Full Report

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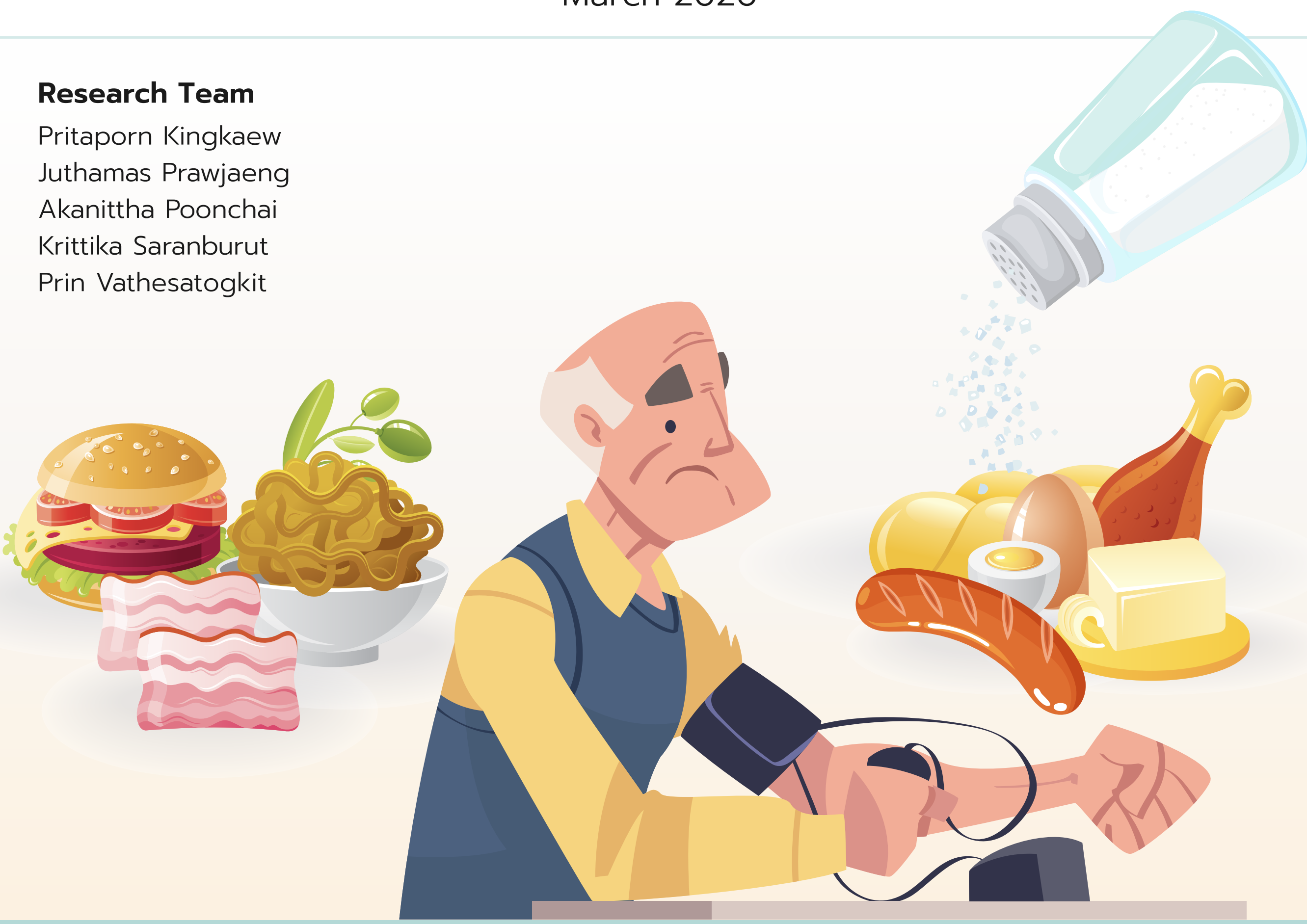

This study is funded by the World Health Organization Country Office for Thailand.

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Abstract

Background: Excessive intake of sodium is associated with elevated blood pressure, a risk factor that contributes to non-communicable diseases such as hypertension, chronic kidney disease, cardiovascular diseases, and stomach cancer. Interventions and policies to control population-wide salt intake have been shown to reduce sodium consumption and blood pressure. However, it is uncertain that public health policies from developed setting will be worthwhile and applicable to the Thai context. The objective of this study was to estimate the cost-effectiveness of policy options for dietary sodium intake control in Thailand.

Methods: A population-based Markov model was constructed to estimate the costs and health outcomes in terms of quality-adjusted life-years (QALYs) of policies—food subsidy, nutrition labelling, voluntary reformulation, mandatory reformulation, health communication, and sodium taxation—compared with the current situation. Cardiovascular disease (including hypertension, coronary heart disease (CHD), cerebrovascular disease (stroke) and heart failure) chronic kidney disease (CKD) and stomach cancer were included in the Markov model. The societal perspective and lifetime horizon were applied. All input parameters were obtained from secondary data sources. The cost-effectiveness threshold of 160,000 THB per QALY gained was used as the threshold to determine the value for money of each policy option. One-way and probabilistic sensitivity analyses were performed to estimate parameter uncertainty.

Results: From a societal perspective, the healthcare costs and direct non-medical costs were estimated to be around 2.28 billion THB over 10 years for the current situation. The costs of policy interventions have a very small fraction (3 - 62 million THB) compared to direct medical costs and direct non-medical costs. On average, sodium reduction policies saved 1,103 up to 12,420 THB per person and increase health outcomes 0.0247 to 0.1381 QALY. Therefore, all policy options for dietary sodium-intake control dominated the current situation. Health communication, mandatory reformulation and sodium taxation averted more death and gained more QALY compared to the other three policies. From the probabilistic sensitivity analysis results, nutrition labelling is being the most cost-effective interventions at a cost-effectiveness threshold of 50,000 THB per QALY gained and health communication becoming the most cost-effectiveness interventions at a higher cost-effectiveness threshold.

Discussion: Though the cost of policy interventions was from the literature review and the cost estimation for sodium taxation did not include costs incurred by the food industry nor any from other sectors than healthcare. The profit and loss from nutrition labelling, reformulation and taxation were not counted. Also, it did not estimate the deadweight loss from consumer and producer surplus nor the tax revenue. The study suggested that any sodium reduction intervention of up to 2,900 million THB a year would still be considered as cost saving.

Conclusion: All policy options for dietary sodium-intake control were cost-saving and the best buy interventions include health communications, mandatory reformulation, and sodium taxation.

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Background

Disease burden of excess dietary sodium intake

High sodium intake is one of the leading dietary risk factors attribute to the global disease burden (1, 2). Excessive intake of sodium is associated with elevated blood pressure, a risk factor that contributes to non-communicable diseases such as hypertension, chronic kidney disease, cardiovascular diseases, and stomach cancer. In 2010, the Global Burden of Disease study estimated that excess dietary salt intake was ranked as the 11th risk factor of the global disease burden; the higher burden was observed in the Southeast Asia Region (7th risk factor) (2). In 2017, it was estimated that 3 million deaths and 70 million DALYs were attributable to high intake of sodium globally, and the leading dietary risk for deaths and DALYs in China, Japan, and Thailand (1).

The effect of dietary sodium on non-communicable diseases

Hypertension is one of the predominant risk factors of cardiovascular disease (CVD) including coronary heart disease (CHD), cerebrovascular disease (stroke), heart failure, and chronic kidney disease (CKD) (3). Hypertension is defined as a blood pressure ≥ 130/80[1] mmHg (stage 1 hypertension) according to the recent guideline recommended by the Eight Joint National Committee (JNC 8) (4). Hypertension is classified into primary hypertension—idiopathic hypertension—and secondary hypertension, depending on existing identifiable causes associated to hypertension (3).

Evidence-based research has been indicated that dietary sodium intake is associated with blood pressure. The result from the INTERMAP[2]—involving 4,680 participants from Japan, China, UK and US—showed that 2 standard deviation higher urinary 24-hour sodium excretion (3,082 mg of sodium) significantly associated with the higher systolic blood pressure (SBP) of 3.45 mmHg (95% CI: 2.45 to 4.45) (5). A meta-analysis of 36 studies suggested that interventions that aim to decrease sodium intake significantly reduced both systolic blood

[1] previously defined as ≥ 140/90 mmHg in the 2014 JNC8 recommendation
[2] International Study on Macro/Micronutrients and Blood Pressure

pressure (3.39 mmHg, 95%CI 2.46 to 4.31) and diastolic blood pressure (1.54 mmHg, 95%CI 0.98 to 2.11) compared to control groups (6).

Blood pressure, especially SBP is commonly known to be associated with cardiovascular diseases and use as a factor to predict the risk of cardiovascular diseases (7-10). The magnitude of the association between hypertension and cardiovascular disease was observed in 36-year follow-up of the Framingham Heart Study. Hypertension increased the relative risk (RR) of stroke (by 3.8 and 2.6 in men and women, respectively), heart failure (by 4.0 and 3.0 in men and women, respectively) and coronary heart disease (by 2.0 and 2.2 in men and women, respectively) (11).

Hypertension can be a cause and a consequence of chronic kidney disease (CKD). Uncontrolled high blood pressure accelerate the deterioration of kidney function resulting from the reduction of capability of blood filtration (12). Also, progressive CKD can exacerbate uncontrolled hypertension. Data from the Modification of Diet in Renal Disease Study showed that the prevalence of hypertension rose progressively from 65% to 95% as the glomerular filtration rate (GFR) fell from 85 to 15 mL/min per 1.73 m^2 and hypertension is normally present in approximately 70% of patients with CKD (stages 3-5) (13).

Excess dietary sodium intake are associated with stomach cancer in observational and case-control studies (14-16). From two meta-analysis studies, risk of stomach cancer in high sodium intake group increased by 1.11 to 1.68-fold compared to control group (14, 15). Similarly, a review of case-control studies reported consistent result on an association between salt or salted food consumption and stomach cancer risk (16). However, the variation of sodium intake-stomach cancer association might be caused by the difference of salt assessment methods, salt intake categorization and salty food definition across studies as well as a difficulty of adjustment for confounding factors due to dietary complexity and various etiology of stomach cancer.

To reduce the global burden of dietary-related non-communicable diseases (NCDs), sodium intake has become a target of global public health issue. Previous study suggested that reducing sodium intake to < 2 g/day is associated with a reduction of SBP (3.47 mmHg) and DBP (1.81 mmHg) compared to ≥2 g/day consumption (6). The WHO, therefore, has recommended the maximum level of sodium intake in adult not more than 2 grams a day (5 grams of salt per day) in order to decrease blood pressure into optimal level as one of the measure to fight against NCDs (17). However, an average global sodium consumption is around 6 grams a day (1) and it was estimated that around 50% reduction in daily salt intake from current levels is in need for most counties to achieve this recommendation (18).

Public health policies to reduce sodium consumption

A wide range of public health policies to reduce sodium consumption has been shown to be effective (18). Salt reduction interventions can be classified into “downstream” and “upstream” approaches which targeting individuals and population, respectively (19). Examples of downstream approaches are dietary counselling in diverse settings (i.e. individuals, schools, worksites, and communities), and mass media campaigns in isolation. Upstream approaches focus on policy-based population strategies including taxation, subsidies, nutrition labelling, voluntary and mandatory reformulation, and comprehensive strategies involving multiple components. The meta-analysis results suggested strategies involving multiple components and "upstream" policies such as mandatory reformulation had higher reductions in the salt consumption than "downstream" interventions, and synergies might be anticipated. For instance, Gase *et al.* (2011) suggested that using labelling, promotion, subsidies and provision of low sodium options could lead to a 0.7±1.8 g/day reduction (19).

Cost-effectiveness of policies to reduce dietary sodium intake

The majority of cost-effectiveness studies in the current literature reported that salt reduction interventions to prevent hypertension and cardiovascular diseases are either cost-saving or cost-effective (20). Schorling *et al.* (2017) systematic review reported that cost-saving strategies are an unspecified intervention, salt/sodium taxes, voluntary or mandatory salt reduction in processed foods, nutrition labelling on salt content and salt awareness campaigns via mass media. In addition, the economic evaluations of population-wide intervention reported to be more cost-effective than targeted salt reduction intervention. The combination of different strategies might be most effective to achieve a salt reduction as recommended by WHO. However, when taken cost of implementation to the strategies, it might not be the most cost-effective strategy.

The comparison across studies might not be appropriate due to different methods such as differed in model, time horizon, perspective, outcome measurement, assumption of effectiveness and types of considered cost. Moreover, the different context across the countries for policy implementation as the review only selected studies that conducted in countries of the organization for Economic Cooperation and Development (OECD) (20) which differs from Thailand, a middle-income country. Further limitation is a lack of transparency of input data, particularly the policy effectiveness of salt intake reduction. Some studies used assumed effectiveness rather than the effectiveness from RCTs or real-life interventions led to wide range of results as well as uncertainty in the incremental cost-effectiveness result.

Thailand situation

Dietary sodium control has been emphasised under the national strategy of the Ministry of Public Health in Thailand since 2013, with a target set at 30% reduction of population sodium intake by 2025. From the Thai National Health Examination Survey IV, the most recent estimated sodium intake were 3.3 grams per day for adults aged over 16 years old (21). This is relatively higher than the target set by the WHO. Ministry of Health in Thailand has adopted the World Health Organization's SHAKE package since 2016 (22). The SHAKE package outlines the population-based policies and interventions that have been effective in reducing population salt intake including:

1) **Surveillance**: measure and monitor salt use;
2) **Harness industry**: promote the reformulation of foods and meals to contain less salt;
3) **Adopt standards for labelling and marketing**: implement standards for effective and accurate labelling and marketing of food;
4) **Knowledge**: education and communicate to empower individuals to eat less salt; and
5) **Environment**: support settings to promote healthy eating.

A cost-effectiveness of five population-based interventions to reduce dietary sodium intake was conducted by the Food and Nutrition Policy for Health Promotion Program (FHP) (23). The policies were identify from the SHAKE package developed by WHO (24). This study used OneHealth Tool[3] to estimate intervention costs and health impacts (i.e. mortality rate and healthy years lived) in 2013-2025. The results showed that the total intervention and program costs were 32,607 million baht. The highest intervention cost was adaptation of standard labelling, approximately 34.5 million baht. It was followed by marketing, surveillance,

[3] a software tool developed the UN Inter Agency Working Group on Costing (IAWG-Costing)

environment, knowledge, and harness industry with the total cost of 15.8, 10.5, 9.1, and 5.3 million baht, respectively. In addition, implementation of the five interventions together could reduce mortality rate from NCDs of 45,000 persons. It also increased healthy years lived of 430,000 years. Compared with no intervention, such interventions could reduce mortality rate of cardiovascular disease (CVD) of 41,000 persons and increase healthy years lived of 228,000 years.

The study suggested that harness industry to promote reformulation was the most cost-effective intervention. The intervention decreased deaths by 37,000 persons from NCDs, and 33,000 from CVD. In addition, the intervention increased healthy years lived of 346,000 years for NCDs group, and 145,000 years for CVD groups. This study indicated important limitations as recommended by the Thai Health Technology Assessment Guidelines as the health care costs related to sodium intake was not taken into account.

A wide range of public health intervention to reduce sodium consumption has been shown to be effective and cost-effective (18). However, the majority of these economic evaluation studies were conducted in high-income countries where the sources of diet sodium differ from low- and middle-income countries. In Thailand, around one-third of Thai population consume salty products—such as fish sauces or soy sauces—during cooking or at the table. Therefore, it is uncertain that public health policies from developed setting will be cost-effective and applicable to the Thai context. There is a need to develop economic models that estimate the impact of public health policies in terms of effectiveness and cost-effectiveness of policy options for dietary sodium intake control to inform decision-makers 'best buy' options that should be implemented in Thailand.

Objective

The objective of this study was to estimate the cost effectiveness of policy options for dietary sodium intake control in Thailand

Methods

Study design

A cost-utility analysis (CUA) was conducted using a population-based Markov model to estimate the costs and benefits in terms of quality-adjusted life year (QALY) of policies to reduce salt intake comparing with current policy in Thai population. Microsoft Excel 2016 (Microsoft Corp., Redmond, WA) was used to run the model with country-specific epidemiology, clinical parameters, and costs. The total costs and incremental costs of policies to reduce salt intake included costs of policy implementation and also healthcare costs saving from diseases preventions. The study was conducted using costs not only incurred from the health system perspective but also from the societal perspective. The lifetime horizon was considered to capture all possible costs and outcomes that might occur. All future costs and benefits were discounted at the rate of 3% per annum following the recommendation of the Thai health technology assessment guideline. All costs were presented in year 2019 THB values (implied PPP conversion rate 1 I$ = 12.24 THB). Summary of important aspects of the study design is shown in **Table 1**.

Table 1 Summary of important aspects of the study design

No.	Item	Details
1	Type of economic evaluation	Cost-utility analysis (CUA)
2	Population of interest	Thai population cohort
3	Interventions	Policy options for dietary sodium intake control that identified and prioritised from a stakeholder consultation meeting: food subsidy, sodium taxation, nutrition labelling, voluntary reformulation, mandatory reformulation, and health communication
4	Comparator	Current situation
5	Analytical approach	Population-based Markov model (see **Figure 1** for the conceptual framework of modelling approach)

No.	Item	Details
6	Perspective	Societal perspective
7	Time horizon for costs and outcomes	Lifetime time horizon
8	Discount rate	An annual discount rate of 3% for both costs and outcomes
9	Health impact	Hypertension, coronary heart diseases, cerebrovascular diseases, chronic kidney diseases, and stomach cancer
10	Primary outcome	Quality-adjusted life year (QALY)
11	Result presentation	Incremental cost-effectiveness ratio (ICER), in THB per QALY gained and cost-effectiveness plane
12	Cost-effectiveness threshold	160,000 THB per QALY gained
13	Uncertainty analysis	One-way (Tornado diagram) & probabilistic sensitivity analysis (Cost-effectiveness acceptability curves)

Model structure and model development

A population-based Markov model was constructed to estimate the costs and health outcomes of policies—food subsidy, nutrition labelling, voluntary reformulation, mandatory reformulation, health communication, and sodium taxation—compared with the current situation based on sodium-related disease from literature review and stakeholder's recommendation from a stakeholder consultation meeting held on July 10th, 2019. Cardiovascular disease (including Hypertension, coronary heart disease (CHD), cerebrovascular disease (stroke) and heart failure) chronic kidney disease (CKD) and stomach cancer were included in the Markov model in basis of progression and relationship of sodium-related diseases. **Figure 2** showed the structure of the model. The circle represents the health states including 'Healthy', and diseases related to high sodium intake, including coronary heart disease (CHD), stroke, chronic kidney disease (CKD) and stomach cancer. Each year (1-year cycle), 'healthy population' can develop diseases related to high sodium intake. 'Healthy' or patients in any disease health state can die from disease-specific or other causes.

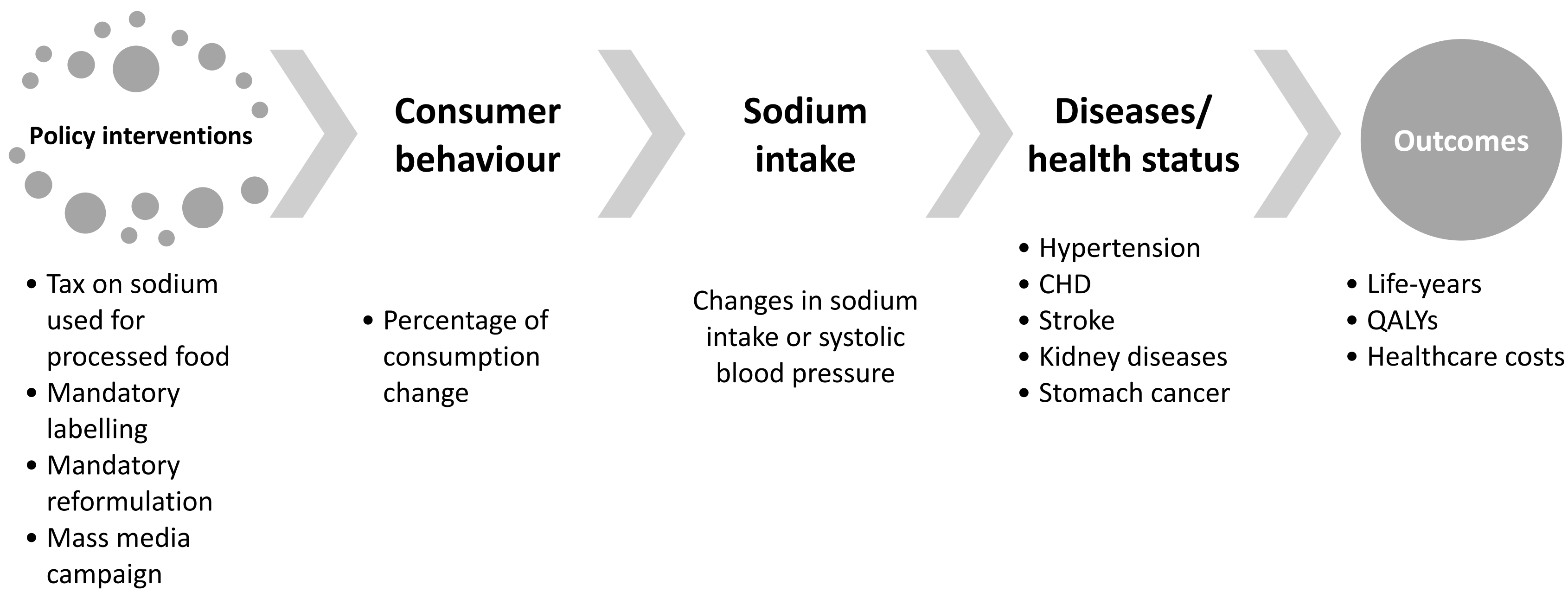


Figure 1 Conceptual framework for modelling approach

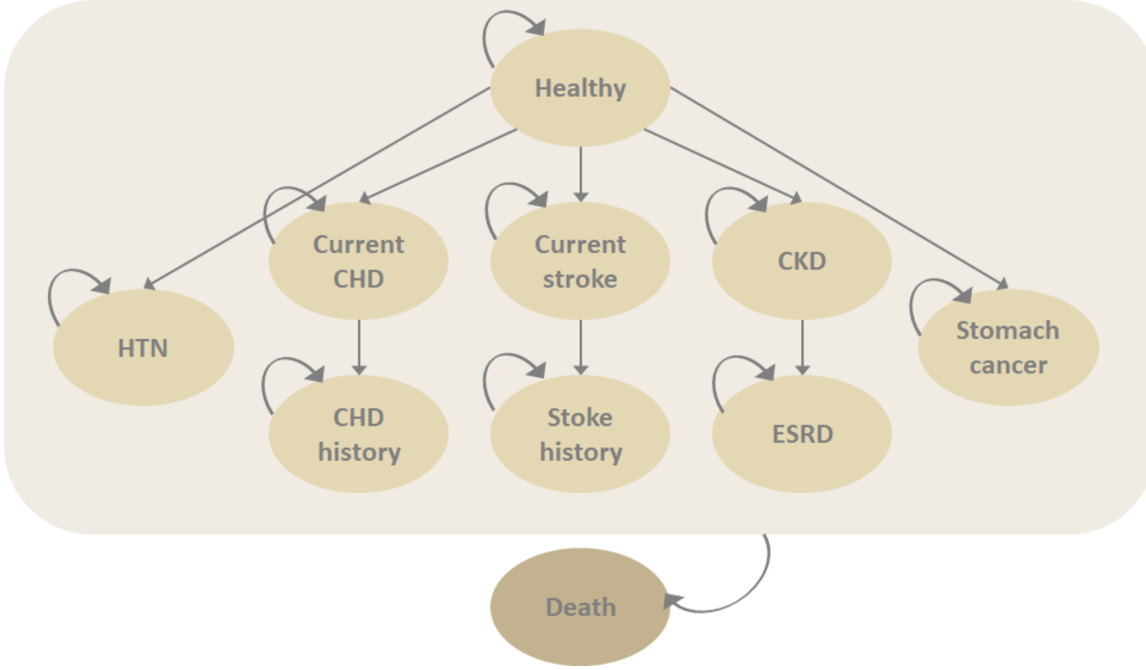


Figure 2 State transition diagram for a Markov model to predict costs and health outcomes from sodium-related diseases

Model inputs

Food consumption behaviour

Frequency of snack and packaged food consumption among Thai population

The National Statistic Office (NSO), Ministry of Digital Economy and Society, has been collecting food consumption behaviour of the Thai population every four years since 2005. The 2017 Food Consumption Behaviour Survey had been integrated with the 2017 Health and Welfare survey to collect additional data on food consumption behaviour and the frequency of food consumption. Food type that has high sodium that was collected includes snacks (fish strips, chips, corn chips, crispy seaweed, cookies, biscuits, and wafer) and packaged food (including instant noodles). An ordered probit model was used to estimate relationships between the pattern of snack consumption or packaged food consumption (no consumption, 1-2 days/week, 3-4 days/week, 5-6 days/week and everyday consumption—ordinal dependent variable), and independent variables including age, gender, household income, and 5-level asset index. All analysis was performed using STATA MP 14 (*oprobit*).

