention and/or post-intervention data. Furthermore, information was insufficient to indicate whether a change in mean salt intake occurred from before intervention to after intervention by social and economic indicators (though we were able to consider differential impact by sex). Thus, the differential impact of these initiatives remains largely unknown. It essential that countries developing a sodium reduction initiative incorporate data monitoring infrastructure in their plans, to permit evaluation of both overall impact and differential impact across social groups. Future reviews should consider health outcomes related to sodium consumption.

Funding

This work was supported by an Operating Grant from the Canadian Institutes of Health Research (CIHR) (Priority Announcement – Sodium and Health – Knowledge-to-action) in partnership with the CIHR Institute of Nutrition, Metabolism, and Diabetes and the CIHR Institute of Population and Public Health (# SOK 116970). L.M. holds an award funded by the CIHR (Institute of Population and Public Health, Institute of Musculoskeletal Health and Arthritis), the Public Health Agency of Canada and Alberta Innovates – Health Solutions. N.R.C.C. holds an award from the Heart and Stroke Foundation of Canada (HSF) Canadian Institutes for Health. J.W. is supported by a National Health and Medical Research Council and National Heart Foundation Career Development Fellowship and grants from the NHMRC, the Victorian Health Promotion Foundation and the WHO.

Conflict of interest: N.C. received consulting fees and travel support from Novartis Foundation in 2016, travel funds from Dieticians of Canada and Boehringer Ingelheim and salary from the HSF and the CIHR.

References

1. Brown IJ, Tzoulaki I, Candeias V, Elliott P. Salt intakes around the world: implications for public health. *Int J Epidemiol* 2009;**38**:791–813.
2. Powles J, Fahimi S, Micha R *et al*son behalf of the 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 24h urinary sodium excretion and dietary surveys worldwide. *BMJ Open* 2013;**3**:e003733. doi:10.1136/bmjopen-2013-003733.

