Cost-effectiveness analysis of low-sodium potassium-rich salt substitutes in Indonesia: an equity modelling study

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Summary

Background Evidence suggests low-sodium potassium-rich salt substitutes (LSSS) are effective in reducing blood pressure (BP). However, the health and economic impacts of LSSS in Indonesia are currently unknown.

Methods We developed a proportional multistate lifetable Markov model to assess a government-led strategy implementing the use of LSSS compared to current regular salt consumption. BP data were derived from the Indonesian Basic Health Research Survey (RISKESDAS 2018), while epidemiological data were from the Global Burden of Disease 2019 study. We estimated implementation costs and the impact of changes in BP on disease events and healthcare costs, and incremental cost-effectiveness ratios. Outcomes were simulated over different time horizons for the 2019 Indonesian population overall, and by income quintiles. Probabilistic sensitivity analysis was done to capture uncertainty.

Findings Over the first 10 years, LSSS could prevent 1.5 million non-fatal cardiovascular disease (CVD) events (8.3%–19.4% reduction) and 643,000 incident chronic kidney disease (CKD) cases (8.2% reduction), while averting over 200,000 CVD and CKD deaths (0.2%–5.2% reduction). This translated to over 24.6 million health-adjusted life years (HALYs) gained over the lifetime of the population, and reduced CVD-related health inequalities (concentration index, −0.075, 95% CI: −0.088 to −0.062). Implementation cost (US$ 1.2 billion [IDR 17.2 trillion] total; US$ 4.5 [IDR 63,665] per capita, as of July 2019) was outweighed by the net health expenditure savings (~US$ 2 billion [IDR 27.7 trillion] total; US$ 7.3 [IDR 103,300] per capita) in the first 10 years. LSSS were cost-saving over the lifetime, and very cost-effective even with a high LSSS price.

Interpretation Scaling the use of LSSS nationally could be a cost-saving strategy to prevent substantial cardiovascular and kidney disease burden in Indonesia.

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Introduction

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in southeast Asia. In 2019, over 1.5 million deaths and 37 million disability-adjusted life years (DALYs) were attributed to CVDs in the southeast Asia region.[1,2] Indonesia is the most populous country in the region, and similarly, CVDs (mostly stroke and heart disease) are the primary cause of death, responsible for 35% of all deaths each year.[2] High blood pressure (BP) is ubiquitous in Indonesia, and it is the leading modifiable risk factor for CVDs. Up to 25% of all coronary heart diseases and 42% of all strokes in Indonesia are attributed to high BP.[3] High BP affects one in three adult Indonesians and nearly half of those aged 40 years and over.[4] Among those with high BP in the country, more than half (57.1%) are undiagnosed, only one in ten receive

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Research in context

Evidence before this study

The WHO has recommended population-wide dietary sodium reduction as a 'best-buy' strategy to tackle the burden of high blood pressure and non-communicable diseases (NCD). Low-sodium potassium-rich salt substitutes (LSSS) are gaining traction as an effective way to achieve this especially in low-income and middle-income countries (LMICs) where most of the salt in the diet is added while cooking or at the table. Using the terms "cost-effectiveness", "salt substitutes", "low-sodium potassium-rich salt", combined with relevant Boolean operators and no language restrictions, we searched the PubMed and Scopus databases from inception to December 2022 for studies evaluating the cost-effectiveness of LSSS in Asia. Of the three studies found, one was a trial-based analyses over five years which did not capture the full scale of the long-term health and economic impacts of salt substitutes. The other studies did not explicitly quantify the cost of reformulating regular salt to the LSSS alternative, which is vital to inform policy implementation. In addition, our search did not find any studies globally which assessed the potential impact of this strategy on health inequalities.