The frequency of snack consumption was more likely to be higher among younger (6-24 years old) female and higher socioeconomic status (**Table 2**). The frequency of packaged food consumption was more likely to be higher among younger male and higher income (**Table 3**). **Figure 3**, **Figure 4**, and **Figure 5** illustrate the predicted probabilities of snack consumption patterns among the Thai population aged 6-24, 25-59, and ≥ 60 years old, respectively. It shows that the higher SES was more likely to snack compared to the lower SES only in population aged 6-24 years old. However, this trend was not observed in packaged food consumption (**Figure 6** to **Figure 8**).

Table 2 Results from ordered probit model for snack consumption

Dependent variable	Probit coefficients (SE)	Predicted probability (%)				
		no consumption	1-2 days/week	3-4 days/week	5-6 days/week	Every day
Age groups (years)						
6-24	ref	30.04%	40.12%	14.13%	5.40%	10.31%
25-59	-1.0058 (0.0499)*	67.95%	25.60%	4.15%	1.09%	1.21%
≥60	-1.5065 (0.0515)*	83.11%	14.67%	1.58%	0.34%	0.30%
Gender						
Female	ref	70.59%	23.28%	3.84%	1.04%	1.25%
Male	-0.1029 (0.0177)*	73.83%	21.12%	3.23%	0.84%	0.98%
5-level asset index						
1	ref	75.06%	20.33%	2.98%	0.76%	0.87%
2	-0.0093 (0.0297)	75.34%	20.14%	2.93%	0.75%	0.84%
3	0.0565 (0.0296)	73.33%	21.53%	3.29%	0.86%	0.99%
4	0.1110 (0.0304)*	71.61%	22.69%	3.61%	0.96%	1.13%
5	0.2265 (0.0342)*	67.80%	25.15%	4.35%	1.20%	1.50%
Log household income	0.1295 (0.0125)*	72.91%	21.88%	3.34%	0.87%	1.00%

Note: * p-value < 0.01; mean household income = 12,378 Thai Baht

Table 3 Results from ordered probit model for packaged food consumption

Dependent variable	Probit coefficients (SE)	Predicted probability (%)				
		no consumption	1-2 days/week	3-4 days/week	5-6 days/week	Every day
Age groups (years)						
6-24	ref	26.54%	50.57%	13.83%	4.43%	4.63%
25-59	-0.5086 (0.0496)*	45.28%	44.17%	7.31%	1.82%	1.42%
≥60	-0.9014 (0.0505)*	60.78%	34.20%	3.76%	0.77%	0.49%
Gender						
Female	ref	51.87%	39.83%	5.84%	1.40%	1.06%
Male	0.0549 (0.0157)*	49.73%	41.12%	6.36%	1.56%	1.23%
5-level asset index						
1	ref	49.27%	41.37%	6.49%	1.61%	1.27%
2	-0.0293 (0.0251)	50.41%	40.70%	6.20%	1.51%	1.18%
3	-0.0372 (0.0254)	50.72%	40.51%	6.13%	1.49%	1.15%
4	-0.0293 (0.0265)	50.41%	40.70%	6.20%	1.51%	1.18%
5	-0.074 (0.0306)*	52.15%	39.64%	5.78%	1.38%	1.05%
Log household income	0.0422 (0.0109)*	50.60%	40.62%	6.14%	1.49%	1.15%

Note: * p-value < 0.01; mean household income = 12,378 Thai Baht

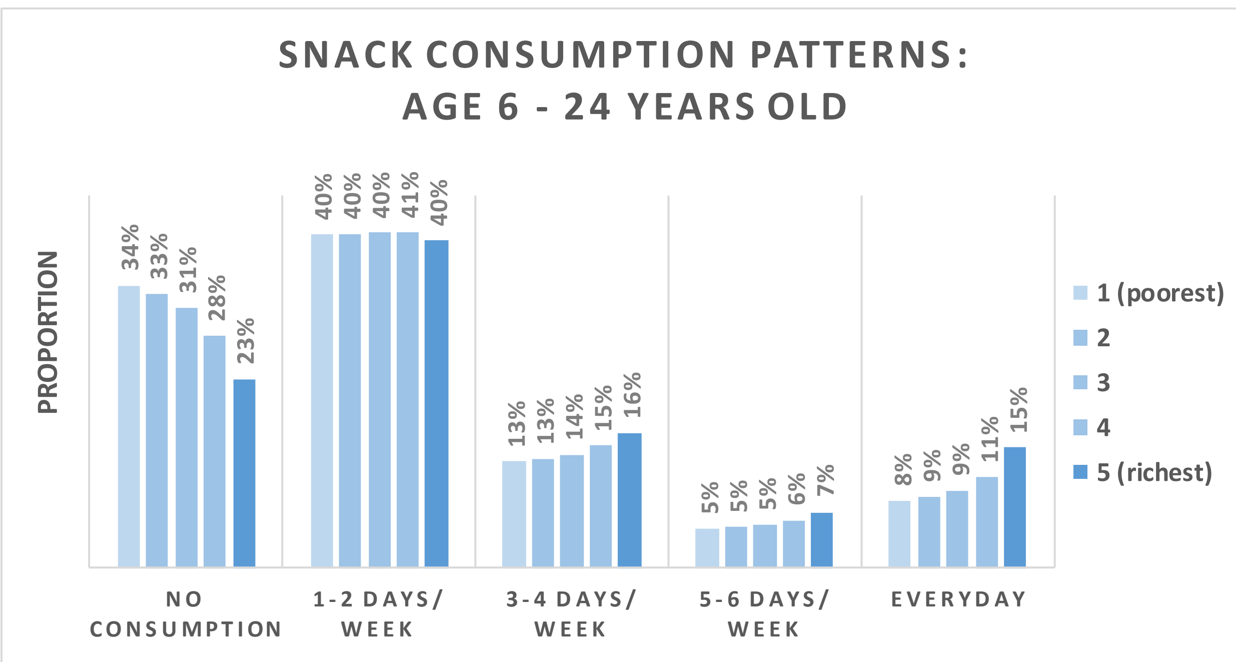


Figure 3 Snack consumption patterns among different socioeconomic status in population aged 6 - 24 years old

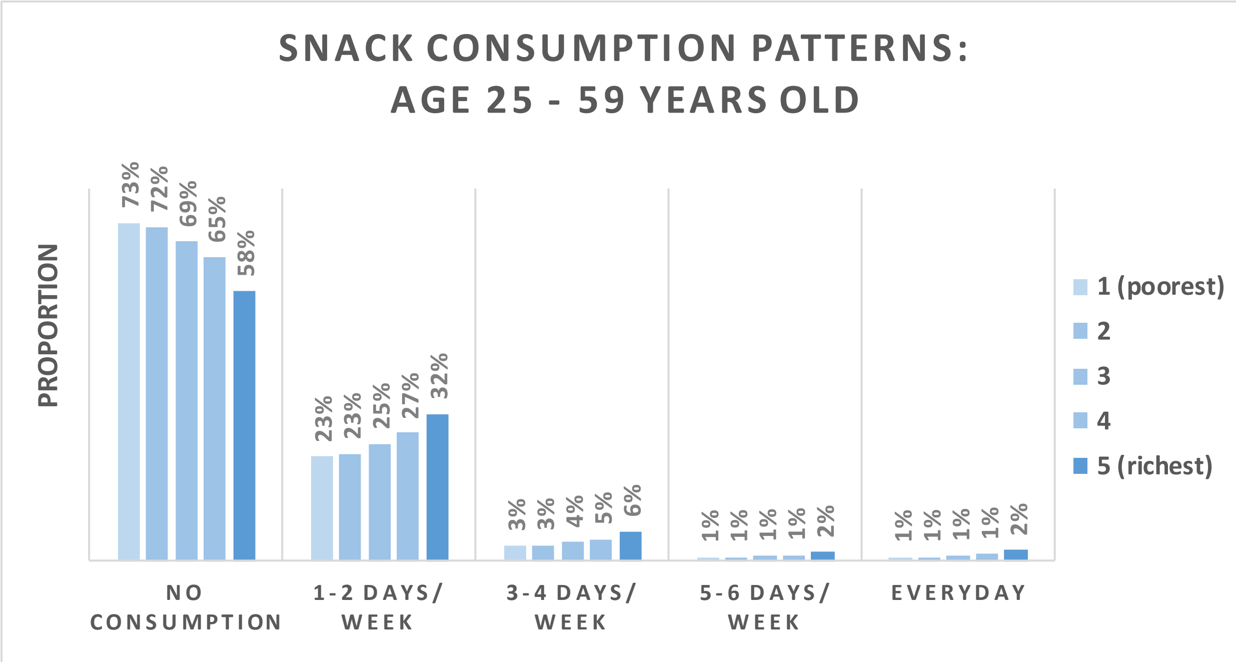


Figure 4 Snack consumption patterns among different socioeconomic status in population aged 25 - 59 years old

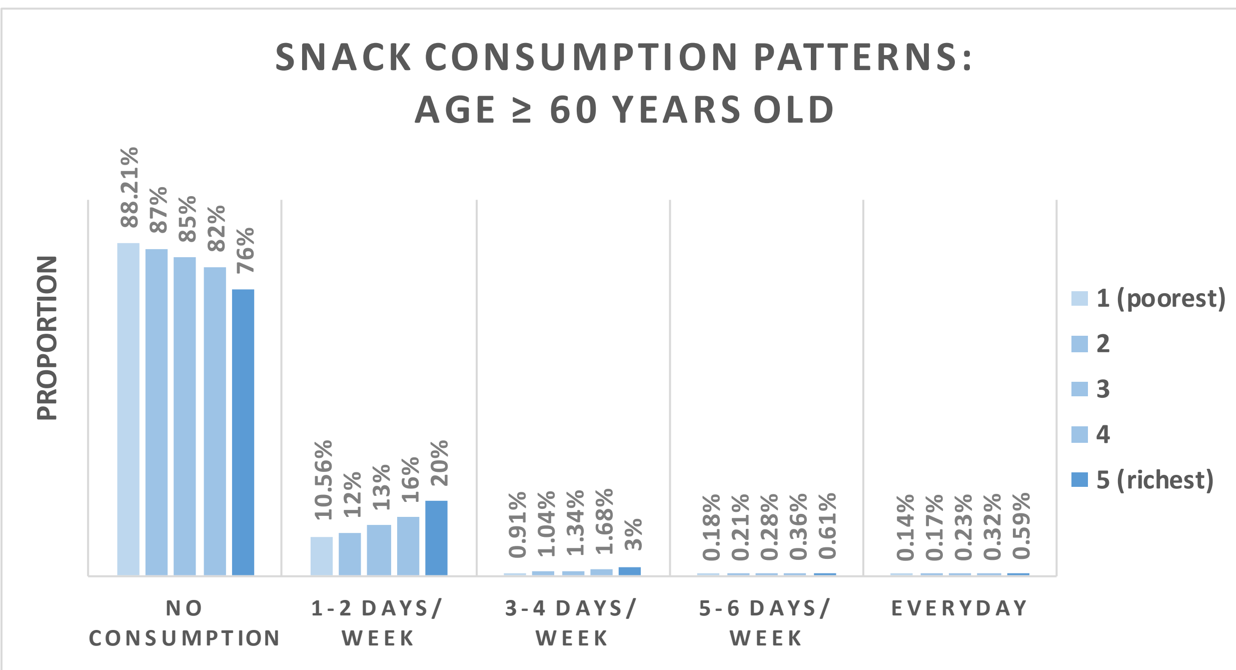


Figure 5 Snack consumption patterns among different socioeconomic status in population aged more than 60 years old

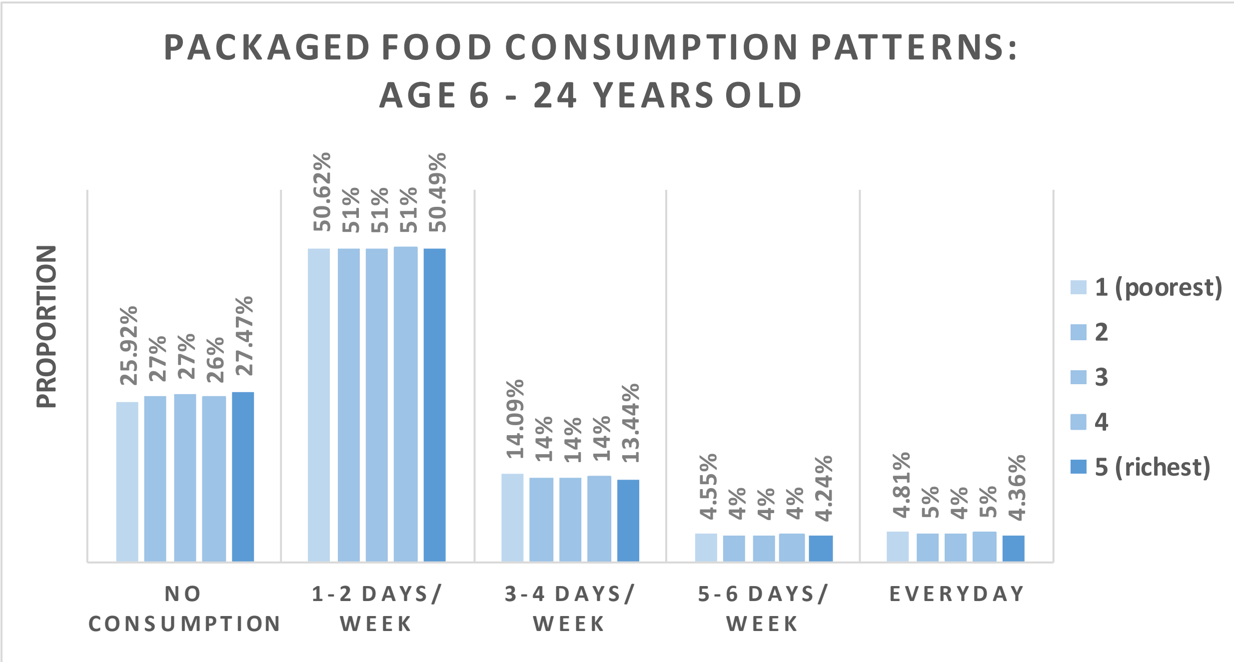


Figure 6 Packaged food consumption patterns among different socioeconomic status in population aged 6 - 24 years old

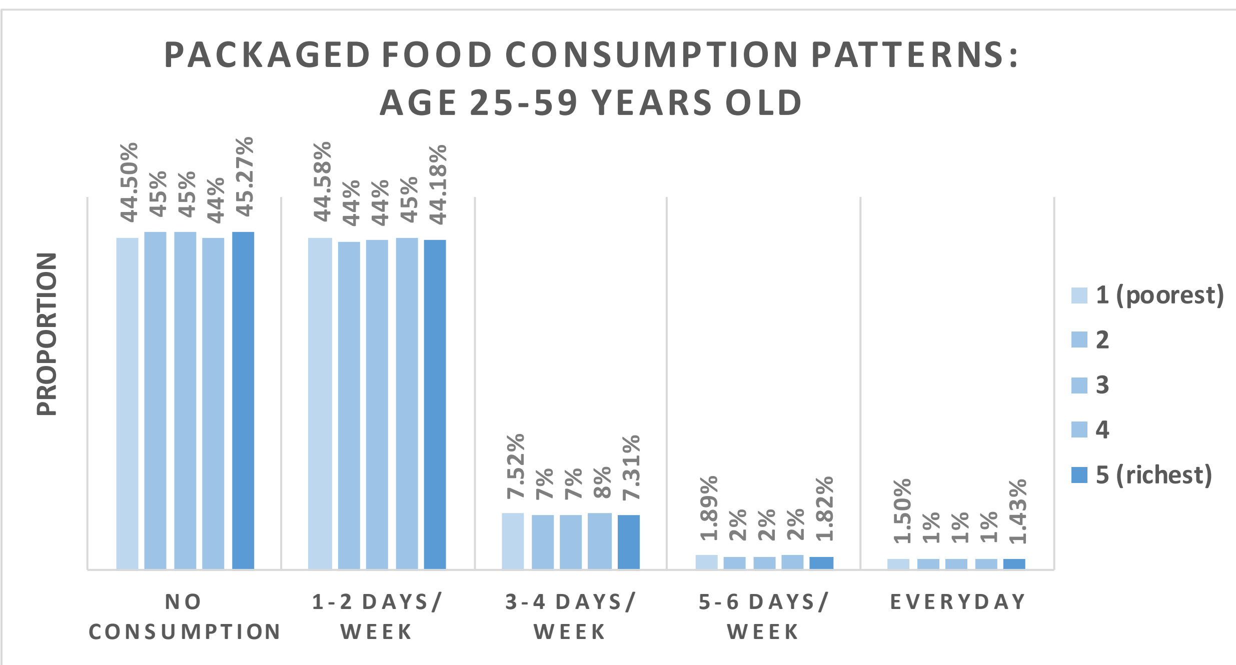


Figure 7 Packaged food consumption patterns among different socioeconomic status in population aged 6 - 24 years old

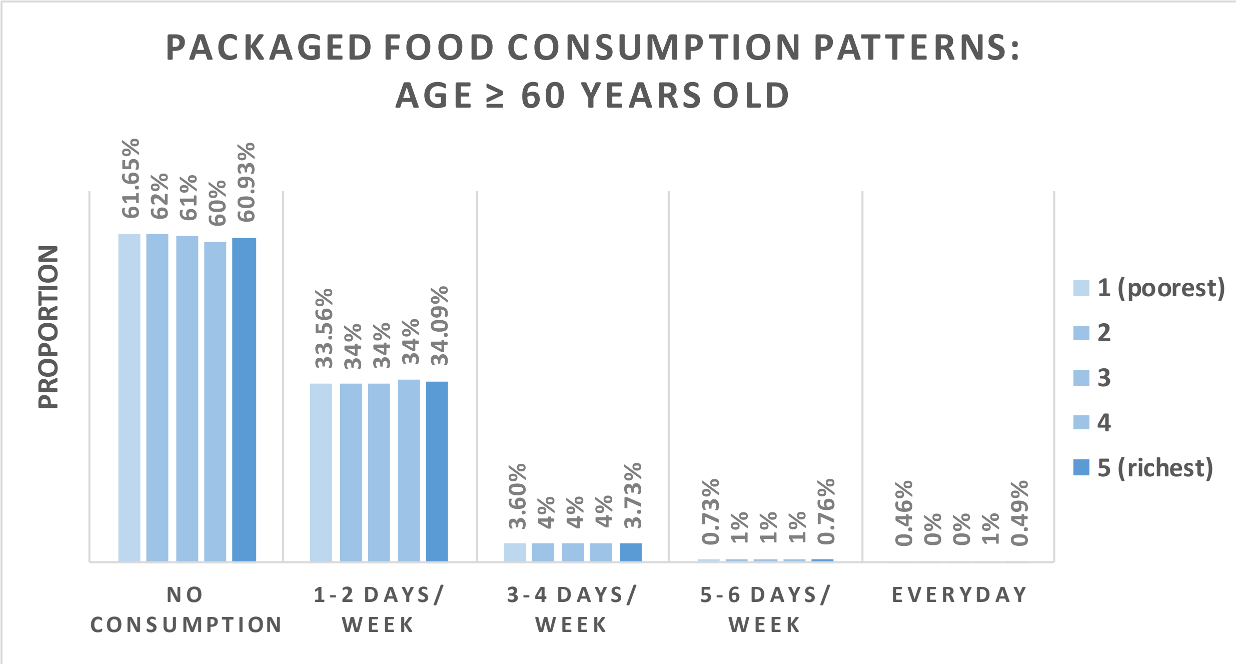


Figure 8 Packaged food consumption patterns among different socioeconomic status in population aged 6 - 24 years old

Average food consumption among Thai population

The contribution of food consumption was obtained from Food consumption data of Thailand survey in 2016 by the National Bureau of Agricultural Commodity and Food Standards (ACSF), Ministry of Agriculture and Cooperatives. This survey was conducted nationally in 8,478 Thai population every 10 years in order to assess food-related risk on food consumption among Thai population. The average contributions of food consumption were reported as 'per capita' and 'eater only' separated by food type and age groups as shown in **Table 4**.