3. World Health Organization. *Diet, Nutrition and the Prevention of Chronic Disease*. Report of a Joint WHO/FAO Expert Consultation. Geneva: WHO, 2003.
4. He FJ, MacGregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. *J Hum Hypertens* 2009;**23**:363–84.
5. Mohan S, Campbell NR. Salt and high blood pressure. *Clin Sci* 2009;**117**:1–11.
6. Strazzullo P, D'Elia L, Kandala NB, Cappuccio FP. Salt intake, stroke, and cardiovascular disease: meta-analysis of prospective studies. *BMJ* 2009;**339**:b4567.
7. World Health Organization. *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*. Geneva: World Health Organization, 2009.
8. Webster JL, Dunford EK, Hawkes C, Neal BC. Salt reduction initiatives around the world. *J Hum Hypertens* 2011;**29**: 1043–50.
9. 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;**10**:e0130247.
10. Rose G. Sick individuals and sick populations. *Int J Epidemiol* 2001;**30**:427–32.
11. Joffres MR, Campbell NR, Manns B, Tu K. Estimate of the benefits of a population-based reduction in dietary sodium additives on hypertension and its related health care costs in Canada. *Can J Cardiol* 2007;**23**:437–43.
12. Dall TM, Fulgoni VL III, Zhang Y, Reimers KJ, Packard PT, Astwood JD. Potential health benefits and medical cost savings from calorie, sodium, and saturated fat reductions in the American diet. *Am J Health Promot* 2009;**23**:412–22.
13. Bibbins-Domingo K, Chertow GM, Coxson PG *et al*. Projected effect of dietary salt reductions on future cardiovascular disease. *N Engl J Med* 2010;**362**:590–99.
14. Smith-Spangler CM, Juusola JL, Enns EA, Owens DK, Garber AM. Population strategies to decrease sodium intake and the burden of cardiovascular disease: a cost-effectiveness analysis. *Ann Intern Med* 2010;**152**:481–87.
15. Whitehead M. A typology of actions to tackle social inequalities in health. *J Epidemiol Commun Health* 2007;**61**:473–78.
16. Frohlich KL, Potvin L. Transcending the known in public health practice: the inequality paradox: the population approach and vulnerable populations. *Am J Public Health* 2008;**98**: 216–21.
17. Commission on the Social Determinants of Health. *Closing the Gap in a Generation: Health Equity Through Action on the Social Determinants of Health*. . Geneva: World Health Organization, 2008.
18. McLaren L, McIntyre L, Kirkpatrick S. Rose's population strategy of prevention need not increase social inequalities in health. *Int J Epidemiol*. 2010;**39**:372–77.
19. Ji C, Kandala NB, Cappuccio FP. Spatial variation of salt intake in Britain and association with socioeconomic status. *BMJ Open* 2013;**3**:e002246.
20. McLaren L, Heidinger S, Dutton D, Tarasuk V, Campbell N. A repeated cross-sectional study of socio-economic inequities in dietary sodium consumption among Canadian adults: implications for national sodium reduction strategies. *Int J Equity Health* 2014;**13**:44.
21. Sumar N, McLaren L. Impact on social inequalities of population strategies of prevention for folate intake in women of childbearing age. *Am J Public Health* 2011;**101**:1218–24.
22. Hooper L, Bartlett C, Davey SG, Ebrahim S. Advice to reduce dietary salt for prevention of cardiovascular disease. *Cochrane Database Syst Rev* 2004;**1**:CD003656.
23. Taylor RS, Ashton KE, Moxham T, Hooper L, Ebrahim S. Reduced dietary salt for the prevention of cardiovascular disease. *Cochrane Database Syst Rev*. 2011;**7**:CD009217.
24. McLaren L, Sumar N, Barberio AM *et al*. Population-level interventions in government jurisdictions for dietary sodium reduction. *Cochrane Database Syst Rev* 2016;**9**: CD010166.
25. Higgins JP, Green S (eds). *Cochrane Handbook for Systematic Reviews of Interventions*. Chichester, UK: Wiley-Blackwell, 2008.
26. GRADE Working Group. *Grading of Recommendations, Assessment, Development, and Evaluation*. http://www.gradeworkinggroup.org/ (December 2015, date last accessed).
27. National Collaborating Centre for Methods and Tools. *PROGRESS Framework: Applying an Equity Lens to Interventions*. Hamilton, ON: McMaster University, 2014 (December 2015, date last accessed).
28. World Health Organization. *Mapping Salt Reduction Initiatives in the WHO European Region*. Copenhagen, Denmark: WHO Regional Office for Europe, 2013.
29. Bi Z, Liang X, Xu A *et al*. Hypertension prevalence, awareness, treatment, and control and sodium intake in Shandong Province, China: baseline results from Shandong–Ministry of Health Action on Salt Reduction and Hypertension (SMASH), 2011. *Prev Chronic Dis* 2014;**11**:E88.
30. Du S, Neiman A, Batis C *et al*. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China. *Am J Clin Nutr* 2014;**99**:334–43.
31. Christensen AI, Ekholm O, Glümer C *et al*. The Danish national health survey 2010. Study design and respondent characteristics. *Scand J Public Health* 2012;**40**:391–97.
32. Laatikainen T, Pietinen P, Valsta L, Sundvall J, Reinivuo H, Tuomilehto J. Sodium in the Finnish diet: 20-year trends in urinary sodium excretion among the adult population. *Eur J Clin Nutr* 2006;**60**:965–70.
33. Puska P. The North Karelia Project: 30 years successfully preventing chronic diseases. *Diabetes Voice* 2008;(**Special issue**):26–29.
34. Pietinen P, Paturi M, Reinivuo H, Tapanainen H, Valsta LM. FINDIET 2007 Survey: energy and nutrient intakes. *Public Health Nutr* 2010; **13**:920–24.
35. Helldán A, Raulio S, Kosola M, Tapanainen H, Ovaskainen ML, Virtanen S. *Finravinto 2012-tutkimus - The National FINDIET 2012 Survey*. Helsinki: National Institute for Health and Welfare, 2013.
36. Meneton P, Lafay L, Tard A *et al*. Dietary sources and correlates of sodium and potassium intakes in the French general population. *Eur J Clin Nutr* 2009;**63**:1169–75.
37. Dubuisson C, Lioret S, Touvier M *et al*. Trends in food and nutritional intakes of French adults from 1999 to 2007: results from the INCA surveys. *Br J Nutr* 2010;**103**:1035–48.