Table 4 The average contributions of food consumption in Thailand

No	Food type	Per capita (gram/person/day)						Eater only (gram/person/day)					
		Age group (year)						Age group (year)					
		3-5	6-12	13-17	18-34	35-64	≥65	3-5	6-12	13-17	18-34	35-64	≥65
Rice and flour product													
1	Instant Rice Porridge	1.69	0.92	1.04	0.52	0.2	0.52	31.29	37.18	36.69	37.92	36.34	47.39
2	Instant noodle	6.52	11.78	14.46	9.82	4.59	1.98	40.2	54.19	61.23	63.47	59.81	53.69
Dry peas, nuts, grains and packaged product													
3	Roasted peanuts	0.84	1.05	1.12	2.18	0.67	0.44	40.04	56.68	54.25	50.92	39.19	43.15
4	Seasoning peanuts	1.18	1.34	1.81	1.09	0.39	0.04	21.75	28.98	32.78	33.21	31.27	17.83
5	Fried peanuts cookies	0.17	0.2	0.54	0.72	0.4	0.23	24.08	32.81	37.38	34.38	32.51	26.6
6	Salted broad beans	0.07	0.15	0.3	0.28	0.33	0.11	19.88	24.55	29	25.96	26.4	23.71
7	Roasted soybeans	0.02	0.04	0.06	0.04	0.04	0.02	17.94	20.25	20.7	25.97	28.11	15.8
8	Gold peas	0.12	0.24	0.43	0.23	0.18	0.02	17.65	28.53	28.44	24.47	25.21	18.12
9	Fried/roasted peas	0.15	0.53	0.84	0.45	0.33	0.05	24.28	30.54	38.2	32.41	36.1	17.29
10	Fried/roasted cashew nuts	0.21	0.38	0.8	0.85	0.19	0.04	17.73	24.44	31.51	31.71	22.48	12.32
11	Pumpkin, sunflower, watermelon kernels	0.56	1.23	1.73	1.7	0.22	0.1	24.13	29.07	32.53	35.39	28.58	23.95
Snacks													
12	Rice flour snacks	1.11	1.44	1.14	0.54	0.14	0.01	14.5	16.49	16.84	14.59	14.73	12.31
13	Wheat flour snacks	1.52	1.4	1.93	1.15	0.3	0.06	16.52	21.55	24.78	24.89	20.77	12.06
14	Mixed wheat flour snacks	1.84	1.94	1.61	0.93	0.11	0.01	19.14	23.74	26.12	26.84	26.22	14.64
15	Puffed corn snacks	1.06	1.08	1.06	0.97	0.11	0.02	16.17	20.22	22.99	24.34	16.97	14.01
16	Mixed puffed corn snacks	1.26	1.74	1.83	0.75	0.11	0.01	28.41	31.92	37.35	34.77	31.35	33.16
17	Potato chips	4.97	6.2	8.51	6.26	0.95	0.18	15.97	23.44	29.33	30.44	20.02	18.05
18	Potato flour snacks	2.06	1.88	2.04	1.78	0.26	0.01	18.16	22.4	26.47	27.83	21.59	10.94
19	Tapioca flour snacks	0.29	0.34	0.43	0.42	0.06	0.03	18.05	25.14	27.05	26.16	17.76	18.79
20	Mixed tapioca flour snacks	2.4	3.66	3.12	2.17	0.4	0.13	24.69	33.47	36.35	39.88	32.95	24.51
21	Fish snacks	0.99	1.52	1.64	1.62	0.22	0.01	9.01	13.31	14.6	15.94	12.48	7.82
22	Seasoning/fried/roasted seaweed snacks	1.38	1.37	1.51	0.77	0.1	0.02	6.61	8.12	9.08	9.24	7.54	9.02

Epidemiological data

Disease progression

The probability of developing coronary heart disease, cerebrovascular disease and chronic kidney disease were calculated based on the predicted equations from the Electricity Generating Authority of Thailand (EGAT) study, using average baseline CVD-factors of Thai population. The EGAT study is an on-going long term of cardiovascular disease events among EGAT employee. This is the only longitudinal cohort study to identify cardiovascular risk factors in Thailand over 30 years of data collection (25). There are three cohorts including EGAT 1 (n = 3,499), EGAT 2 (n = 3,000), and EGAT 3 (n = 2,500), started to follow-up since 1985, 1998, and 2009, respectively.

Patient-level time-to-event data available from EGAT1 and EGAT2 were used for estimating the annual transitional probability of coronary heart disease (fatal and non-fatal MI) and cerebrovascular disease (fatal and non-fatal stroke). A parametric Weibull model was employed to fit the data where,

$$S(t) = exp\big(-H(t)\big)$$

$$H(t) = \lambda t^{\gamma}$$

$$S(t) = exp(-\lambda t^{\gamma})$$

and the λ parameter gives the scale of the distribution and the γ parameter defines the shape of hazard rate.

$$\ln \lambda = \alpha + \sum_{i=1}^{j} \beta_1\, age + \beta_2 male + \beta_3 SBP + \beta_4\, DM + \beta_5\, smoke + \beta_6\, LDL + \beta_7\, HDL$$

$$tp(t_u) = 1 - exp\big(H(t-u) - H(t)\big)$$

Table 5 Coefficient from parametric Weibull model: coronary heart disease (fatal and non-fatal MI)

Covariates	Coefficient	SE	p-value	95% CI
Age (year)	0.0251	0.0077	0.0010	0.0100 to 0.0403
Gender (male = 1)	0.7474	0.1817	0.0000	0.3914 to 1.1035
SBP (mmHg)	0.0156	0.0024	0.0000	0.0108 to 0.0203
Diabetes (Yes = 1)	0.7976	0.1321	0.0000	0.5387 to 1.0565
Smoking status (Current smoking = 1)	0.2437	0.1203	0.0430	0.0078 to 0.4795
LDL (mg/dl)	0.0035	0.0012	0.0040	0.0011 to 0.0059
HDL (mg/dl)	-0.0127	0.0048	0.0080	-0.0221 to -0.0034
Constant term (α)	-13.4233	0.6795	0.0000	-14.7552 to -12.0915
/ln_p	0.2228	0.0515	0.0000	0.1218 to 0.3238

Table 6 Coefficient from parametric Weibull model: cerebrovascular disease (fatal + non-fatal stroke)

Covariates	Coefficient	SE	p-value	95% CI
Age (year)	0.0691	0.0127	0.0000	0.0443 to 0.0939
Gender (male = 1)	0.2561	0.2569	0.3190	-0.2475 to 0.7597
SBP (mmHg)	0.0192	0.0037	0.0000	0.012 to 0.0264
Diabetes (Yes = 1)	0.7218	0.2020	0.0000	0.3259 to 1.1178
Smoking status (Current smoking = 1)	0.3682	0.1923	0.0560	-0.0088 to 0.7451
LDL (mg/dl)	-0.0011	0.0021	0.5870	-0.0052 to 0.003

HDL (mg/dl)	-0.0046	0.0073	0.5300	-0.0189 to 0.0097
Constant term (α)	-15.4849	1.0641	0.0000	-17.5704 to -13.3993
/ln_p	0.0635	0.0818	0.4380	-0.097 to 0.2239

For chronic kidney disease status, defined as estimate glomerular filtration rate (eGFR) less than 60 mL/min/1.73 m^2 (26). The risk scores to predict decreased glomerular filtration rate at 10 years in the Thai population where

$$Full\ score = \alpha + \beta_1 age + \beta_2 male + \beta_3 SBP + \beta_4 DM + \beta_5 WC$$

PFullScore= 1/(1+exp(-Full Score))

Table 7 Coefficient from regression model: Chronic kidney disease

Covariates	Coefficient	SE	p-value	95% CI
Age (year)	0.0558	0.0093	<0.001	1.0384 to 1.0768
Gender (male = 1)	0.6033	0.1845	0.001	1.2734 to 2.6247
SBP (mmHg)	0.0236	0.0037	<0.001	1.0164 to 1.0315
Diabetes (Yes = 1)	0.5586	0.1933	0.004	1.1969 to 2.5537
Waist circumference (cm)	0.0159	0.0078	0.041	1.0007 to 1.0317
Constant term (α)	-10.2736	0.846	<0.001	

Baseline risk factors

For the current scenario of policy implementation as a base case analysis, baseline risk factors of diseases were taken from Thailand's National Health Examination Survey (NHES) V. The Thai NHES is a cross-sectional survey of a representative non-institutionalized Thai population, scheduled to be completed every 5 years. The notable strengths of the survey are in the methodology, quality assurance, and the use of physical and laboratory examinations. In addition, the survey includes demographic and socioeconomic factors that are helpful for further analysis. However, individual data of the survey is not available for analysis; we then use the current published survey data in this study. For the NHES V in 2014, the survey included participants aged 15 years and above, in the total of 22,095 participants. The summary of average baseline CVD-factors showed in **Table 7**.

Table 7 Summary of risk factors of the Thai population for disease prediction models

	Baseline	Mean (SD)*
1.	Prevalence of hypertension (%)	4.0 – 64.9
2.	Prevalence of diabetes mellitus (%)	2.1 – 19.2
3.	Waist circumference (cm.)	76.4 (9.1) – 85.1 (16.8)
4.	Systolic blood pressure (SBP, mmHg)	111.9 (9.5) – 138.4 (29.9)
5.	Current smoking status (%)	11.7 – 22.3
6.	Low Density Lipoprotein-Cholesterol level (LDL-C, mg/dl)	110.0 (12.3) – 125.6 (12.7)
7.	High Density Lipoprotein-Cholesterol level (HDL-C, mg/dl)	47.7 (20.7) – 50.3 (9.4)
8.	Triglyceride level (TG, mg/dl)	102.5 (42.5) – 156.4 (101.7)
9.	Total cholesterol level (mg/dl)	180.8 (30.2) – 205.4 (47.0)

* presenting the highest mean – lowest mean (standard deviation) analysed by age groups and gender

The prevalence of hypertension increased with age from 4% among adults aged 15-29 to 65% among elderly aged above 80 (see **Figure 9**Error! Reference source not found.), with a similar pattern for both male and female. Hypertension was more prevalent in females than in males in older age groups (60 years old and above) and vice versa for the younger age group (15-59 years old).

The total mean prevalence of diabetes among both genders was from 2.1% for adults aged 15-29 years to 19.2% for those aged 60-69 years. In overall, the mean prevalence of diabetes was slightly higher in female than in male, from 2.8% in female aged 15-29 years to 21.9% in those aged 60-69 years, and from 1.5% to 16.1% in male aged 15-29 and 70-79, respectively (see **Figure 10**).

The total mean smoking status among both genders ranged from 11.7% to 22.3%. Smoking prevalence was remarkably higher among male than female, from 21.8% for male aged 80 years and over to 45.8% for male aged 30-44 years. For female, smoking prevalence was not over 5.1% for all age groups. The highest smoking prevalence of male was at age 30-44 years at 45.8% and female aged over 80 years at 5.1% (see **Figure 11**).

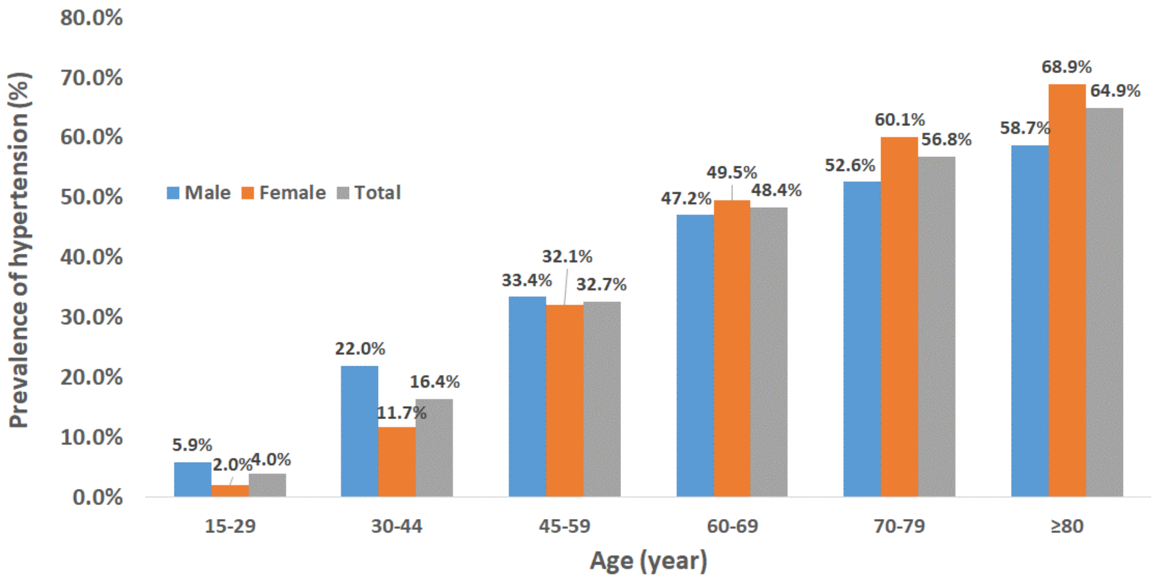


Figure 9 Prevalence of hypertension among adults aged 15 and over, by gender and age

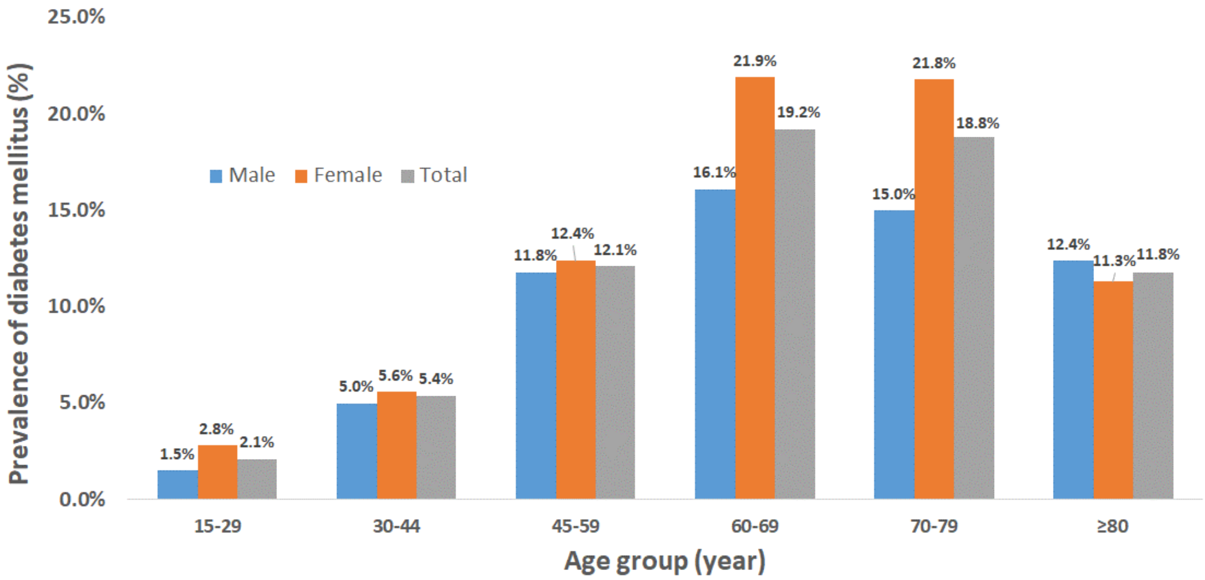


Figure 10 Prevalence of diabetes mellitus among adults aged 15 and over, by gender and age

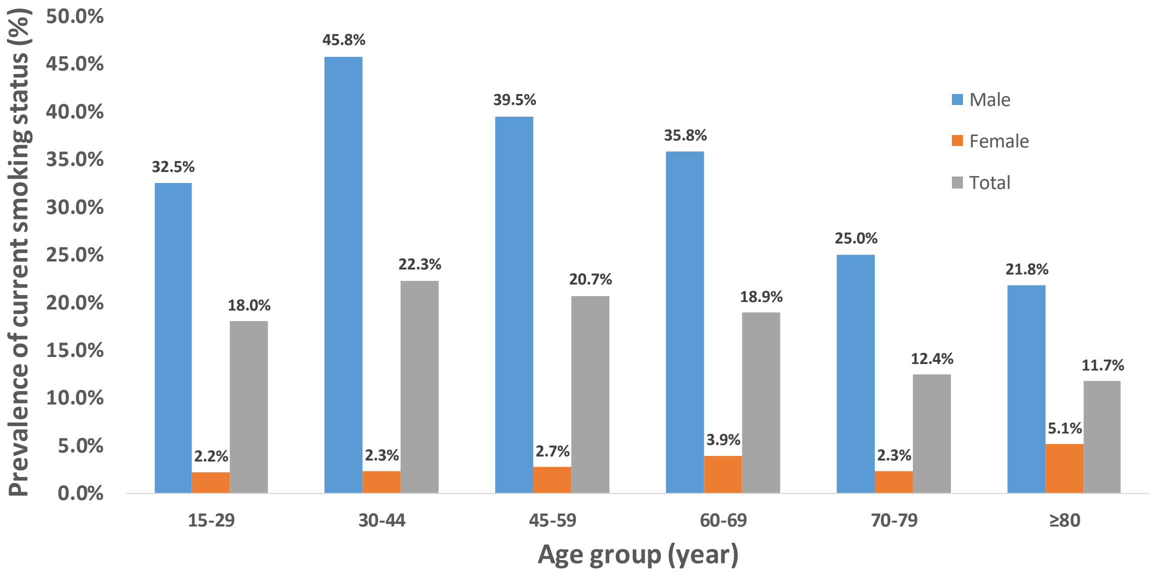


Figure 11 Prevalence of current smoking among adults aged 15 and over, by gender and age

The total mean systolic blood pressure among both genders increased with age, from 111.9 (9.5) mmHg for adults aged 15-29 years to 138.4 (26.8) mmHg for those aged 80 years and over. By gender, the mean systolic blood pressure increased from 116.7 (8.5) mmHg to 138.0 (38.4) mmHg for male, and 106.6 (9.0) mmHg to 138.7 (25.4) cm for female. At aged 15-69 years, the blood pressure of male was slightly higher than female (see **Table 8**).

Table 8 Mean systolic blood pressure among adults aged 15 and over, by gender and age

Systolic blood pressure (mm Hg)									
Age	Male			Female			Total		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
15-29	116.7	8.5	1,199	106.6	9.0	1,438	111.9	9.5	2,637
30-44	123.5	12.3	1,423	114.7	14.2	2,200	118.7	13.9	3,623
45-59	127.7	16.1	2,335	125.2	18.5	3,489	126.4	17.5	5,824
60-69	131.3	28.9	1,907	130.6	28.5	2,457	130.9	28.8	4,364
70-79	133.8	31.2	992	134.3	28.8	1,265	134.1	29.9	2,257
≥80	138.0	28.4	351	138.7	25.4	382	138.4	26.8	733

The total mean waist circumcision among both genders was from 76.4 (9.1) cm for adults aged 15-29 years to 85.1 (16.8) cm for those aged 60-69 years. By gender, the lowest mean waist circumcision was 78.3 (8.7) cm at aged 15-29 years, and the highest mean was 84.8 (9.6) cm at aged 45-59 years for male. For female, the mean waist circumcision ranged from 74.2 (9.3) cm to 85.8 (17.4) cm at aged 15-29 and 60-69 years, respectively. It can be seen that the mean waist circumcision of female was slightly higher than male at aged 60 years and over (see **Table 9**).

Table 9 Mean waist circumcision among adults aged 15 and over, by gender and age

Waist Circumcision (cm)									
	Male			Female			Total		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
15-29	78.3	8.7	1,196	74.2	9.3	1,431	76.4	9.1	2,627
30-44	83.5	9.4	1,422	81.5	11.3	2,196	82.4	10.5	3,618
45-59	84.8	9.6	2,333	84.1	11.8	3,486	84.4	10.7	5,819
60-69	84.2	16	1,898	85.8	17.4	2,457	85.1	16.8	4,355
70-79	82.7	16.3	990	84.3	16.9	1,259	83.6	16.7	2,249
≥80	80.2	14.9	346	81.2	13.5	377	80.8	14.1	723

The total Low-Density Lipoprotein-Cholesterol level (LDL-C) among both genders ranged from 110.00 (13.30) mg/dl to 125.62 (12.76) mg/dl. By gender, the highest LDL-C level of male was 121.46 (8.80) mg/dl at aged 45-59 years which was lower than female of 130.50 (23.44) mg/dl at aged 60-69 years (see **Table 10**).

Table 10 Mean Low Density Lipoprotein-Cholesterol level (mg/dL)* among adults aged 15 and over, by gender and age

Low Density Lipoprotein-Cholesterol level (HDL-C, mg/dl) calculated from Friedewald equation*						
Age	Male		Female		Total	
	Mean	SD	Mean	SD	Mean	SD
15-29	106.48	10.30	113.82	14.64	110.00	12.30
30-44	118.14	4.50	120.50	13.88	119.34	8.00
45-59	121.46	8.80	129.48	18.62	125.62	12.76
60-69	119.02	21.46	130.50	23.44	125.08	23.34
70-79	120.28	26.24	124.12	24.86	122.48	25.58
≥80	112.30	17.76	124.52	24.84	119.62	23.22

** **Calculated from Friedewald equation**: LDL cholesterol (mg/dL) = total cholesterol – HDL cholesterol – (triglycerides/5)*

The total mean cholesterol among both genders ranged from 180.8 (30.2) mg/dl to 205.4 (47.0) mg/dl. By gender, total cholesterol of male was from 176.3 (27.6) mg/dl to 201.6 (42.4) mg/dl which was lower than female, ranging from 185.7 (32.5) mg/dl to 211.5 (72.5) mg/dl. The age group that had the highest total cholesterol was 45-59 years for male, and 60-69 years for female (see **Table 11**).

Table 11 Mean total cholesterol (mg/dL) among adults aged 15 and over, by gender and age

Total cholesterol (mg/dL)									
Age	Male			Female			Total		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
15-29	176.3	27.6	1,101	185.7	32.5	1,308	180.8	30.2	2,409
30-44	199.9	35.8	1,333	195.3	40.2	2,077	197.4	38.4	3,410
45-59	201.6	42.4	2,230	209.0	50.7	3,317	205.4	47.0	5,547
60-69	194.4	66.7	1,847	211.5	72.5	2,360	203.4	71.0	4,207
70-79	195.0	68.3	962	202.8	67.7	1,216	199.4	68.2	2,178
≥80	184.5	56.9	340	199.6	54.2	370	193.6	56.6	710

The total High-Density Lipoprotein-Cholesterol level (HDL-C) among both genders ranged from 47.4 (20.8) mg/dl to 50.3 (9.4) mg/dl. By gender, the highest HDL-C level of male was 47.9 (8.5) mg/dl which was lower than female at 52.9 mg/dl at the same group (15-29 years) (see **Table 12**).

Table 12 Mean High Density Lipoprotein-Cholesterol level (mg/dL) among adults aged 15 and over, by gender and age

High Density Lipoprotein-Cholesterol level (HDL-C, mg/dl)									
Age	Male			Female			Total		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
15-29	47.9	8.5	1,101	52.9	10.1	1,308	50.3	9.4	2,409
30-44	47.1	11.3	1,333	51.3	12.9	2,077	49.4	12.3	3,410
45-59	45.3	12.1	2,230	51.6	14.9	3,317	48.5	13.9	5,547
60-69	45.0	18.9	1,847	49.6	21.8	2,360	47.4	20.8	4,207
70-79	46.7	20.8	962	48.5	20.5	1,216	47.7	20.7	2,178
≥80	47.6	20.1	340	47.7	16.9	370	47.7	18.2	710

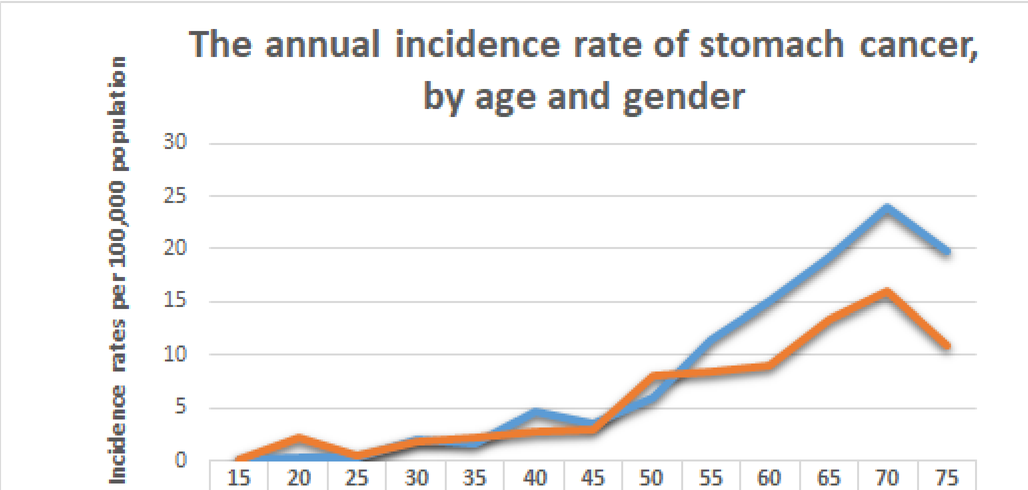
The total triglyceride among both genders ranged from 102.5 (42.5) mg/dl to 156.4 (101.7) mg/dl. By gender, the highest triglyceride level of male was 174.2 (107.5) mg/dl at aged 45-59 years which was lower than female of 157.0 (136.3) mg/dl at aged 60-69 years (see **Table 13**).

Table 13 Mean triglyceride (mg/dL) among adults aged 15 and over, by gender and age

Age	Triglyceride (mg/dL)								
	Male			Female			Total		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
15-29	109.6	44.0	1,101	94.9	38.8	1,308	102.5	42.5	2,409
30-44	173.3	100.0	1,333	117.5	67.1	2,077	143.3	90.5	3,410
45-59	174.2	107.5	2,230	139.6	85.9	3,317	156.4	101.7	5,547
60-69	151.9	131.7	1,847	157.0	136.3	2,360	154.6	134.3	4,207
70-79	140.1	106.3	962	150.9	111.7	1,216	146.1	109.6	2,178
≥80	123.0	95.2	340	136.9	62.3	370	131.4	75.9	710

Stomach cancer

From the cancer registry in Thailand, around 2,853 new cases of stomach cancer were diagnosed each year in Thailand (27). In 2014, the age-standardized incidence rates (ASR) of stomach cancer were 3.56 and 2.82 per 100,000 population, in male and female respectively. The annual incidence rate of stomach cancer increased with age (see **Figure 12**).



	15	20	25	30	35	40	45	50	55	60	65	70	75
Male	0.01	0.20	0.36	2.00	1.58	4.70	3.47	6.01	11.4	15.1	19.1	23.9	19.7
Female	0.00	2.26	0.44	1.72	2.11	2.72	2.95	8.12	8.34	8.99	13.3	15.9	10.8

Figure 12 Annual incidence rate of stomach cancer by age groups and gender

Mortality

General population

Age- and gender-specific mortality data for the Thai general population were obtained from the World Health Organization (WHO) Global Health Observatory (GHO) data repository (2016) (28) and the demographic data was taken from the Department of Provincial Administration, Ministry of Interior, Thailand (2017) (29).

Disease-specific mortality data

Disease-specific mortality data were obtained from Thai literatures (see details in **Table 14**). Annual probability of patient after stroke were from a survival study in Thailand. For annual probability of death after the first stroke were estimated from weighted average of median survival among ischemic stroke and haemorrhagic stroke.

For coronary heart disease, the mortality rate of acute coronary syndrome was taken from the Thai Registry in Acute Coronary Syndrome (TRACS) study and the NHSO database. The TRACS is a multi-centre prospective nation-wide registration for acute coronary syndrome from 39 hospitals in Thailand. It was estimated that the mortality rate was estimated to be 18% after 12-month follow-up. For annual mortality rate, death status among the reported cardiovascular disease cases from the NHSO.

Annual probability of stomach cancer were taken from the survival rate from a survival study conducted using the population-based cancer registry at the Faculty of Medicine, Srinagarind hospital, Khon Kaen University from 2000-2012, with the total follow-up person time was 562.86 person-years (n=650) (30). 5-year relative survival rate was 18.15% (95% CI: 14.32%-22.37%). The survival rate for the first year was 32.67% (95% CI: 28.88% to 36.51%). From year 2 onward, it was estimated that around 13.67% would die from stomach cancer annually, assumed the constant rate over time.

Table 14 Disease mortality, their values and distributions, and sources

Input parameters	Distribution	Values	SE	References
Stroke				
Probability of death after stroke (< 30 day)	Beta	0.2582	0.00	(31)
Median survival time among ischemic stroke in male (months)	Gamma	83	0.51	(31)
Median survival time among ischemic stroke in female (months)	Gamma	79	0.51	(31)

Input parameters	Distribution	Values	SE	References
Median survival time among heamorrhagic stroke in male (months)	Gamma	103	1.28	(31)
Median survival time among heamorrhagic stroke in female (months)	Gamma	97	1.53	(31)
Annual probability of death after surviving first stroke		0.0916		
Coronary heart disease (CHD)				
Probability of death after the first acute coronary syndrome (ACS) per year	Beta	0.1772	0.0001	Srimahachota (2012) TRACS
Mortality rate of coronary heart disease per year (MI, CAD, and CHF)	Beta	0.0829	0.0000	NHSO database
Stomach cancer				
Mortality rate of stomach cancer - year 1	Beta	0.6733	0.0195	(30)
Mortality rate of stomach cancer - year 2 onward	Beta	0.1367	0.0205	(30)

Effectiveness of salt reduction policies

A systematic review and meta-analysis of salt reduction policies were conducted in 2019, following a good practice of the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines in 2009 (32). A PRISMA flow diagram is presented in **Figure 13**. The literature search was conducted from two electronic databases MEDLINE (via Pubmed) and the Cochrane Library, and reference lists of the retrieved studies from the two databases. Search strategies were developed in relation to salt reduction policies, details in **Appendix 1**. The inclusion criteria were 1) clinical studies—including RCTs, empirical observational studies, natural experiments, before-after study design, 2) estimate the effectiveness of any single or combinations of salt reduction policies, 3) reported the effectiveness in terms of salt/sodium intake (g/day or mg/day), sodium level in blood or urine, and blood pressure, and 4) published in English.

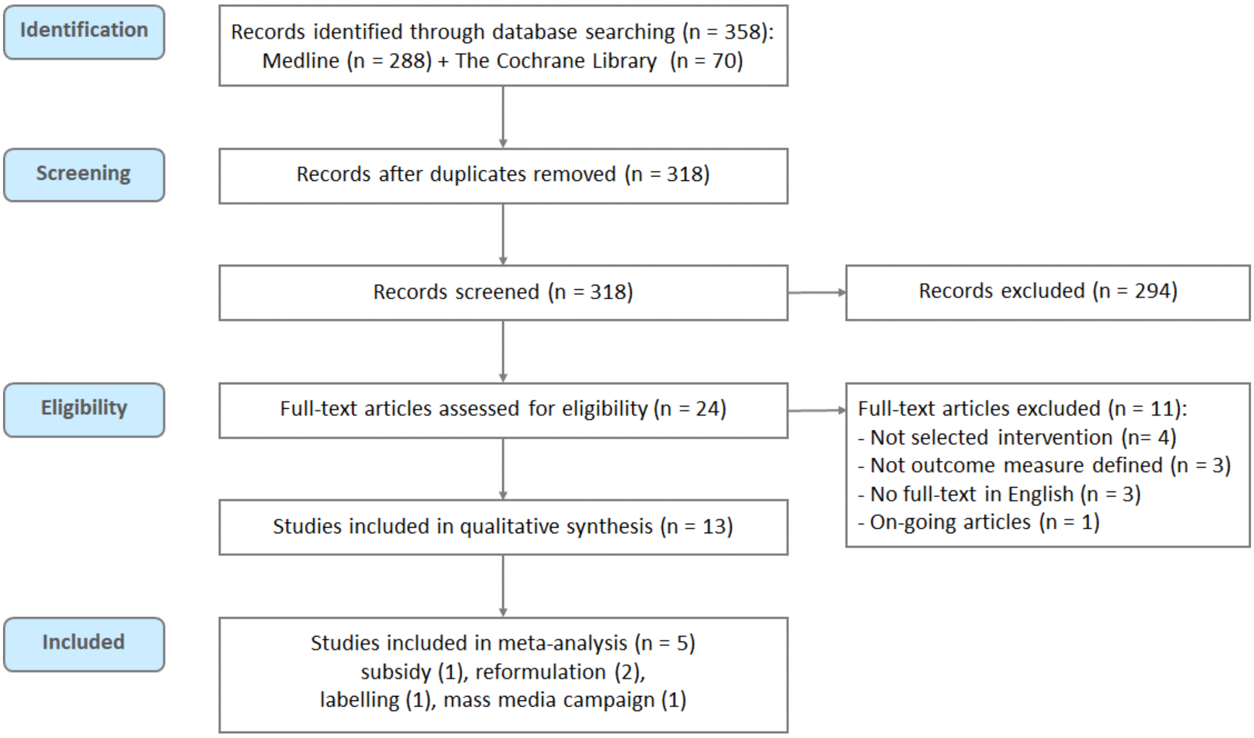


Figure 13 PRISMA flow diagram

A total of 358 citations were identified from MEDLINE and the Cochrane Library. After removed duplicate articles using EndNote^{TM} X8, two reviewers (AP, JP) independently screened titles and abstracts of 318 records for inclusion. The full-text articles of the eligible records were then obtained and reviewed against the inclusion criteria. Any discrepancy during the screening the abstract and reviewing the full-text were resolved through a consensus discussion with a third reviewer (PK). The screening of the abstract excluded 294 studies, with 24 studies eventually being retrieved to review the full-text articles. Data extraction was conducted by two reviewers (AP, JP) independently using data extraction form and discussed to reach a consensus.

There were 13 studies included in the systematic review, including two studies on taxation and subsidy; four studies on nutrition labelling; four studies on food reformulation; and three studies on mass media communication (see summary of included studies in **Appendix 2**). Since the reported outcomes of these studies vary, only studies that reported the difference in systolic blood pressure were included in the meta-analysis. Details of studies included in this analysis are summarised below.

Subsidy

Li, *et al*. (2016) conducted an 18-month cluster-randomized trial in 120 villages to estimate an effectiveness of a community-based sodium reduction by providing price subsidy coupons of salt substitute in combination with community-based health education program in China (33). The study reported that the difference of 24-hr urinary sodium excretion, mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) between 60 villages received the interventions and 59 control villages received no intervention were -14 mmol/day (95% confidence interval (CI) -26 to -1; p = 0.03), -1.1 mmHg systolic (95% CI; -3.3 to +1.1, p = 0.33) and -0.7 mmHg diastolic (-2.2 to +0.8, p = 0.35), respectively.

Food reformulation

There were two RCT studies to estimate the impact of food reformulation on people with elevated blood pressure. Firstly, Charlton, *et al*. (2008) conducted a double-blind controlled trial to assess the impact of a food-based intervention on blood pressure in South Africa (34). The study was undertaken in 80 men and women aged 50-75 years, with drug-treated mild-to-moderate hypertension. The intervention was 8-week provision of six food items with a modified cation content (salt replacement (SOLOTM), bread, margarine, stock cubes, soup mix and a flavour enhancer) and 500 ml of maas (fermented milk)/d. The control diet provided the same quantities of the targeted foods. The study reported that the mean systolic blood pressure in intervention group was a significant reduction of 6.19 mmHg (95% CI: -0.94 to -11.44). The largest intervention effect in 24-hour blood pressure was for wake systolic blood pressure with a reduction of 5.1 mmHg (95 % CI 0.4 to 9.9).

Secondly, a 5-week randomized crossover trial to investigate the effectiveness of bread reformulation was conducted in Republic of Ireland by Cashman *et al.* (2019) (35). Among 97 adults with mildly to moderately elevated blood pressure, mean systolic blood pressure in reduced-salt salt white and brown pan breads with no-salt margarine (0.3 g salt/100 g) compared with usual-salt diet (1.2 g salt/ 100 g) group was significantly reduced -3.3 mmHg (p < 0.0001) but there was no significant change of diastolic blood pressure (p = 0.81) and urinary sodium excretion (p > 0.12). **Figure 14** depicts the forest plot of the two study.

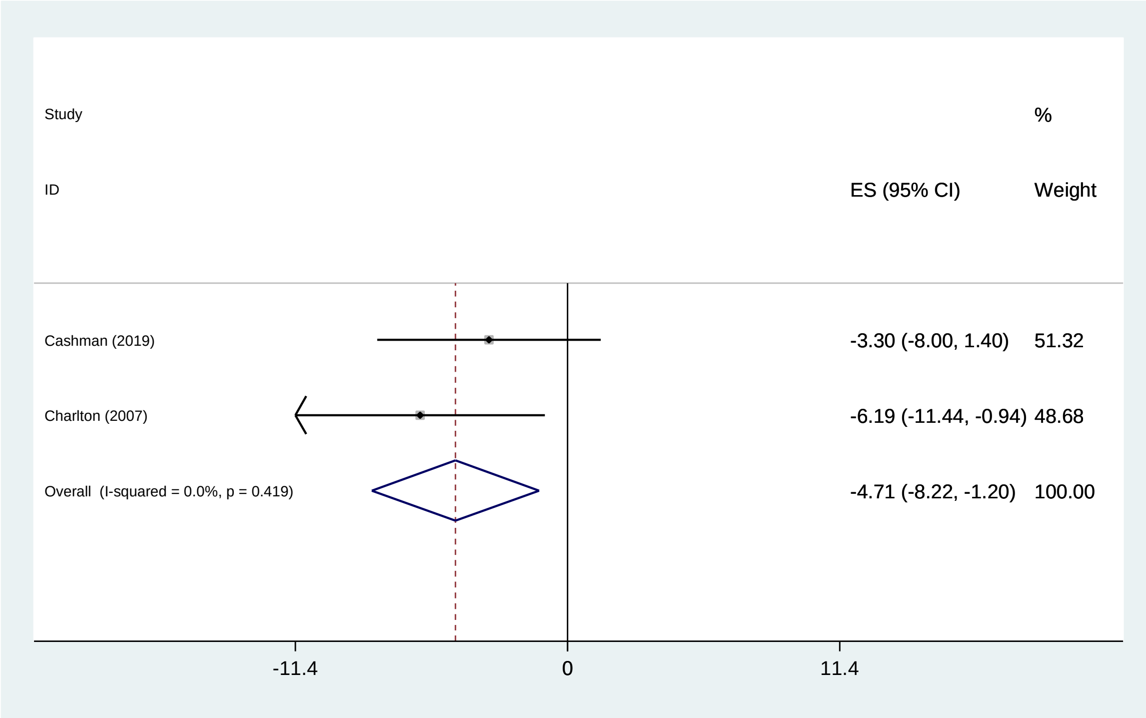


Figure 14 Forest plot diagram of a reduction in systolic blood pressure among food reformulation studies

Estimate effectiveness of voluntary food reformulation

Food manufacturers in Thailand have been encouraged by the Thai government to reformulate their product to contain less sodium. For the products that meets the criteria are awarded with "healthier choice" logo on their products. An analysis from Neilson (Thailand) retail index in 2019, it was estimated that 17.6% of the total sales of instant noodles in Thailand are registered as "healthier choice" products[4]. The proportion of sales of healthier logo products increased from 2018 (14.5%), therefore, the sale growth of healthier logo instant noodles was 29% compared to the overall sale growth of 6%. Therefore, the effectiveness of voluntary reformulation was calculated from the effectiveness of mandatory reformulation adjusted with market share of healthier logo products in 2019.

[4] Healthier logo products (http://healthierlogo.com/), update December 2019

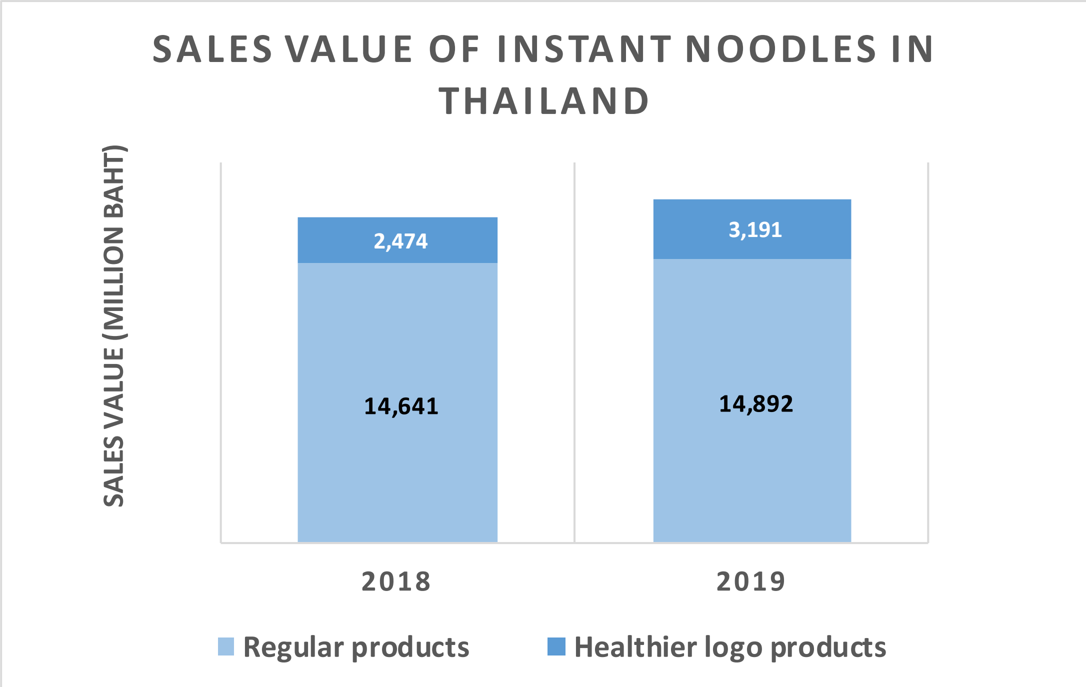


Figure 15 Sales value of instant noodles in Thailand from 2018 to 2019

Nutrition labelling

A 6-week, two-arm, parallel, randomized controlled trial in New Zealand was conducted to determine the effectiveness of SaltSwitch smartphone application to make lower salt food choices in 66 adults with diagnosed cardiovascular disease (36). The application can scan the barcode of a packaged food and receive an immediate, interpretive, traffic light nutrition label on the screen, along with suggestions for lower salt alternatives. The study reported that systolic blood pressure at follow-up in the intervention group was 129 mmHg (95% CI, 125 to 133). The corresponding value for participants in the control was 131 mmHg (95% CI, 127 to 135) mmHg. The mean difference between groups was not statistically significant (-1.7 mmHg, 95% CI: -7.4 to 3.9 mmHg; p = 0.54).

Mass media campaign and health communication

The evaluation of effectiveness of mass media campaign (the Communication for Behavioral Impact (COMBI)–Eat Less Salt) in Vietnam with adults aged 25 to 64 years living within the wards and communes of Viet Tri city was conducted by Do *et al.* (2016) (37). A repeat cross-sectional study design at baseline and 12-month period of intervention was used to assess an integrated mix of 4 communication action areas: mass media communication (TV, Film, radio program, newsletter); school-based programme; community-based programmes; targeting programme for high-risk (hypertension) groups. The study reported that the mean systolic blood pressure and diastolic blood pressure were significantly lower following the intervention. The net reductions in systolic blood pressure and diastolic blood pressure were 5.93 mmHg (95% CI 8.03 to 3.83; P<0.001) and 4.86 mmHg (95% CI, 6.21 to 3.51; P<0.001), respectively.

Taxation

There is no clinical study to estimate the effect of sodium taxation on health outcomes such as blood pressure. From a systematic review of the effectiveness of food taxes and subsidies (38), there is an economic evaluation study that applied the effect of excise tax on sodium used in commercial food production. When the price of salty food increased by 40%, it would reduce sodium consumption by 6% (range, 1.2% to 21.6%) (39).

A more recent experiment on effects of sodium tax was conducted by using a virtual supermarket, with shoppers randomly assigned to varying price sets of products with different tax and subsidy options (40). Price ExaM study was a five-week randomised experiment to observe the effect of food price changes on consumer purchases in New Zealand virtual supermarket. A systematic 4,258 price variation for foods and beverages to represent five taxes and subsidies scenarios—including sweetened beverage and carbonated drink tax, fruit and vegetable subsidy, saturated fat tax, sugar tax, and salt tax—were weekly assigned to 1,132 adult shoppers in 5 online virtual supermarkets. For sodium tax, $0.02 per 100 mg sodium or $0.04 per 100 mg sodium price sets were applied in this experiment. The result suggested that the percentage changes of total sodium weight for salt tax policy were -20.0% (95%CI: -27.3 to -13.2) compared with control group. A dose-response effect was also observed in the higher salt tax (mean difference of -12.05 g compared to the control group, 95% CI: -16.16 to -7.93) compared to the lower rate (mean difference of -9.32 g compared to the control group, 95% CI: -13.54 to -5.10).

In September 2011, Hungary introduced the "Public Health Product Tax" at a rate of 130 Forint (13 THB) per kg of pre-packaged sugary/salty products. An impact assessment reported that higher prices of salty snacks was the reason for people decision to change their consumption. In 2012, one year after the introduction of this policy, 81% of the respondents reported that increase prices were the reason while only 56% of the respondents reported as the reason in 2014. However, the report suggested that Hungarian people learn that salty snacks are unhealthy and therefore change their consumption (50% of the respondents reported as the reason for decreasing consumption).

In Thailand, there is an initiation to prepare for taxation policy and no tax policy is imposed on food with high sodium content in 2019. Sodium taxation policy is planned to be imposed on pre-packed food and snacks which accounted to only one-third of the food consumption among the Thai population (one-third from home cook and one-third from food stall/restaurant). Moreover, around 17% to 70% and 39% to 73% of the Thai population consumed snack and packaged food (see "Food consumption behaviour" section). The estimated effect of sodium tax was based on an additive effect from taxation from Hungarian assessment of the impact of a public health product, voluntary food reformulation, and mass media. **Figure 16** presented the summary of the reductions in systolic blood pressure resulting from each policy implementation.

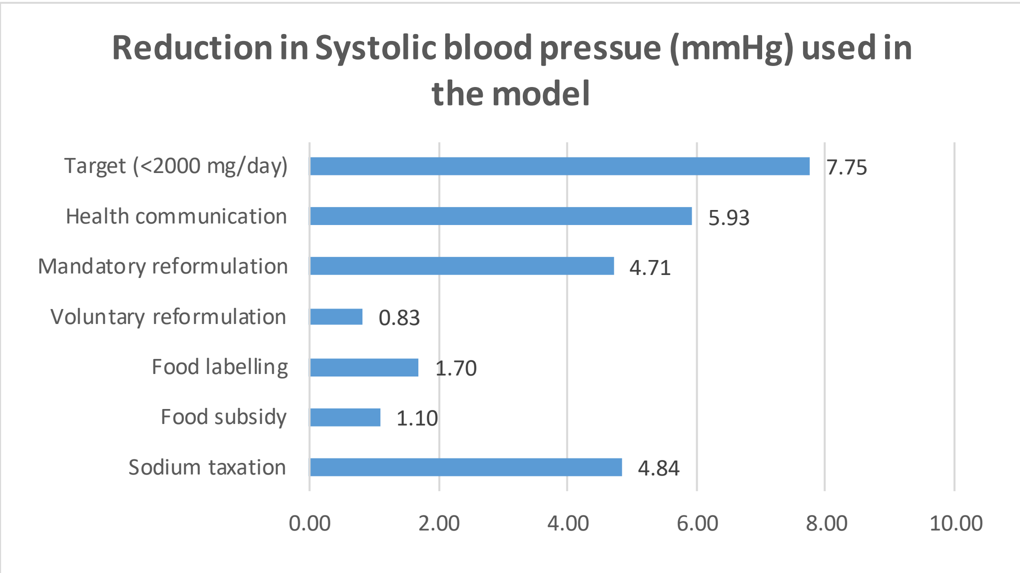


Figure 16 Estimated effect of sodium reduction policy on systolic blood pressure (mmHg)

Reduction in disease events

The reduction in salt intake lead to the reduction of disease events. A recent meta-analysis of 19 studies suggested that high sodium intake associated with an increased risk of stroke (risk ratio 1.24, 95% CI: 1.08 to 1.43, I^2 = 49), though the result for coronary heart disease were inconclusive (risk ratio 1.04, 95% CI: 0.86 to 1.24, I^2 = 68) (6). Fang *et al.* (2015) (14) reported the association between stomach cancer and excess dietary salt (risk ratio 1.11, 95% CI: 1.05 to 1.16, I^2 = 26).