38. Harrington J, Perry I, Lutomski J *et al*. *SLÁN 2007: Survey of Lifestyle, Attitudes and Nutrition in Ireland. Dietary Habits of the Irish Population*. Dublin: Department of Health and Children, 2008.
39. Morgan K, McGee H, Watson D *et al*. SLAN 2007: Survey of Lifestyle, Attitudes & Nutrition in Ireland: Main Report. *Psychol Rep* 2008;**3**:196.
40. Perry IJ, Browne G, Loughrey M, Harrington J, Lutomski J, Fitzgerald AP. *Dietary Salt Intake and Related Risk Factors in the Irish Population*. Cork, Ireland: Safefood, 2010.
41. Irish Universities Nutrition Alliance. *National Adult Nutrition Survey: Summary Report on Food and Nutrient Intakes, Physical Measurements, Physical Activity Patterns and Food Choice Motives*. Trinity College, Dublin: Irish Universities Nutrition Alliance, 2011.
42. Irish Social Science Data Archive. Survey on Lifestyle and Attitude to Nutrition (SLÁN). http://www.ucd.ie/issda/ (May 2015, date last accessed).
43. Udagawa K, Miyoshi M, Yoshiike N. Mid-term evaluation of "Health Japan 21": focus area for the nutrition and diet. *Asia Pac J Clin Nutr* 2008;**17**:445–52.
44. Miura K, Ando K, Tsuchihashi T *et al*. Report of the Salt Reduction Committee of the Japanese Society of Hypertension. (2) Goal and strategies of dietary salt reduction in the management of hypertension. *Hypertens Res* 2013;**36**:1020–25.
45. Ikeda N, Takimoto H, Imai S, Miyachi M, Nishi N. Data Resource Profile: The Japan National Health and Nutrition Survey (NHNS). *Int J Epidemiol* 2015;**44**:1842–49.
46. Hendriksen MA, van Raaij JM, Geleijnse JM, Wilson-van den Hooven C, Ocké MC, van der A DL. Monitoring salt and iodine intakes in Dutch adults between 2006 and 2010 using 24 h urinary sodium and iodine excretions. *Public Health Nutr* 2014;**17**:1431–38.
47. University of Otago and Ministry of Health. *Methodology Report for the 2008/09 New Zealand Adult Nutrition Survey*. Wellington: Ministry of Health, 2011.
48. New Zealand Ministry for Primary Industries. *New Zealand Total Diet Study (NZTDS)*. Wellington: New Zealand Ministry for Primary Industries, 2016.
49. Mordasini C, Abetel G, Lauterburg H *et al*. [Sodium chloride intake and supply of iodine in the Swiss population.] *Schweiz Mede Wochenschr*. 1984;**114**:1924–29.
50. Chappuis A, Bochud M, Glatz N, Vuistiner P, Paccaud F, Burnier M. *[Swiss Survey on Salt Intake: Main Results.]* Lausanne, Switzerland: Service de Néphrologie et Institut Universitaire de Médecine Sociale et Préventive (CHUV), 2011.
51. Aekplakorn W, Chariyalertsak S, Kessomboon P *et al*. Thai National Health Examination Survey IV Study Group: Prevalence and management of diabetes and metabolic risk factors in Thai adults: the Thai National Health Examination Survey IV, 2009. *Diabetes Care* 2011;**34**:1980–85.
52. Supornsilaphachai C. Evolution of salt reduction initiatives in Thailand: lessons for other countries in the South-East Asia Region. *Reg Health Forum* 2013;**17**:61–71.
53. Erdem Y, Arici M, Altun B *et al*. The relationship between hypertension and salt intake in Turkish population: SALTURK study. *Blood Press* 2010;**19**:31318.
54. Henderson L, Irving K, Gregory J *et al*. The National Diet & Nutrition Survey: Adults Aged 19 to 64 Years. **Vol. 3** *Vitamin and Mineral Intake and Urinary Analytes*. London: HMSO, 2003.
55. National Centre for Social Research. *A Survey of 24 Hour and Spot Urinary Sodium and Potassium Excretion in a Representative Sample of the Scottish Population*. London: National Centre for Social Research Joint Health Surveys Unit, 2007.
56. National Centre for Social Research. *An Assessment of Dietary Sodium Levels Among Adults (Aged 19–64) in the UK General Population in 2008*. Cambridge, UK: MRC Human Nutrition Research, 2008.
57. Scottish Centre for Social Research. *A Survey of 24 Hour Urinary Sodium Excretion in a Representative Sample of the Scottish Population as a Measure of Salt Intake*. Edinburgh, UK: Scottish Centre for Social Research, 2011.
58. Sadler K, Nicholson S, Steer T *et al*. *National Diet and Nutrition Survey - Assessment of Dietary Sodium in Adults (Aged 19 to 64 Years) in England, 2011*. London: Department of Health, 2011.
59. Millett C, Laverty AA, Stylianou N, Bibbins-Domingo K, Pape UJ. Impacts of a national strategy to reduce population salt intake in England: serial cross sectional study. *PLoS On*. 2012;**7**:e29836.
60. Wyness LA, Butriss JL, Stanner SA. Reducing the population's sodium intake: the UK Food Standards Agency's salt reduction programme. *Public Health Nutr* 2012;**15**:254–61.
61. Shankar B, Brambila-Macias J, Traill B, Mazzocchi M, Capacci S. An evaluation of the UK Food Standards Agency's salt campaign. *Health Econ* 2013;**22**:243–50.
62. 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. *BMed Open* 2014;**4**:e004549.
63. Cogswell ME, Zhang Z, Carriquiry AL *et al*. Sodium and potassium intakes among US adults: NHANES 2003–2008. *Am J Clin Nutr* 2012;**96**:647–57.
64. Centers for Disease Control and Prevention. Trends in the prevalence of excess dietary sodium intake - United States, 2003–2010. *Morb Mortal Wkly Rep* 2013;**62**:1021–25.
65. Wang G, Bowman BA. Recent economic evaluations of interventions to prevent cardiovascular disease by reducing sodium intake. *Curr Atheroscler Rep* 2013;**15**:1–9.
66. Pfeiffer CM, Hughes JP, Cogswell ME *et al*. Urine sodium excretion increased slightly among US adults between 1988 and 2010. *J Nutr* 2014;**144**:698–705.
67. World Bank. *Country and Lending Groups*. http://data.worldbank.org/about/country-and-lending-groups. (June 2016, date last accessed).
68. Rychetnik L, Frommer M, Hawe P, Shiell A. Criteria for evaluating evidence on public health interventions. *J Epidemiol Community Health* 2002;**56**:119–27.