Cost measurement

Cost parameters included the cost of policies to reduce sodium intake, healthcare costs for sodium-related diseases, and direct non-medical costs. All cost parameters were converted in 2019 values by using consumer price index (CPI), and presented in Thai baht (THB), implied PPP conversion rate (1I$ = 12.24 THB)[5].

Cost of salt reduction policies

The costs of implementing nutrition labelling, mass media and reformulation were derived from a previous study conducted by the Food and Nutrition Policy for Health Promotion Program (FHP), Thailand in 2018 (23). This study evaluated the effectiveness and cost-effectiveness of five population-based interventions to reduce dietary sodium intake under recommendation by the SHAKE package. Costs of policy implementation were classified into four categories: human resource, media, material and procedure (see detail in **Table 15**). The cost of taxation was estimated using the number of meeting preparation and the human resources that contribute to the preparation of sodium taxation among the Salt Network in Thailand. From the analysis, the cost of taxation was applied for two years since there will be no extra costs from the Excise department. The average annual cost of policy implementation was used in the model (**Table 16**). Costs of all policies was estimated to affect 49.3 million Thai population.

Direct medical costs

Direct medical costs (costs related to medical care, including rehabilitation) for sodium-related diseases were analysed using health administrative databases of the National Health Security Office (NHSO). The data included all hospital charges, number of in-patient admissions, and out-patient visits from 1 January 2018 to 31 December 2018, of sodium-related diseases classified by International Classification of Diseases (ICD) 10 (see **Appendix 4**). Only primary diagnosis cases of the selected ICD-10 were included in the analysis. The ratios of costs-to-charges (RCCs) of 1.63 and 1.43 were used to adjust the charges reported from tertiary/secondary hospitals and primary hospitals, respectively. The average cost of

[5] https://www.imf.org/external/datamapper/PPPEX@WEO/OEMDC/ADVEC/WEOWORLD/THA

medical care per out-patient visit and in-patient admission and the average number of out-patient visit and in-patient admission per person per year are presented in **Table 16**.

Direct non-medical costs

Direct non-medical costs including additional costs of transportation and food expenditure and informal care by relatives were calculated based on the unit costs and time loss from the Standard cost lists for health technology assessment in Thailand (41). For income loss of relatives, the gross national income (GNI) per capita of 218,200 Baht was used to estimate the income loss per hour (see **Table 16**).

Table 15 Cost of salt reduction policies in Thailand

Policy measures	Costs of policy implementation by years				
Nutrition labelling	**2013**	**2014**	**2015**	**2016**	**2017**
Human resource	180,000	180,000	780,000	948,000	720,000
Media	0	0	290,000	800,000	679,000
Material	0	0	151,800	210,000	250,000
Procedure	1,600,000	1,400,000	4,848,200	8,003,700	13,318,900
Total	**1,780,000**	**1,580,000**	**6,070,000**	**9,961,700**	**14,967,900**
Mass media	**2013**	**2014**	**2015**	**2016**	**2017**
Human resource	0	0	0	0	1,210,776
Media	0	0	0	60,000	2,130,000
Material	0	0	101,800	180,000	220,000
Procedure	0	0	0	4,000,000	1,149,600
Total	**0**	**0**	**101,800**	**4,240,000**	**4,710,376**
Reformulation	**2013**	**2014**	**2015**	**2016**	**2017**
Human resource	50,000	37,500	365,000	438,000	373,690
Media	0	0	30,000	5,000	0
Material	0	47,500	231,000	233,000	267,800
Procedure	950,000	665,000	554,000	0	1,060,650
Total	**1,000,000**	**750,000**	**1,180,000**	**676,000**	**1,702,140**

Table 16 Input cost parameters, their values and distributions, and sources

Parameters	Distribution	Mean	SE	References
Cost of salt reduction polices				
Annual cost of nutrition labelling policy	Gamma	7,024,218	2,591,465	(23)
Annual cost of mass media policy	Gamma	3,080,717	1,493,781	(23)
Annual cost of food reformulation policy	Gamma	1,087,069	186,430	(23)
Annual cost of taxation	n/a	1,521,600	-	Data collection
Direct medical costs				
Average cost of medical care per one out-patient visit				
Hypertension	Gamma	1,554	10	Analysis from the e-claim database, NHSO
Ischemic heart disease (IHD) or coronary artery disease (CAD)	Gamma	3,664	124	
Heart failure	Gamma	2,397	90	
Cardiac arrest	Gamma	6,624	2,027	
Myocardial infarction	Gamma	4,737	438	
Cerebrovascular disease	Gamma	2,770	83	
Transient ischaemic attack	Gamma	2,259	78	
Stomach cancer	Gamma	4,452	192	
Chronic kidney disease	Gamma	2,663	31	
End-stage renal disease (ESRD): continuous ambulatory peritoneal dialysis (CAPD)	Gamma	2,268	422	Analysis from the CKD DMIS database, NHSO
ESRD: haemodialysis (HD)	Gamma	1,516	58	
Kidney transplant & follow-up	Gamma	44,734	1,589	
Transplant patients who required immunosuppressive drug	Gamma	16,773	4,154	
Average cost of medical care per one in-patient admission				
Hypertension	Gamma	7,083	165	Analysis from the e-claim database, NHSO
IHD or CAD	Gamma	74,246	1,347	
Heart failure	Gamma	20,622	206	
Cardiac arrest	Gamma	37,838	4,778	
Myocardial infarction	Gamma	56,113	726	
Cerebrovascular disease	Gamma	37,542	534	
Transient ischaemic attack	Gamma	8,587	60	
Stomach cancer	Gamma	39,542	551	
Chronic kidney disease	Gamma	10,552	44	
ESRD	Gamma	14,090	73	

Parameters	Distribution	Mean	SE	References
Average number of out-patient visit per person per year				
Hypertension	Gamma	3.02	0.015	Analysis from the e-claim database, NHSO
IHD or CAD	Gamma	2.69	0.093	
Heart failure	Gamma	1.96	0.105	
Cardiac arrest	Gamma	1.00	0.001	
Myocardial infarction	Gamma	1.73	0.128	
Cerebrovascular disease	Gamma	2.62	0.099	
Transient ischaemic attack	Gamma	2.10	0.070	
Stomach cancer	Gamma	4.50	1.692	
Chronic kidney disease	Gamma	3.08	0.194	
ESRD: CAPD	Gamma	11.64	1.09	Analysis from the CKD DMIS database, NHSO
ESRD: HD	Gamma	98.40	83.77	
Kidney transplant & follow-up per visit	Gamma	2.07	0.15	
Transplant patients who required immunosuppressive drug	Gamma	10.75	2.75	
Average number of admission per person per year				
Hypertension	Gamma	1.09	0.0018	Analysis from the e-claim database, NHSO
IHD or CAD	Gamma	1.15	0.0032	
Heart failure	Gamma	1.24	0.0036	
Cardiac arrest	Gamma	1.01	0.0010	
Myocardial infarction	Gamma	1.16	0.0026	
Cerebrovascular disease	Gamma	1.08	0.0011	
Transient ischaemic attack	Gamma	1.06	0.0007	
Stomach cancer	Gamma	2.29	0.0847	
Chronic kidney disease	Gamma	1.21	0.0029	
End-stage renal disease	Gamma	1.86	0.0111	
Duration of admission per person				
Hypertension	Gamma	2.74	0.07	Analysis from the e-claim database, NHSO
IHD or CAD	Gamma	4.19	0.11	
Heart failure	Gamma	5.01	0.05	
Cardiac arrest	Gamma	6.41	1.34	
Myocardial infarction	Gamma	5.74	0.07	
Cerebrovascular disease	Gamma	6.33	0.12	
Transient ischaemic attack	Gamma	2.07	0.02	
Stomach cancer	Gamma	6.87	0.12	
Chronic kidney disease	Gamma	2.37	0.03	
End-stage renal disease	Gamma	3.60	0.02	

Parameters	Distribution	Mean	SE	References
Direct non-medical costs				
Travel cost	Gamma	154.20	12.55	Costing menu
Food cost	Gamma	67.22	6.85	
Time loss for one OPD visit (minutes)	Gamma	361.00	7.91	
Income loss of relatives (per hour)	n/a	87	-	*

* Calculate from the gross national income (GNI) per capita of 218,200 Baht (IMF Chain Volume Measures, 2017) divide by 52 weeks per year and 48 hours a week

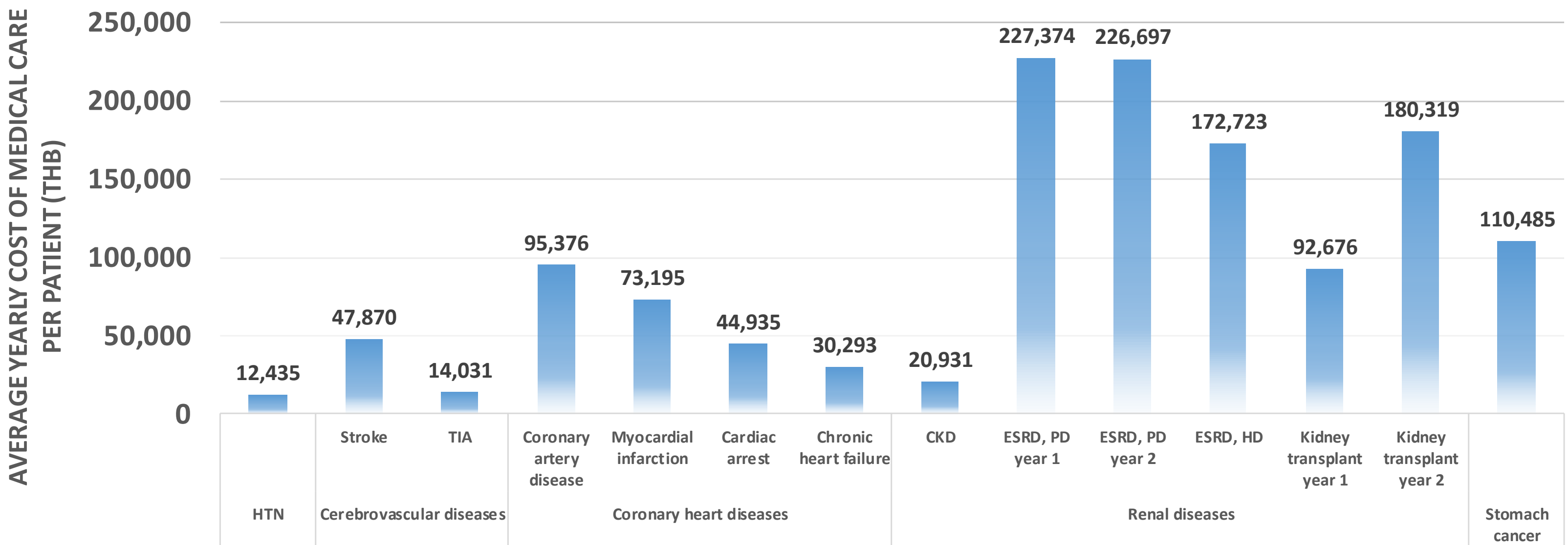


Figure 17 Average direct medical cost per patient per year

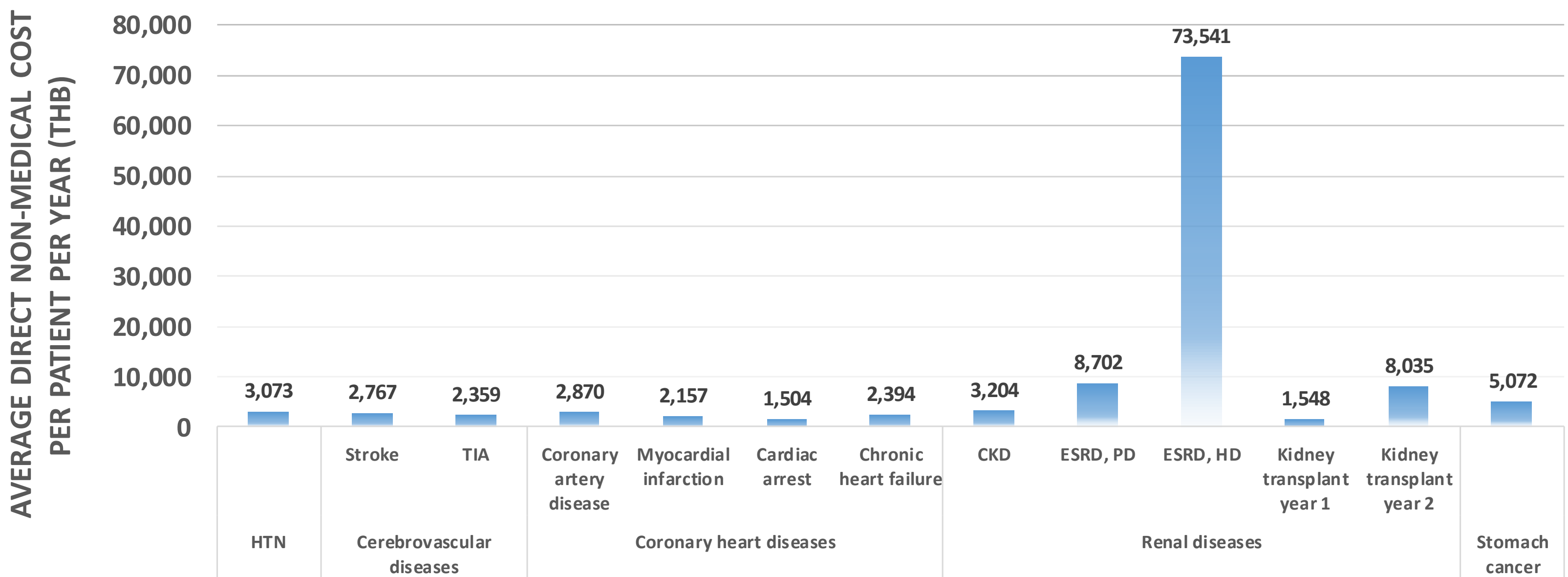


Figure 18 Average direct non-medical cost per patient per year

Utility

Population norm utility values

Health-related quality of life of the Thai population was based on data collected from the national survey among 1,207 Thai participants, using EQ-5D-5L (42). The EQ-5D-5L instrument describes health in five different dimensions (mobility, self-care, usual activities, pain and discomfort, anxiety and depression), each with five possible levels (no problems, slight problems, moderate problems, severe problems, unable to/extreme problems) (43). The Thai value set was based on the coefficients generated from a hybrid model (42). The utility-based on age and gender was then analysed using BETAMIX model (STATA 14). The expected utility that was used for the general population by age and gender are depicted in **Figure 19**, see detail in **Appendix 5**. The utility values decrease with age and the higher value was observed in female compared to male.

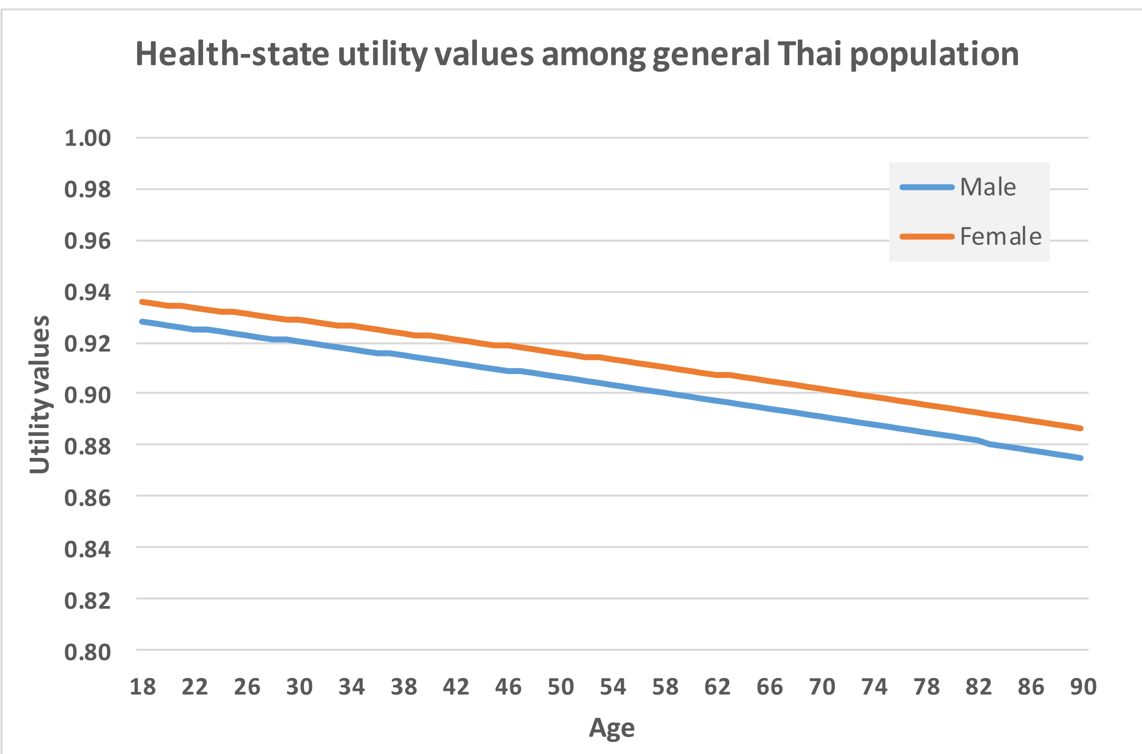


Figure 19 Health-state utility values among general Thai population by age and gender

Disease-specific utility

A literature review of studies that reported the use of EQ-5D (either EQ-5D-3L or EQ-5D-5L) was conducted in MEDLINE (PubMed) and the Thai HTA database (http://db.hitap.net/). The key word search was ((((("Quality of Life"[Mesh]) OR "health utility"[Title/Abstract]) OR "health utilities" [Title/Abstract])) AND ((utility[Title/Abstract]) OR EuroQol[Title/Abstract]))) AND ((thai[Title/Abstract]) OR thailand[Title/Abstract]) in October 2019. The inclusion criteria were studies that measure health-related quality of life using EQ-5D (either EQ-5D-3L or EQ-5D-5L) among Thai sample in the following diseases, cardiovascular disease, chronic kidney diseases, and stomach cancer with similar participant characteristics. Forty-one literature were identified from MEDLINE (PubMed) and 449 citations were identified from the Thai HTA database.

There were 8 studies included in the model. For health state utility of diseases that presented in more than one study, a meta-analysis of utility scores was conducted using STATA. The pooled mean of studies reporting EQ-5D utility estimates for end-stage renal disease patients receiving peritoneal dialysis and haemodialysis are presented in **Figure 20** and **Figure 21**, respectively. Utility decrement values for persons with previous history of heart disease, stroke, and chronic kidney disease were calculated from subtracting the utility value of person with the disease from the utility value of person without the disease. It was assumed that the utility values for patients with hypertension equal to the utility values of the general Thai population since there is no significant difference in the quality of life among patient with or without hypertension (44). **Table 17** summarises all the utility values used in this study.

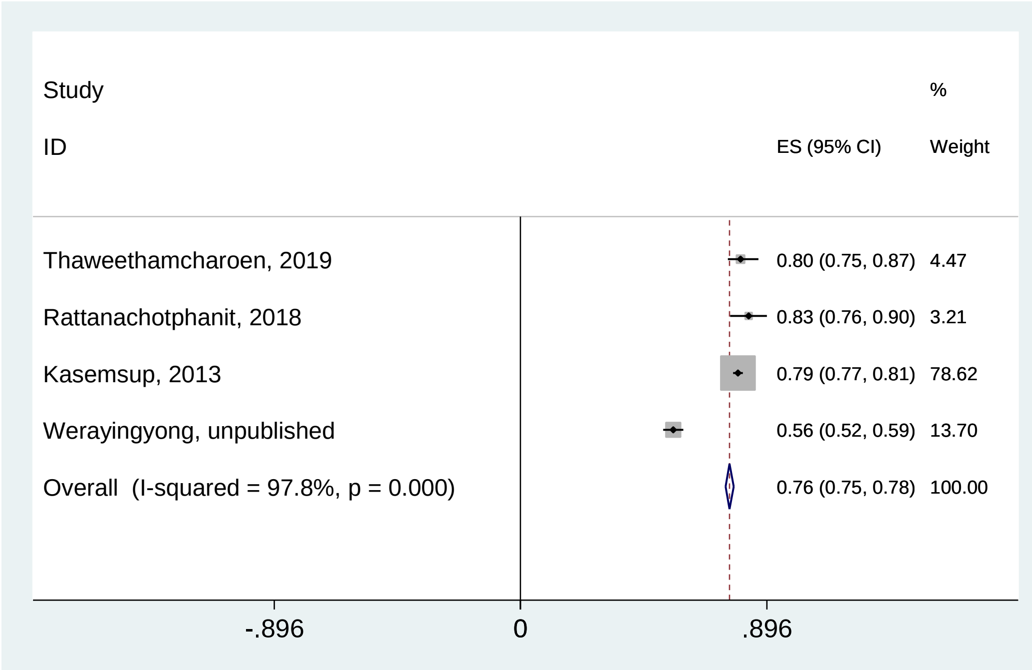


Figure 20 Forest plots of pooled mean (95% CI) of studies reporting EQ-5D utility estimates among end-stage renal disease patients receiving peritoneal dialysis.

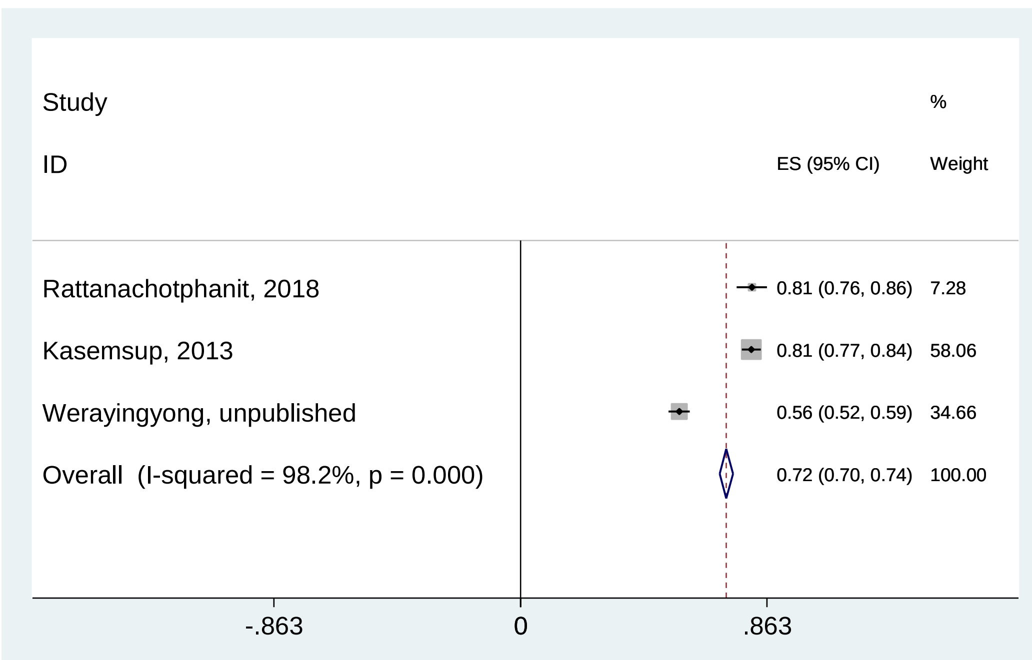


Figure 21 Forest plots of pooled mean (95% CI) of studies reporting EQ-5D utility estimates among end-stage renal disease patients receiving haemodialysis.

Table 17 Input utility values, their values and distributions, and sources

Parameters	Distribution	Mean	SE	References
Patients with hypertension	*assume to be equal to general population (44)*			
Stroke patients (n=28, EQ-5D-3L)	Beta	0.7000	0.0076	(45)
Person without stroke medical history (n=4631, EQ-5D-3L)	Beta	0.8420	0.0025	(46)
Person with stroke medical history (n=58, EQ-5D-3L)	Beta	0.7730	0.0274	(46)
Person without Coronary heart disease medical history (n=4617, EQ-5D-3L)	Beta	0.8420	0.0025	(46)
Person with Coronary heart disease medical history (n=72, EQ-5D-3L)	Beta	0.8060	0.0227	(46)
Person without CKD medical history (n=4624, EQ-5D-3L)	Beta	0.8420	0.0025	(46)
Person with CKD medical history (n=65, EQ-5D-3L)	Beta	0.7950	0.0216	(46)
ESRD patients receiving peritoneal dialysis (meta-analysis, n = 1,431)	Beta	0.7600	0.0079	(47-50)
ESRD patients receiving haemodialysis (meta-analysis, n = 577)	Beta	0.7200	0.0102	(47, 49, 50)
ESRD patients receiving kidney transplant	Beta	0.9850	0.0125	(50)
Stomach cancer	Beta	0.4700	0.0300	(51)

CKD: Chronic Kidney Disease; **ESRD** End-stage renal disease

Model assumptions

There was a number of model assumption in this study. First, the population cohort can only develop one disease over their lifetime. Second, voluntary measures such as food reformulation would not achieve 100% compliance across food industry. From the policy implementing for the past year for food reformulation, it showed that only 18% of the total sales of instant noodles market were reformulated for sodium content.

Data analysis and presentation of results

The incremental cost-effectiveness ratio (ICER) of each policy option was calculated based on the incremental cost and incremental QALY of each policy option compared to 'current situation'. The results were presented using the cost-effectiveness plane where the x-axis is incremental QALYs and the y-axis is incremental costs. The cost-effectiveness threshold of 160,000 THB per QALY gained was used as the threshold to determine the value for money of each policy option as recommended by the Subcommittee for Development of Benefits Package and Service Delivery, the National Health Security Office (NHSO).

A one-way sensitivity analysis and a probabilistic sensitivity analysis (PSA) were performed to determine the uncertainty of model parameters. The discount rate of 0 – 6% was used to observe any changes in the conclusion of results as recommended in the Thai health technology assessment guideline. For one-way sensitivity analysis, each parameter was varied at a time across the plausible range and shown graphically as a tornado diagram.

PSA was conducted to examine the effect of all parameter uncertainty simultaneously using a Monte Carlo simulation using Microsoft Excel 2016 (Microsoft Corp., Redmond, WA). The simulation was run for 1,000 iterations to yield a range of possible values for total costs, health outcomes, and incremental cost-effectiveness ratios (ICERs) in THB per QALY gained. The probability distributions were determined according to the range of each input parameter value. The normal distribution was used as a default. The beta distribution was used when parameter values ranged between zero and one, such as in probability and utility parameters. The gamma distribution was used when parameter values ranged between zero and positive infinity, such as costs parameters. The results of PSA were presented by a cost-effectiveness plans and acceptability curves.

Results

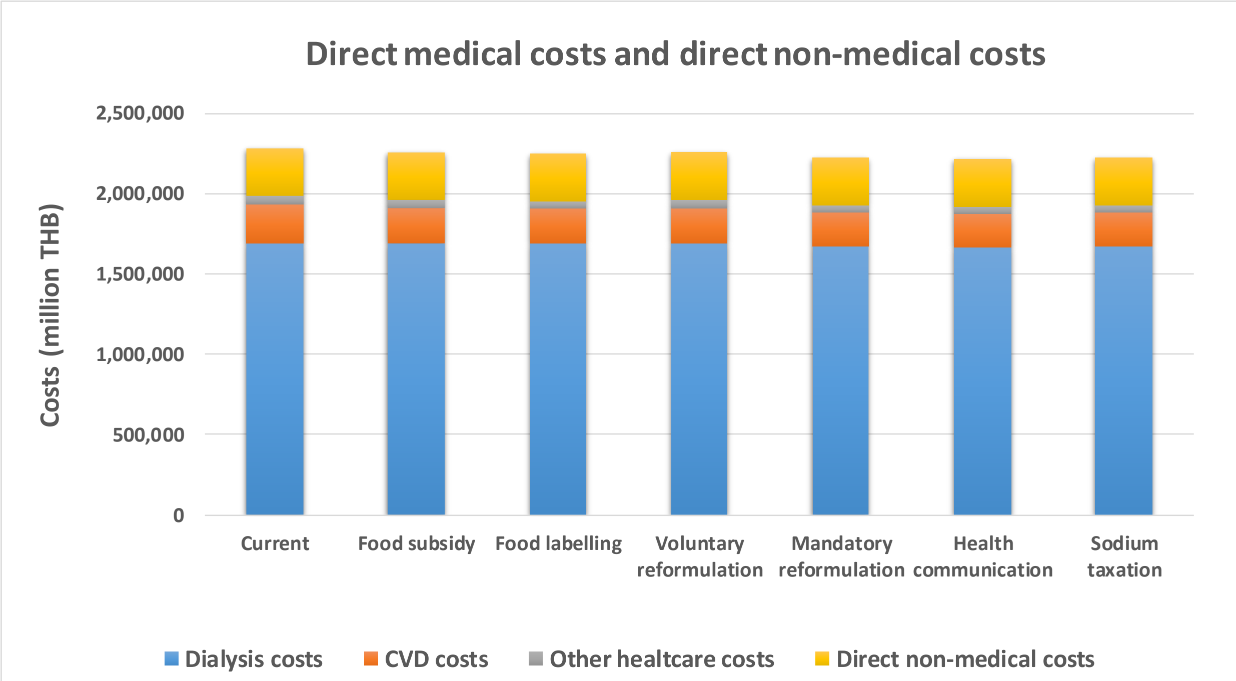
Cost

For the current situation, the total costs of sodium-related diseases—including direct medical cost and direct non-medical cost—was estimated to be around 2.28 billion THB over a 10-year period. Around 87% of the total cost was healthcare costs for sodium-related diseases and 13% contributed to the direct non-medical costs. The costs of sodium control policies ranged from 3 to 62 million THB for 10-year policy implementation (**Table 18**). The costs of policy interventions have a very small fraction compared to direct medical costs and direct non-medical costs. Considered by disease groups, the large proportion of healthcare costs are due to costs associated with treatment for chronic kidney disease patients (76%) (**Figure 22**). Therefore, the net benefit of these policies is around 27,000 to 71,000 million THB (**Figure 23**).

Table 18 Total costs of policy intervention and healthcare costs (10-year population cohort)

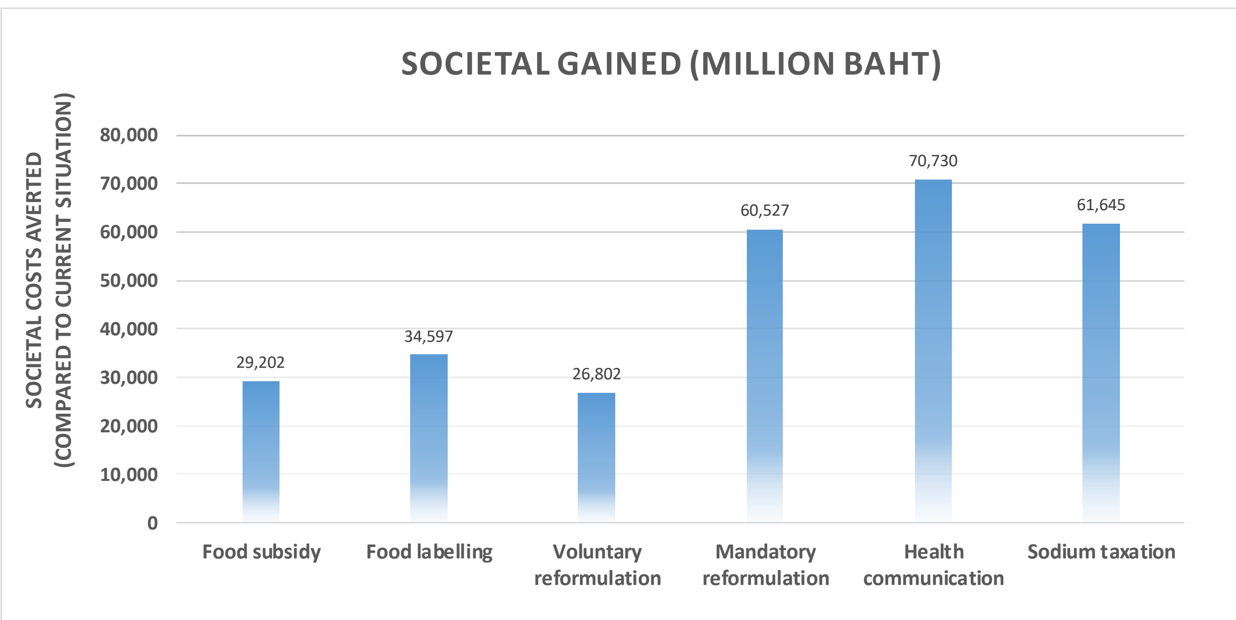
Dietary sodium intake control policy	Policy cost (million THB)	Direct medical cost (million THB)	Direct non-medical cost (million THB)	Net cost (million THB)
Current situation	-	1,985,577	297,549	2,283,126
Food subsidy	-	1,958,470	295,455	2,253,924
Nutrition labelling	62	1,953,681	294,910	2,248,652
Voluntary reformulation	10	1,960,633	295,700	2,256,343
Mandatory reformulation	10	1,930,346	292,263	2,222,618
Health communication	27	1,921,196	291,227	2,212,450
Sodium taxation	3	1,929,336	292,148	2,221,487
Incremental to the current situation				
Food subsidy	-	-27,107	-2,095	-29,202
Nutrition labelling	62	-31,896	-2,639	-34,474
Voluntary reformulation	10	-24,944	-1,849	-26,783
Mandatory reformulation	10	-55,231	-5,287	-60,508
Health communication	27	-64,380	-6,323	-70,676
Sodium taxation	3	-56,241	-5,401	-61,639

Note: Costs (million THB), discounted at 3% per annum



Estimated from population cohort over 10 years

Figure 22 Breakdown costs of healthcare by diseases and direct non-medical costs



Estimated from an annual average of population cohort over 10 years

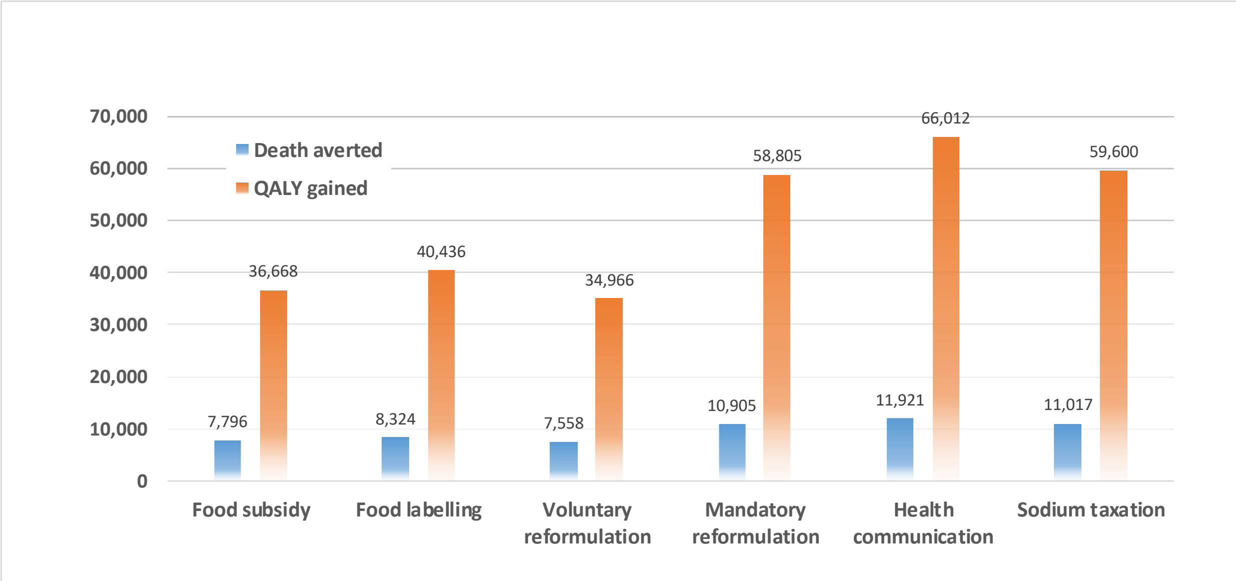
Figure 23 Societal gained from each sodium control policy per year

Health outcomes

For the current situation, the total deaths of sodium-related diseases were estimated to be 748,956 deaths over a 10-year period. The reduction of one unit of systolic blood pressure among the Thai population can averted 77,519 deaths from cardiovascular diseases, chronic kidney diseases and stomach cancer over a 10-year period. Sodium reduction policies are estimated to avert 75,578 to 119,208 deaths resulting in a population QALY gained of 349,664 to 660,121 QALY over a 10-year period. Health communication, mandatory reformulation and sodium taxation averted more death and gained more QALY compared to the other three policies, details in **Figure 25**.

Table 19 Total sodium-related deaths and QALY among 10-year population cohort among policy intervention

Dietary sodium intake control policy	Sodium related Deaths	QALY
Current situation (baseline)	748,956	279,045,579
Food subsidy	670,994	279,412,259
Nutrition labelling	665,712	279,449,940
Voluntary reformulation	673,378	279,395,243
Mandatory reformulation	639,903	279,633,628
Health communication	629,748	279,705,700
Sodium taxation	638,783	279,641,584
Incremental to the current situation		
Food subsidy	-77,962	366,680
Nutrition labelling	-83,244	404,361
Voluntary reformulation	-75,578	349,664
Mandatory reformulation	-109,053	588,049
Health communication	-119,208	660,121
Sodium taxation	-110,173	596,005



Estimated from an annual average of population cohort over 10 years

Figure 24 Death averted and quality-adjusted life-year (QALY) gained from each sodium reduction policy per year

Cost-effectiveness analysis

All sodium reduction policies are dominants (with lower costs and greater health outcomes) compared to the current situation. When considering the effect of sodium reduction policies for individuals by age group and gender, on average, sodium reduction policies saved 1,103 up to 12,420 THB per person and increase health outcomes 0.0247 to 0.1381 QALY. These policies are more beneficial to male compared to females. The benefit in terms of cost-saving and QALY gained increases as the age increases until 50-year old cohort, then the estimated benefit reduced with age (see details in **Table 20**). When considering the effect of sodium reduction policies for the Thai population cohort aged between 30 and 85 years old, the incremental costs ranged from -26,783 to -70,676 million THB and the health benefits ranged from 349,664 to 660,121 QALY gained (**Figure 25**).

Table 20 Incremental cost and incremental quality-adjusted life-year (QALY) comparing sodium reduction policies to the current situation, by gender and age groups

Sodium reduction policies	Female		Male	
	Inc. cost (THB)	Inc. QALY	Inc. cost (THB)	Inc. QALY
Age 30				
Subsidy	-1,927	0.0288	-2,570	0.0427
Label	-2,888	0.0381	-3,820	0.0548
Voluntary reformulation	-1,492	0.0246	-2,006	0.0372
Mandatory reformulation	-7,597	0.0837	-9,976	0.1144
Health communication	-9,452	0.1018	-12,416	0.1381
Tax	-7,802	0.0857	-10,245	0.1170
Age 40				
Subsidy	-2,080	0.0367	-2,588	0.0488
Label	-3,083	0.0458	-3,817	0.0595
Voluntary reformulation	-1,627	0.0325	-2,034	0.0439
Mandatory reformulation	-8,007	0.0908	-9,879	0.1127
Health communication	-9,949	0.1086	-12,287	0.1340
Tax	-8,221	0.0928	-10,144	0.1151
Age 50				
Subsidy	-2,281	0.0468	-2,637	0.0567
Label	-3,346	0.0566	-3,850	0.0665
Voluntary reformulation	-1,800	0.0424	-2,091	0.0522
Mandatory reformulation	-8,585	0.1049	-9,849	0.1151
Health communication	-10,659	0.1241	-12,240	0.1346
Tax	-8,814	0.1070	-10,112	0.1173
Age 60				
Subsidy	-1,814	0.0462	-1,939	0.0505
Label	-2,578	0.0527	-2,750	0.0564
Voluntary reformulation	-1,469	0.0433	-1,574	0.0479
Mandatory reformulation	-6,349	0.0848	-6,773	0.0855
Health communication	-7,845	0.0976	-8,380	0.0971
Tax	-6,514	0.0862	-6,949	0.0868
Age 70				
Subsidy	-1,318	0.0375	-1,308	0.0365
Label	-1,769	0.0410	-1,764	0.0395
Voluntary reformulation	-1,113	0.0360	-1,103	0.0352
Mandatory reformulation	-4,006	0.0584	-4,034	0.0544
Health communication	-4,895	0.0653	-4,943	0.0604
Tax	-4,104	0.0592	-4,134	0.0551

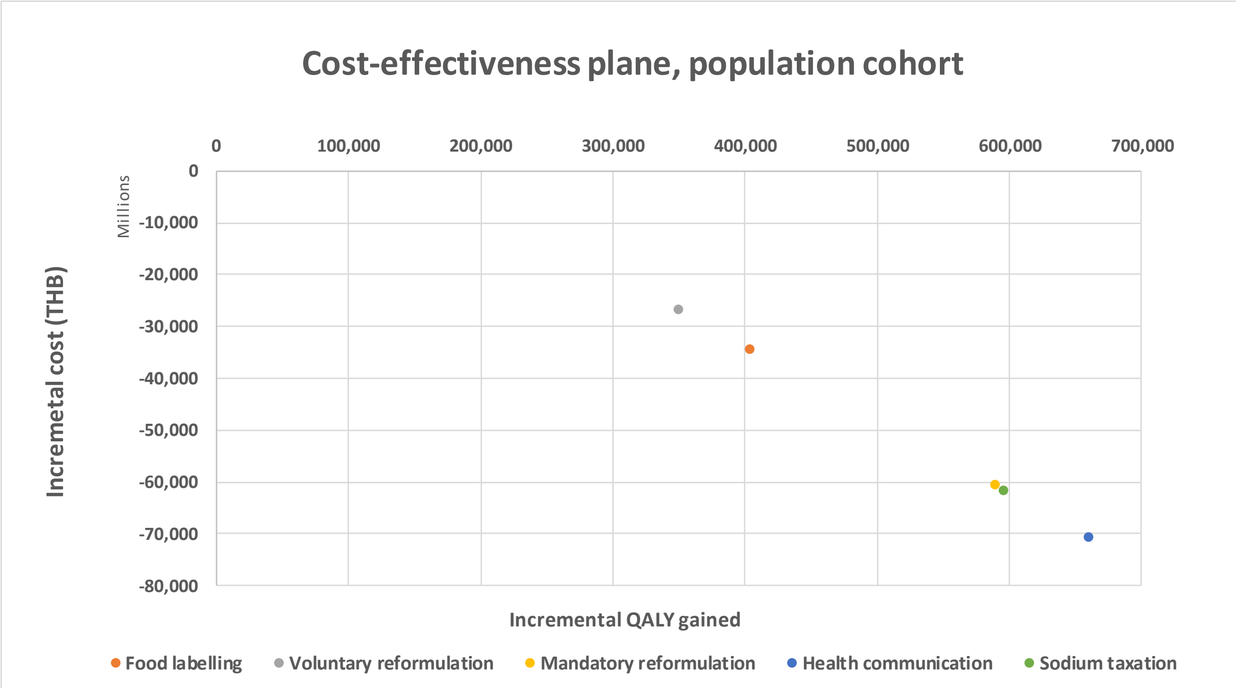


Figure 25 Cost-effectiveness plane presenting the incremental costs and incremental QALY of policy options for dietary sodium intake control compared to the current situation

Sensitivity analysis

Deterministic sensitivity analysis

Multiple one-way sensitivity analyses were conducted to estimate the impact of each parameter on the ICER. The results suggested that all policy scenarios remain cost-savings interventions compared to the current situation. The most sensitive parameters are presented in Tornado diagrams **Figure 26** to **Figure 31** for each policy. Each bar indicates the percentage of changes in the incremental cost-effectiveness ratio (ICER) when the minimum value (2.5% credible interval) and maximum value (97.5% credible interval) were used. From the sensitivity analyses, the effectiveness of sodium reduction policies, annual direct medical costs and direct non-medical costs for ESRD patients undergo haemodialysis, and risk ratio of diseases development is found to be more sensitive. The bar indicated positive percentage changes in ICER determine the less cost-saving result whereas the bar on the negative percentage refers to the more cost-saving results. None of the scenarios is found to influence the conclusion of this study where all policies are cost-saving.

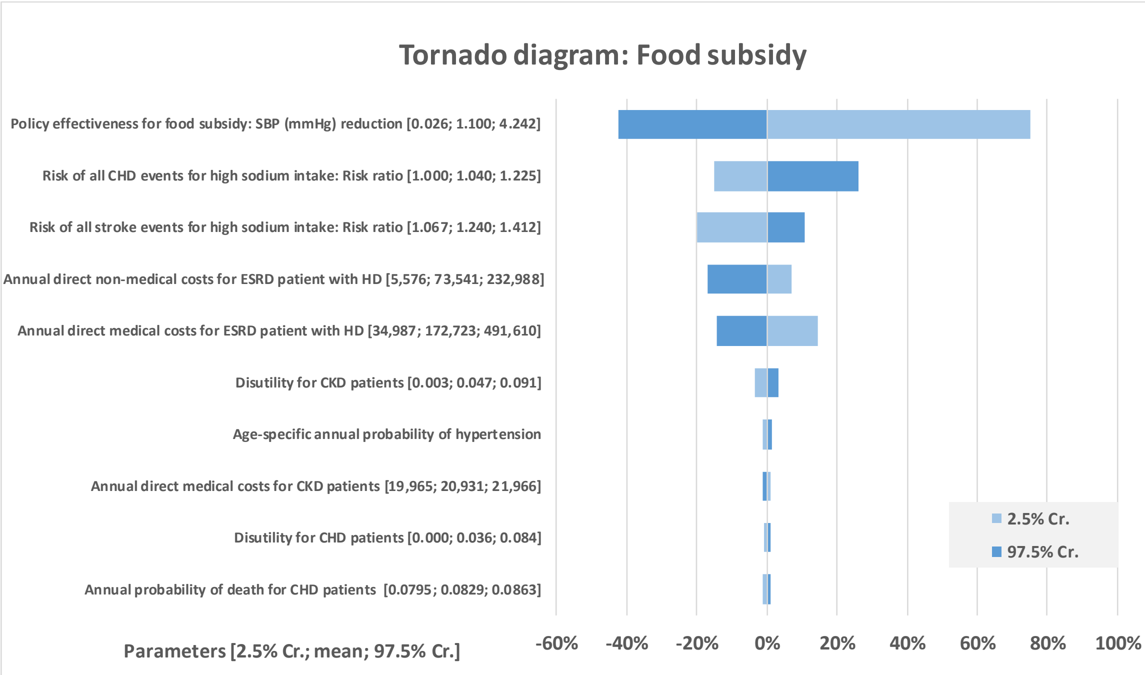


Figure 26 Tornado diagram of food subsidy policy

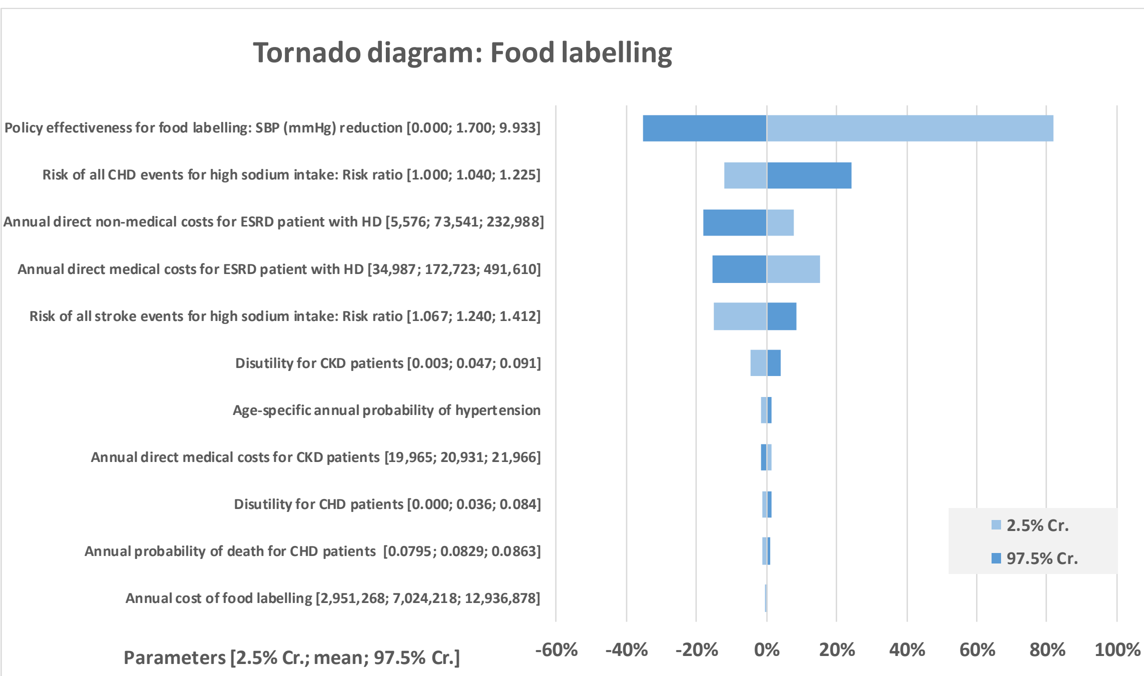


Figure 27 Tornado diagram of nutrition labelling policy

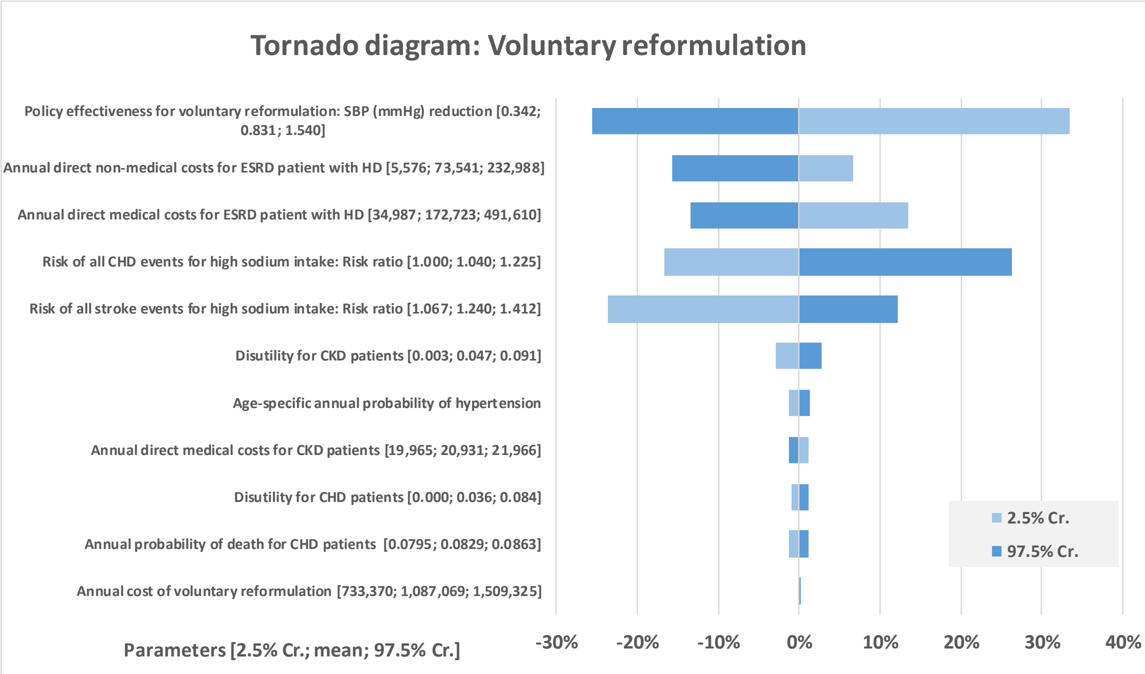


Figure 28 Tornado diagram of voluntary reformulation policy

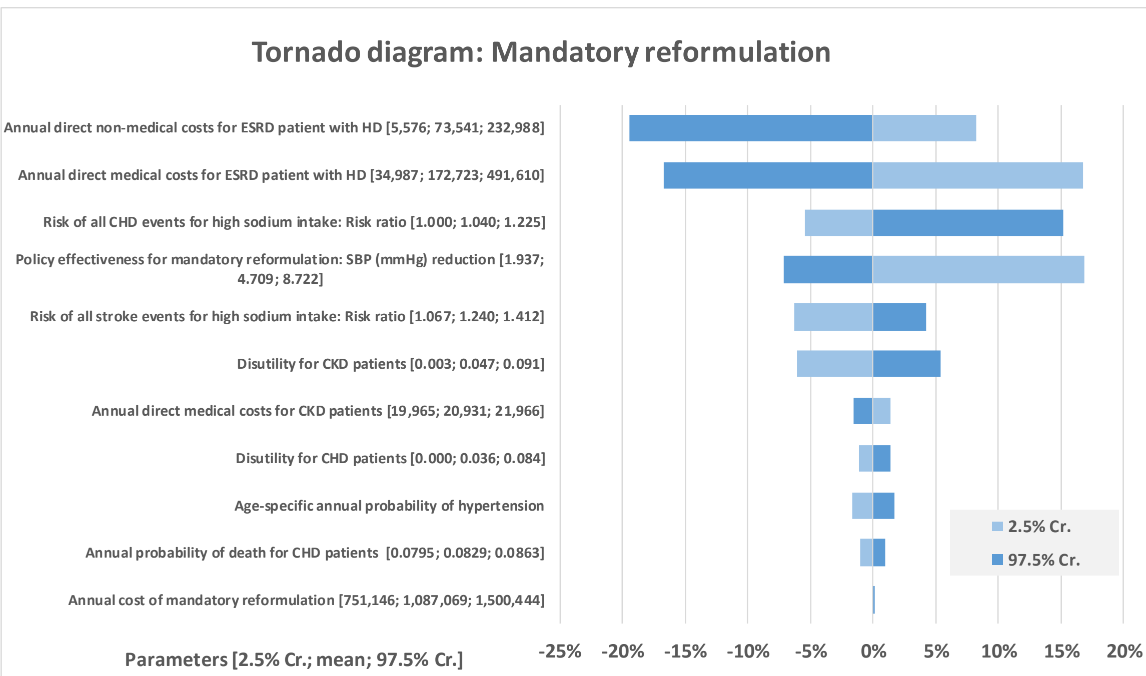


Figure 29 Tornado diagram of mandatory reformulation policy

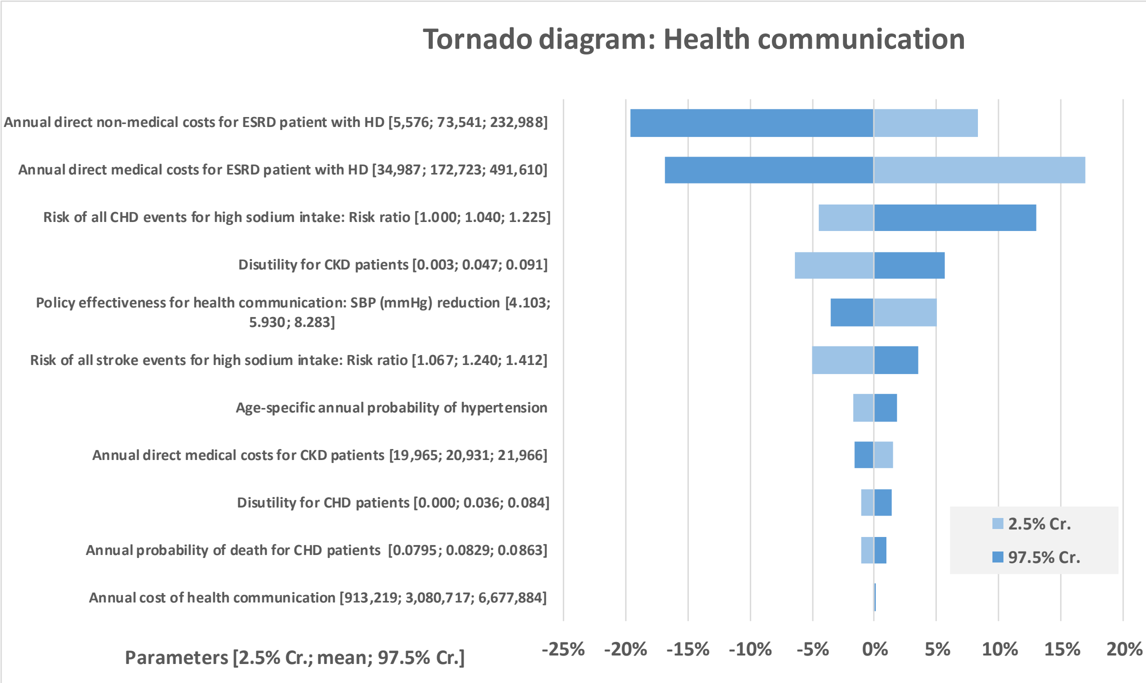


Figure 30 Tornado diagram of health communication policy

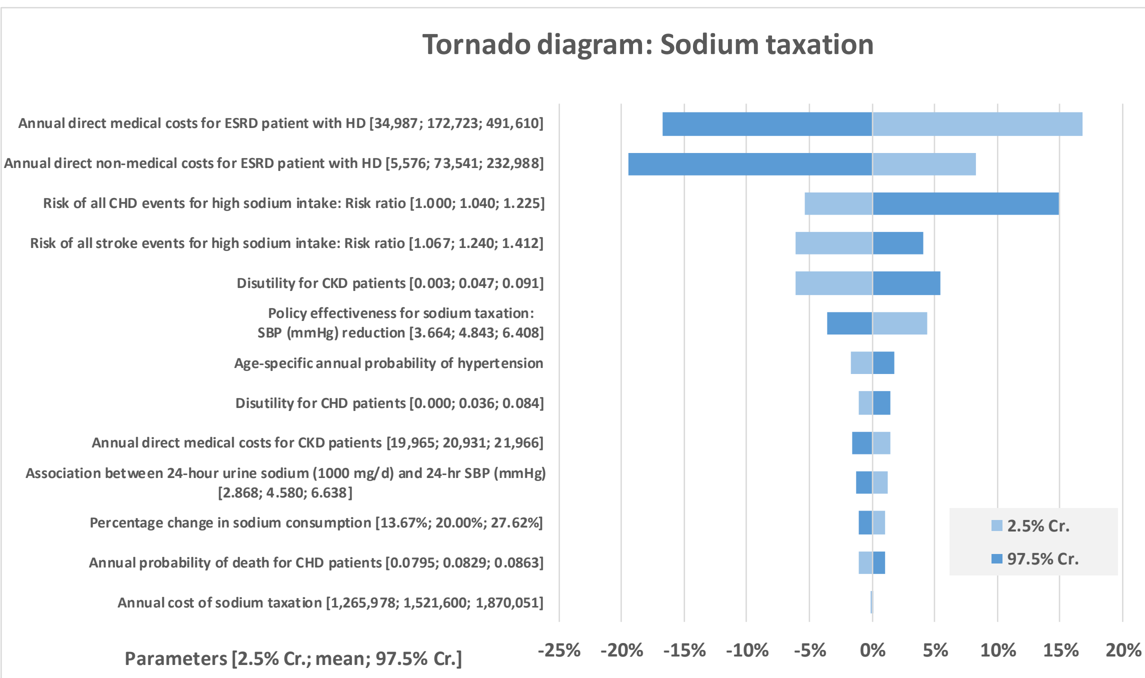
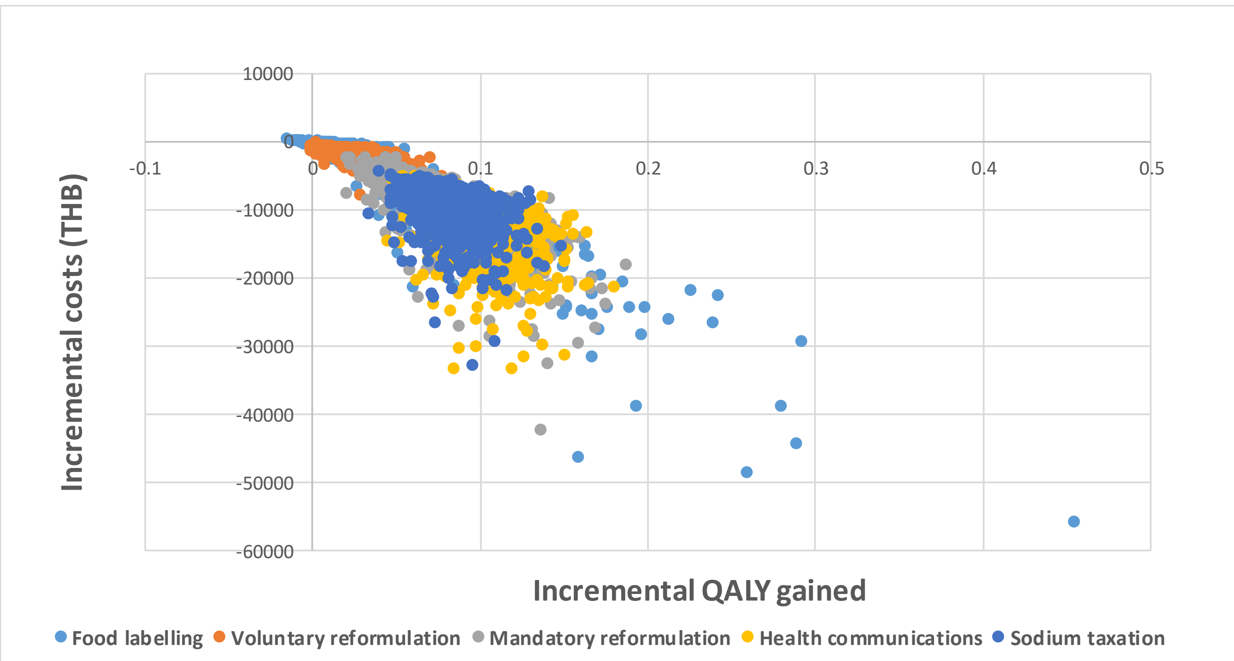


Figure 31 Tornado diagram of sodium taxation policy

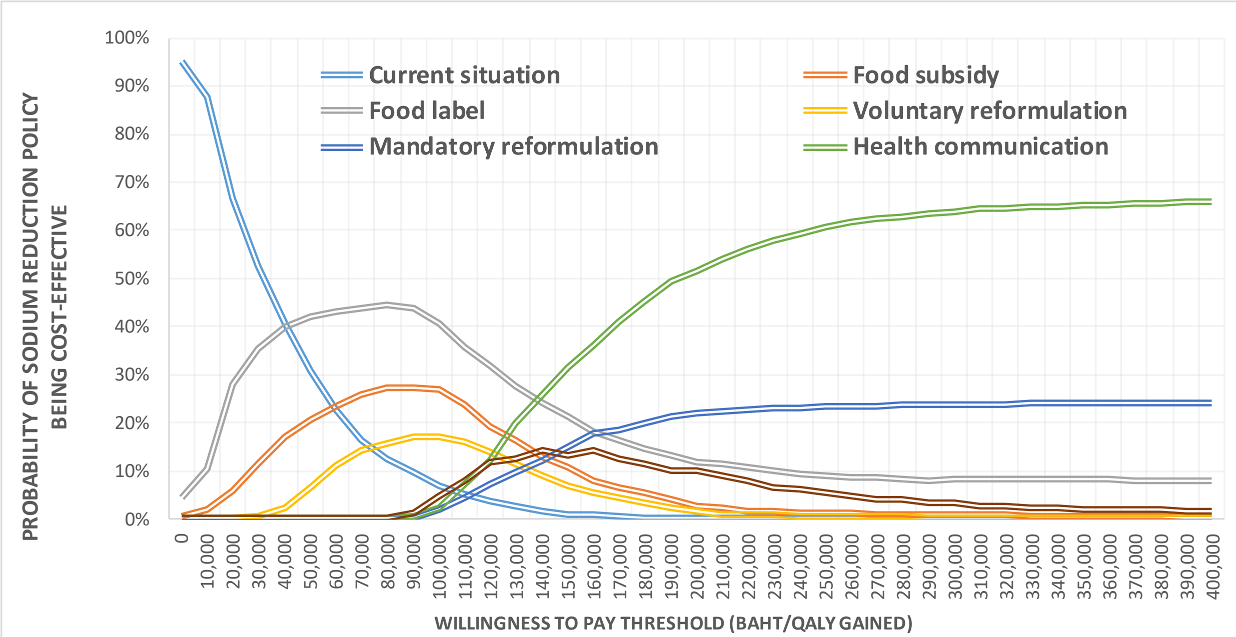
Probabilistic sensitivity analysis

The results from probabilistic sensitivity analysis suggested that at a cost-effectiveness threshold over 50,000 THB per QALY gained, nutrition labelling policy is being the most cost-effective interventions. At a higher cost-effectiveness threshold, health communication becoming the most cost-effectiveness interventions. The incremental costs and incremental effects for each of the 1,000 iterations of the policies were plotted on the cost-effectiveness plane. All policies fall in the cost-saving quadrant, being cheaper than the current situation and produced the higher heath gain.



Note: *1,000 simulations from 30-year old male cohort*

Figure 32 Cost-effectiveness plane presenting the incremental costs and incremental QALY of policy options for dietary sodium intake control compared to the current situation



Note: *1,000 simulations from 30-year old male cohort*

Figure 33 Cost-effectiveness acceptability curve of each policy option

Discussions

Principal findings

This economic evaluation study estimated the impact of sodium reduction policy, including subsidy, nutrition labelling, voluntary reformulation, mandatory reformulation, health communication, and sodium taxation comparing with the current situation in the Thai population. All policies scenarios are cost-saving as the policy costs are only a fraction compared to the direct medical costs and direct non-medical costs of sodium-related diseases. On average, sodium reduction policies saved 1,103 up to 12,420 THB per person and increase health outcomes 0.0247 to 0.1381 QALY. The estimated net savings of the policies over a 10-year period were around 27,000 to 71,000 million THB when discounted at 3% per annum. Health communication strategies aimed to reduce the use of discretionary salt at the table and cooking and improve the selection of low-salt foods through mass media communication, school-based programme and community-based programme were found to be effective in terms of reducing blood pressure, following by taxation on salty pre-packed food and mandatory food reformulation. The sensitivity analysis of individual parameters and all parameters highlight that the conclusion of this study remains the same despite parameters uncertainties.

Strengths and limitations of the study

This study has several strengths. First, the transitional probability of cardiovascular diseases and chronic kidney diseases was estimated from the only long-term cohort Thai population, reflecting the use of local data. Second, the reduction of clinical outcomes—i.e. systolic blood pressure—was used to estimate the policy effectiveness. Since the association between blood pressure and cardiovascular disease events and chronic kidney disease events are very well established, this study model the benefit of sodium reduction policy through the reported blood pressure reduction. Third, healthcare costs of diseases related to excess sodium intake were based on health administrative databases from the National Health Security Office, reflecting the national treatment standard and the actual healthcare burden.

The conclusion of this study are subject to several limitations. The cost of sodium taxation in this study did not include costs incurred by the food industry nor any from other sectors than healthcare. The profit and loss from nutrition labelling, reformulation and taxation are not count. The model in this study did not estimate the deadweight loss from consumer and producer surplus nor the tax revenue.

The nature of price elasticities for salty food and tax revenue are crucial parameters to estimate any deadweight loss. Though price elasticity of demand is an empirical foundation to estimate effects from pricing policies, it only takes into account consumers preference based on price rather than consumers' behaviour towards healthier choices which is the goal of public health policies. However, it is highly unlikely that this effect would offset the cost of healthcare. Further study can investigate on the price and quantity changes for unhealthy food for future public health policies and explore the impact on food industry.

The current situation implies that the population risk of cardiovascular diseases and chronic kidney disease remain constant where as there is an observed rise in population blood pressure and chronic kidney disease cases in Thailand. Moreover, this study did not take into account for costs and benefits from blood pressure reduction such as diabetes and obesity. Therefore, the result from this study is rather conservative towards the benefit of sodium reduction policies.

Comparison with other studies

A number of cost-effectiveness study of in the global community provided similar finding where the population-based interventions aimed to reduce sodium consumptions are cost-saving (18, 20, 52). The majority of cost-effectiveness studies were conducted in high-income settings where healthcare costs might be higher than the low- and middle-income countries and public health interventions tend to be more cost-effective. This study suggested that even in the context of middle-income country, sodium-reduction policies are also cost-savings. Nghiem *et al* (2015) estimates an effect of legistration-based interventions to be the most cost-saving intervention, besides a hypothetical Sinking Lid intervention, limits of food-grade salt into the market (52) which differ from this study. The New Zealand model applied intervention effect sizes from the reduction of sodium intake where as the model in this study used systolic blood pressure to determine intervention effect size. In Thailand, Guideline Daily Amounts (GDAs) labelling has been established for 13 food classification[6]; however, the understanding of GDA labelling were still low even among highly educated samples (53). The effectiveness of nutrition labelling system depends heavily on an ability to interpret and availability of healthier alternatives. The results from SaltSwitch intervention that allow for immediate and interpretive label system only suggests a positive effect on household purchases of salt from packaged foods, not the urinary sodium excretion or systolic blood pressure (36). The benefit in terms of a reduction in systolic blood pressure was minimal; however, the study was underpowered to detect any significant changes in these clinical outcomes. Therefore, an effectiveness of nutrition labelling used in this study was from a trial in New Zealand.

Implications for policy and practice

This study provide evidence for policy makers and indicated that blood pressure can be used as national programme evaluator since the 24-hr urine sodium for the national population survey are costly for regularly monitoring. Any policy attempt to reduce one unit of population systolic blood pressure can avert around 7,800 deaths from cardiovascular diseases, and chronic kidney diseases, with a total saving of 2,900 million THB per year. This implies that any sodium reduction intervention of up to 2,900 million THB a year would still be considered as cost saving. Moreover, there is a strong dose-response reduction between the magnitude of the sodium reduction achieved and the magnitude of the fall in blood pressure (54-56).

Though the results reported each intervention separately but the policy should not involved only single technology as most of the effects from literature review suggested that combinations of interventions are more effective. Higher priority should be health communication via taxation and educating the public about harms of excess sodium and the readability of nutrition labelling and able to choose healthier food choice are the keys to improvement of population health.

[6] snacks, chocolate and chocolate flavored like products, bakery products, semi-processed food, chilled and frozen ready-to-eat meals, beverages, ready-to-drink tea, ready-to-drink coffee, flavoured milk, fermented milk, other milk products, soy bean beverages, and ready-to-eat ice cream

Conclusion

Around 2.28 billion THB were costs of sodium-related diseases over a 10-year period. All policy were found to be cost-saving interventions and the best buy interventions include health communications, mandatory reformulation, and sodium taxation.

Conflict of interest

The authors declare they have no conflict of interests.

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Appendix

Appendix 1: Electronic search strategies for systematic review of the effectiveness of population interventions to reduce salt intake

Database: MEDLINE (Pubmed)

Date: 8 October 2019

Search result: 288

Search Strategy:

#1 Search (sodium[Title/Abstract]) OR salt[Title/Abstract]

#2 Search (Effectiveness[Title/Abstract]) OR Effect[Title/Abstract]

#3 Search ((((((((public policy[Title/Abstract]) OR health policy[Title/Abstract]) OR nutrition policy[Title/Abstract]) OR policy[Title/Abstract]) OR policies[Title/Abstract]) OR intervention*[Title/Abstract]) OR strateg*[Title/Abstract]) OR initiative*[Title/Abstract]) OR program*[Title/Abstract]) OR policy option*[Title/Abstract]

#4 Search Reformulation[Title/Abstract]

#5 Search (((((campaign*[Title/Abstract]) OR market*[Title/Abstract]) OR health promotion[Title/Abstract]) OR Advert*[Title/Abstract]) OR Commercial[Title/Abstract]) OR Mass Media[Title/Abstract]

#6 Search (((((“nutrition facts”[Transliterated Title]) OR “nutrition fact”[Title/Abstract]) OR “nutrition label”[Title/Abstract]) OR “nutrition labels”[Title/Abstract]) OR “nutrition labeling”[Title/Abstract]) OR “nutrition labelling”[Title/Abstract]

#7 Search (Search ((((Regulation[Title/Abstract]) OR Legislation[Title/Abstract]) OR Tax[Title/Abstract]) OR Subsidy[Title/Abstract]) OR fiscal[Title/Abstract])

#8 #4 OR #5 OR #6 OR #7

#9 #1 AND #2 AND #3 AND #8

Filter for article types: Clinical study; Clinical trial; Clinical trial protocol; Clinical trial, phase I; Clinical trial, phase II; Clinical trial, phase III; Clinical trial, phase IV; Meta-analysis; RCT; Review; Systematic review

Database: Cochrane Library

Date: 16 Aug 2019

Search result: 70

Search Strategy:

#1 (salt):ti in Cochrane Reviews, Trials
#2 (sodium):ti in Cochrane Reviews, Trials
#3 #1 OR #2
#4 (Regulation):ab (Word variations have been searched) in Cochrane Reviews, Trials
#5 (Legislation):ab (Word variations have been searched) in Cochrane Reviews, Trials
#6 (Tax):ab (Word variations have been searched) in Cochrane Reviews, Trials
#7 (Subsidy):ab (Word variations have been searched) in Cochrane Reviews, Trials
#8 (fiscal):ab (Word variations have been searched) in Cochrane Reviews, Trials
#9 #4 OR #5 OR #6 OR #7 OR #8 in Trials (Word variations have been searched)
#10 (Reformulation):ab (Word variations have been searched) in Cochrane Reviews, Trials
#11 (campaign):ab (Word variations have been searched) in Cochrane Reviews, Trials
#12 (marketing):ab (Word variations have been searched) in Cochrane Reviews, Trials
#13 (health promotion):ab (Word variations have been searched) in Cochrane Reviews, Trials
#14 (Advert*):ab (Word variations have been searched) in Cochrane Reviews, Trials
#15 (Commercial):ab (Word variations have been searched) in Cochrane Reviews, Trials
#16 (Mass Media):ab (Word variations have been searched) in Trials
#17 #11 OR #12 OR #13 OR #14 OR #15 OR #16
#18 (nutrition):ab (Word variations have been searched) in Cochrane Reviews, Trials
#19 label* in Cochrane Reviews, Trials
#20 #18 AND #19
#21 (public policy):ab (Word variations have been searched) in Cochrane Reviews, Trials
#22 (health policy):ab (Word variations have been searched) in Cochrane Reviews, Trials
#23 (nutrition policy):ab (Word variations have been searched) in Cochrane Reviews, Trials
#24 (polices):ab (Word variations have been searched) in Cochrane Reviews, Trials
#25 (intervention*):ab (Word variations have been searched) in Cochrane Reviews, Trials
#26 (strategies):ab (Word variations have been searched) in Cochrane Reviews, Trials
#27 (program*):ab (Word variations have been searched) in Cochrane Reviews, Trials
#28 (policy option):ab (Word variations have been searched) in Cochrane Reviews, Trials
#29 #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28
#30 (effect*):ti,ab,kw (Word variations have been searched) in Cochrane Reviews, Trials
#31 #9 OR #10 OR #17 OR #20 in Cochrane Reviews, Trials
#32 #3 AND #29 AND #30 AND #31 in Cochrane Reviews, Trials

Appendix 2: Summary of included studies from systematic review

Studies	Study characteristics			Intervention: descriptions and sample size (n)	Participant characteristics					Outcome measurement
	Country	Study design	Policy types		% female (n)	Mean age	Mean BMI	Mean SBP	Mean urine sodium (mmol/day)	
Taxation & subsidy										
Li (2016)	China	Randomized controlled trial	**Mixed policy:** - Price subsidy (PS)+ health education (HE) - HE only	**Control:** 59 villages received no intervention (n = 1,272)	50% (n=636)	55±14	25 ±3.6	n/a	n/a	**Interventions vs control** • 24-hr urinary sodium excretion: 237±97 vs 251±94 mmol/day • SBP: 141±22 vs 142±23 mmHg
				Intervention: 30 villages received HE and price subsidy coupons and 30 villages received HE but no coupons (n = 1,294)	50% (n=647)	55±15	24 ±3.5	n/a	n/a	
Thow (2014)	US (with UK data)	Systematic review of economic evaluation	Food taxes	No intervention	n/a	n/a	n/a	n/a	n/a	Sodium tax increasing the price of salty foods by 40% would reduce sodium consumption by 6% (range, 1.2% to 21.6%)
				Government collaboration with food manufacturers to voluntarily cut sodium in processed foods	n/a	n/a	n/a	n/a	n/a	
				Tax to decrease sodium consumption	n/a	n/a	n/a	n/a	n/a	
Nutrition labelling										
Babio (2013)	Spain	Randomised controlled trial with cross over design	Front-of-pack GDA nutrition fact	**Control:** Monochrome GDA, then Multiple-traffic -light (MTL) GDA system (n =38)	48.8% (n=19)	16.1 ± 0.7	21.0 ± 3.3	n/a	n/a	**Intervention vs control** • Mean difference of salt intake: -400 mg (SE = 500 mg)
				Intervention: MTL GDA system, then Monochrome GDA (n =41)	55.3% (n = 23)	16.2 ± 1	21.5 ± 3.4	n/a	n/a	
Machín (2017)	Uruguay	Randomised controlled trial	Front-of-pack (FoP) nutrition information	**Control:** No FoP nutrition information, guideline daily amount system (n =352)	93% (n =327)	36-50	n/a	n/a	n/a	**Intervention 2 vs intervention 1 vs control** • Sodium amount included in the shopping cart: 15,588 vs 15,659 vs 19,399 mg Assumption; sodium amount included in the shopping cart equals sodium consumption
				Intervention: Traffic light system (n =425)	90% (n =382)	36-50	n/a	n/a	n/a	
				Intervention: Warning system (n =405)	92% (n =373)	36-50	n/a	n/a	n/a	
Elfassy (2015)	US	Cross-sectional survey	Nutrition fact (NF)	**Control:** Nonfrequent use of NF	53.8% (n =891)	25-44	n/a	n/a	n/a	**Intervention vs control** • Sodium intake: 3,084 vs 3,059 mg
				Intervention: Frequent use of the NF			n/a	n/a	n/a	
Eyles (2017)	New Zealand	6-week, two-arm, parallel, randomised controlled trial	Traffic light nutrition label	**Control:** No FoodSwitch app, be able to access usual cardiac rehabilitation services (n =33)	24% (n=8)	65 ± 8	29 ± 4	134 ± 15	143.7 ± 39.5	**Intervention vs control** • 24-hr urinary sodium excretion: 154.1 (95%CI: 146.0 -162.2) vs 153.6 (95%CI: 145.5 - 161.7) mmol/day • SBP: 131 (95%CI: 127 - 135) vs 129 (95%CI: 125 - 133) mmHg A reduction of 0.7 g of salt per person per day during the 4-week intervention phase.
				Intervention: SaltSwitch smartphone app to interpret traffic light nutrition, along with a list of healthier lower-salt alternatives to 'switch' to (n =33)	9% (n=3)	64 ± 7	28 ± 4	131 ± 15	157.6 ± 31.1	
Food reformulation										

Studies	Study characteristics			Intervention: descriptions and sample size (n)	Participant characteristics					Outcome measurement
	Country	Study design	Policy types		% female (n)	Mean age	Mean BMI	Mean SBP	Mean urine sodium (mmol/day)	
Janseen (2015)	Netherlands	Randomized pretest-posttest control trial	Food reformulation: lunch	**Control:** Lunches with regular foods (n =32)	42% (n =16)	24 ± 3	22 ± 3	n/a	n/a	**Interventions vs control** • 24-hr urinary sodium excretion: 119 ± 45 vs 165 ± 56 mmol/day • Mean difference of sodium intake: -1,093 mg
				Intervention: Lunches with reduced-sodium foods (n =33)	56% (n =20)	23 ± 3	22 ± 2	n/a	n/a	
Cashman (2019)	Ireland	Randomized crossover trial	Food reformulation: bread, no-salt margarine and meats with no added salt	**Control:** Usual-salt diet (1.2 g salt/100 g) (n =50)	43% (n =41)	47.8 ± 9.3	27.2 ± 6.4	138.5 ± 10.4	108.3 ± 45.7	**Interventions vs control** • 24-hr urinary sodium excretion: 77.6 ± 35.6 vs 106.0 ± 53.6 mmol/day • SBP: 131.0 ± 11.0 vs 134.3 ± 12.1 mmHg
				Intervention: 5-week reduced-salt diet (0.3 g salt/100 g) (n =46)						
Mu (2009)	China	Randomized, single-blind, placebo-controlled trial	Reformulation: Salt Substitute Containing Potassium and Calcium	**Control:** Usual-salt diet (n =114)	47.4% (n = 54)	21.4 ± 3.9	23.8 ± 2.1	124.3 ± 14.1	137 ± 49	**Intervention 2 vs Intervention 1 vs control** • 24-hr urinary sodium excretion: 87 ± 41 vs 136 ± 40 vs 135 ± 46 mmol/day • Mean difference of SBP: -5.8 vs -5.9 vs 1.3 mmHg
				Intervention 1: Added- 10 mmol of K and- 10 mmol of Ca (n =101)	50.4% (n = 56)	20.3 ± 3.1	23.6 ± 2.0	123.8 ± 12.9	140 ± 59	
				Intervention 2: Salt-restricted diet Goal was 50–100 mmol per person per day at the end of 2 years (n =110)	47.3% (n = 52)	20.6 ± 3.1	23.4 ± 1.9	121.5 ± 12.8	141 ± 56	
Charlton (2007)	South Africa	Randomised, double-blind, controlled trial	Food reformulation: brown bread, margarine, stock cubes, soup mixes and Aromat (monosodium glutamate enhancer)	**Control:** Standard commercial composition food (n =40)	85% (n=34)	60.4 ± 7.4	35.3 ± 6.0	135.4 ± 16.7	173.2 ± 52.4	**Intervention vs control** • 24-hr urinary sodium excretion: 154.3 ± 64.0 vs 169.3 ± 57.7 mmol/day • Mean difference of SBP: -6.194 ± 2.6 mmHg • Mean difference of sodium intake: -1,167 ± 1,532
				Intervention: Modified foods plus a salt replacement (SoloTM) and 500 ml of maas (fermented milk commonly eaten) daily (n =40)	83% (n=33)	61.8 ± 6.6	32.9 ± 5.8	133.9 ± 14.6	171.7 ± 53.7	
Mass media communication										
Fortmann (1990)	USA	Quasi-experimental study	Mass media communication	**Control:** No education program (n =1,176)	52.0% (n=611)	35.6 ± 0.49	23.8 ± 0.12	122.3 ± 0.50	n/a	**Intervention vs control** • SBP: 126.0 vs 123.3 mmHg
				Intervention: Mass media (TV, radio, announcements) and direct, interpersonal education programs (4.5 years of intervention) (n = 1,188)	52.6% (n=623)	37.4 ± 0.49	24.6 ± 0.13	125.2 ± 0.48	n/a	
Shankar (2012)	UK	Cross-sectional study (pre-post evaluation of post-policy implementation)	Mass media campaign (series of advertisements)	**Baseline**: 2003 pre-intervention period **Intervention:** Salt reduction campaign 2003-2007	n/a	n/a	n/a	n/a	n/a	The impact of evaluating 4-year post-policy implementation was shown 1.5% sodium reduction as measured by spot urinary sodium readings. 2003: 2,507.69 mg/day 2004: 2,559.44 mg/day 2005: 2,298.62 mg/day 2006: 2,242.27 mg/day 2007: 2,165.68 mg/day
Phuong Do (2016)	Vietnam	Cross-sectional study, pre-post design	An integrated mix of 4 communication action areas	**Baseline** (n =509) **Intervention:**	50.69% (n=258)	45.27 ± 11.85	21.94 ± 2.72	126.35 ± 17.63	n/a	• **Salt intake: Intervention vs control** 24-hour urine and spot urine samples using different equations:

Studies	Study characteristics			Intervention: descriptions and sample size (n)	Participant characteristics					Outcome measurement
	Country	Study design	Policy types		% female (n)	Mean age	Mean BMI	Mean SBP	Mean urine sodium (mmol/day)	
				A 12-month period of Eat Less Salt (ELS) Program: (n =513) 1. Mass media communication (TV,Flim,radio program,newsletter) 2. Intervention in schools 3. Community communication programs 4. High-risk and hypertension groups	54.40% (n=278)	44.83 ± 11.7	21.82 ± 2.57	120.42 ± 16.47	n/a	**1. INTERSALT equation*:** 8.05 ± 2.11 mg VS 8.48 ± 2.13 mg 2. 24-h urine: 7.44 ± 4.09 mg VS 9.43 ± 3.69 mg 3. Tanaka equation: 9.21 ± 2.84 mg VS 9.94 ± 2.64 mg 4. Mage equation: 8.74 ± 8.25 mg VS 10.07 ± 8.50 mg 5. Kawasaki equation: 12.88 ± 5.19 mg VS 13.98 ± 5.06 mg 6. Simple equation: 10.64 ± 9.38 mg VS12.37 ± 9.85 mg ***primary outcome**

Appendix 3: CHEERS checklist—Items to include when reporting economic evaluations of health interventions

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	1
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	3
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study.	10-13
		Present the study question and its relevance for health policy or practice decisions.	14
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	15
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	15
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	15
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	15
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	15
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	15
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	37
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	n/a
	11b	*Synthesis-based estimates*: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	36-42
Measurement and valuation of	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	49

Section/item	Item No	Recommendation	Reported on page No/ line No
preference based outcomes			
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	n/a
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	42-46
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	15, 43
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	16-18
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	52
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	53
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	18-49
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	Table 18, 19, 20

Section/item	Item No	Recommendation	Reported on page No/ line No
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	n/a
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	59-64
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	n/a
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	65-67
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	2
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	68

Appendix 4: Diseases included in this study, defined by the International Classification of Diseases (ICD) 10

Diseases	Details	ICD-10
Hypertension	Essential (primary) hypertension	I10
	Hypertensive heart disease	I11, I11.0, I11.9
	Hypertensive renal disease	I12, I12.0, I12.9
	Hypertensive heart and renal disease	I13, I13.0, I13.1, I13.2, I13.9
	Secondary hypertension	I15, I15.0, I15.1, I15.2, I15.8, I15.9
Ischemic heart disease or coronary artery disease	Angina pectoris	I20, I12.0, I20.1, I20.8, I20.9
	Acute myocardial infarction	I21, I21.0, I21.1, I21.2, I21.3, I21.4, I21.9
	Subsequent ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction	I22, I22.0, I22.1, I22.8, I22.9
	Certain current complications following ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction (within the 28-day period)	I23, I23.0, I23.1, I23.2, I23.3, I23.4, I23.5, I23.6, I23.8
	Other acute ischemic heart diseases	I24, I24.0, I24.1, I24.8, I24.9
	Chronic ischemic heart disease	I25, I25.0, I25.1, I25.2, I25.3, I25.4, I25.5, I25.6, I25.8, I25.9
Cardiac arrest		I46
Heart failure		I50
Cerebrovascular disease	Nontraumatic subarachnoid hemorrhage	I60, I60.0, I60.1, I60.2, I60.3, I60.4, I60.5, I60.6, I60.7, I60.8, I60.9
	Nontraumatic intracerebral hemorrhage	I61, I61.0, I61.1, I61.2, I61.3, I61.4, I61.5, I61.6, I61.8, I61.9
	Other and unspecified nontraumatic intracranial hemorrhage	I62, I62.0, I62.1, I62.9
	Cerebral infarction	I63, I63.0, I63.1, I63.2, I63.3, I63.4, I63.5, I63.6, I63.8, I63.9
	Stroke, not specified as haemorrhage or infarction	I64
	Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction	I65, I65.0, I65.1, I65.2, I65.3, I65.8, I65.9
	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction	I66, I66.0, I66.1, I66.2, I66.3, I66.4, I66.8, I66.9
	Other cerebrovascular diseases	I67, I67.0, I67.1, I67.2, I67.3, I67.4, I67.5, I67.6, I67.7, I67.8, I67.9
	Cerebrovascular disorders in diseases classified elsewhere	I68, I68.0, I68.1, I68.2, I68.8
	Sequelae of cerebrovascular disease	I69, I69.0, I69.1, I69.2, I69.3, I69.4, I69.8

Diseases	Details	ICD-10
	Transient cerebral ischemic attack, unspecified	G45.9
Chronic kidney disease	Chronic kidney disease	N18
	Chronic kidney disease, stage 1	N18.1
	Chronic kidney disease, stage 2 (mild)	N18.2
	Chronic kidney disease, stage 3 (moderate)	N18.3
	Chronic kidney disease, stage 4 (severe)	N18.4
	Chronic kidney disease, stage 5	N18.5
	End stage renal disease	N18.6
	Chronic kidney disease, unspecified	N18.9
	Unspecified kidney failure	N19
Stomach cancer	Malignant neoplasm of stomach	C16
	Cardia	C16.0
	Fundus of stomach	C16.1
	Body of stomach	C16.2
	Pyloric antrum	C16.3
	Pylorus	C16.4
	Lesser curvature of stomach, unspecified	C16.5
	Greater curvature of stomach, unspecified	C16.6
	Overlapping lesion of stomach	C16.8
	Stomach, unspecified	C16.9

Note: ICD-10, the International Classification of Diseases (ICD) 10

Appendix 5: EQ-5D-5L index Thai population norms

Age	Male		Female		Age	Male		Female	
	Mean	SE	Mean	SE		Mean	SE	Mean	SE
18	0.9278	0.0030	0.9357	0.0039	55	0.9027	0.0060	0.9126	0.0053
19	0.9272	0.0058	0.9351	0.0051	56	0.9020	0.0061	0.9119	0.0054
20	0.9266	0.0057	0.9346	0.0051	57	0.9012	0.0062	0.9112	0.0055
21	0.9259	0.0028	0.9340	0.0050	58	0.9005	0.0047	0.9105	0.0042
22	0.9253	0.0028	0.9334	0.0049	59	0.8997	0.0065	0.9098	0.0042
23	0.9247	0.0028	0.9328	0.0049	60	0.8990	0.0049	0.9091	0.0059
24	0.9241	0.0055	0.9322	0.0048	61	0.8982	0.0034	0.9084	0.0045
25	0.9234	0.0054	0.9317	0.0035	62	0.8975	0.0070	0.9077	0.0062
26	0.9228	0.0045	0.9311	0.0049	63	0.8967	0.0071	0.9070	0.0063
27	0.9221	0.0053	0.9305	0.0046	64	0.8959	0.0054	0.9063	0.0047
28	0.9215	0.0053	0.9299	0.0047	65	0.8952	0.0055	0.9056	0.0066
29	0.9208	0.0051	0.9293	0.0034	66	0.8944	0.0076	0.9048	0.0055
30	0.9202	0.0026	0.9287	0.0045	67	0.8936	0.0077	0.9041	0.0070
31	0.9195	0.0043	0.9281	0.0046	68	0.8928	0.0059	0.9034	0.0071
32	0.9188	0.0043	0.9275	0.0046	69	0.8921	0.0082	0.9027	0.0037
33	0.9182	0.0037	0.9268	0.0023	70	0.8913	0.0062	0.9019	0.0075
34	0.9175	0.0049	0.9262	0.0033	71	0.8905	0.0043	0.9012	0.0038
35	0.9168	0.0041	0.9256	0.0033	72	0.8897	0.0065	0.9005	0.0058
36	0.9162	0.0049	0.9250	0.0043	73	0.8889	0.0045	0.8997	0.0040
37	0.9155	0.0050	0.9244	0.0043	74	0.8881	0.0091	0.8990	0.0061
38	0.9148	0.0049	0.9237	0.0043	75	0.8873	0.0093	0.8982	0.0083
39	0.9141	0.0051	0.9231	0.0045	76	0.8865	0.0096	0.8975	0.0076
40	0.9134	0.0050	0.9225	0.0033	77	0.8857	0.0073	0.8967	0.0045
41	0.9127	0.0037	0.9218	0.0044	78	0.8848	0.0101	0.8960	0.0089
42	0.9121	0.0050	0.9212	0.0044	79	0.8840	0.0103	0.8952	0.0069
43	0.9114	0.0038	0.9205	0.0037	80	0.8832	0.0105	0.8945	0.0094
44	0.9107	0.0026	0.9199	0.0045	81	0.8824	0.0108	0.8937	0.0096
45	0.9100	0.0051	0.9192	0.0045	82	0.8815	0.0083	0.8929	0.0098
46	0.9092	0.0052	0.9186	0.0045	83	0.8807	0.0090	0.8922	0.0075
47	0.9085	0.0039	0.9179	0.0046	84	0.8799	0.0058	0.8914	0.0103
48	0.9078	0.0027	0.9173	0.0047	85	0.8790	0.0119	0.8906	0.0106
49	0.9071	0.0054	0.9166	0.0047	86	0.8782	0.0122	0.8898	0.0108
50	0.9064	0.0055	0.9159	0.0036	87	0.8773	0.0125	0.8890	0.0111
51	0.9057	0.0056	0.9153	0.0049	88	0.8765	0.0127	0.8882	0.0113
52	0.9049	0.0057	0.9146	0.0050	89	0.8756	0.0128	0.8874	0.0058
53	0.9042	0.0058	0.9139	0.0050	90	0.8748	0.0131	0.8866	0.0119
54	0.9035	0.0059	0.9132	0.0052					