Added value of this study

This study capitalises on nationally representative datasets and Indonesia-specific data from the Global Burden of Disease 2019 study to simulate the impact and cost-effectiveness of LSSS compared to current regular salt intake. Implementing the LSSS policy including program development, monitoring, and salt reformulation at scale in Indonesia could cost about US$ 4.6 per capita over 10 years. The results show that sizeable cardiovascular and renal disease events could be averted, generating substantial savings in related healthcare costs. The reduced vascular events and mortality translate to greater longevity, and by extension, further demand for healthcare services. Our modelling projections demonstrate that on balance, the policy will result in a net saving in total health expenditure. Compared to consuming regular sodium chloride salts, LSSS were a dominant strategy with a 100% probability of being cost-saving at 10 years, 20 years and over the life course of the Indonesian population. Importantly, our analysis is the first to demonstrate that a switch from regular salt to LSSS could reduce cardiovascular health inequalities, with greater reductions in disease rates and healthy life years gained among the people with low income.

Implications of all the available evidence

Our analysis demonstrates that a government-led policy scaling the use of LSSS nationally in Indonesia would be good value for money. We provide quantitative estimates of the decision uncertainty associated with implementing this policy in Indonesia and similar LMICs. In March 2023, the WHO launched a public consultation on draft guidelines for the use of LSSS. Our results are very timely as they will inform the upcoming WHO guidelines on the evidence gaps related to implementation costs, cost-effectiveness, and the possible impacts on health inequalities. This will contribute towards global efforts to stem premature mortality from NCDs and enhance progress towards the Sustainable Development Goals by 2030.

treatment and just 14.3% have their BP controlled.[4] Identifying effective and affordable strategies to address high BP is therefore critical to reduce the CVD burden in Indonesia.

Excess sodium intake and inadequate consumption of potassium are major drivers of high BP globally.[5] On average, Indonesians consume 2700–3500 mg/day of sodium and about 946 mg/day of potassium.[6,7] These values are well-above (maximum 2000 mg/day for sodium) and substantially below (minimum 3500 mg/day for potassium) WHO and national recommendations.[5,8,9] Dose-response meta-analyses of randomised controlled trials have shown that lower sodium consumption and adequate potassium intake reduce BP.[10,11] The use of low-sodium potassium-rich salt substitutes (LSSS), where a fraction of the sodium chloride (NaCl) in regular salt is replaced with potassium chloride (KCl), is gaining traction as an effective strategy to optimise intakes of these nutrients and control high BP.[12–14] This is particularly relevant in settings where most of the sodium in the diet is added during cooking or at the table. While long-term adherence to behaviour change interventions can be a challenge, the use of LSSS requires much less effort from consumers and is likely to be sustainable for primary prevention. However, the potential impact of this strategy on population health, and whether this would be good value for money in Indonesia is yet to be evaluated.

The government of Indonesia included sodium reduction as part of the National Strategic Action Plan for the Prevention and Control of NCDs, 2016–2019.[15] However, specific sodium reduction policies are yet to be developed and implemented.[16] With nearly three-quarters of the sodium in the diet from discretionary sources,[7] we theorise that LSSS are likely to be beneficial in Indonesia. Thus, the aim of this study was to (i) quantify the health benefits i.e., averted cardiovascular and renal events, deaths, and healthy life years, (ii) investigate the potential health equity impacts, (iii) estimate the policy implementation costs and healthcare costs, and (iv) evaluate the cost-effectiveness of implementing a LSSS policy in Indonesia.

Methods

The salt substitute policy

We modelled a government-led national sodium reduction policy in which all the discretional regular salt (100% NaCl) currently consumed in Indonesia was progressively replaced with LSSS. The replacement was assumed to be accompanied by a media campaign raising population awareness about the benefits of lower salt intake. To estimate the effect of salt substitutes on BP, we used evidence from a meta-analysis of randomised trials,[14] which found that LSSS reduced mean systolic BP by 7.81 mmHg (95% CI: −9.47 to −6.15) and mean diastolic BP by 3.96 mmHg (95% CI: −5.17 to −2.74). Of the 19 studies included in this meta-analysis, 10 were conducted in low-income and middle-income countries (LMICs), specifically China (8 studies) and Brazil (2 studies). These countries and Indonesia share some similarities in dietary patterns, with most of the sodium in their diets (Brazil—68.2%, China—69.7%, and Indonesia—73.2%) coming from discretionary sources.[17] Given the above parallel in dietary sodium intake, we assumed the evidence from this systematic review was reasonably aligned to the primary analysis of this study, in which the LSSS policy was set to target discretionary sodium intake. We modelled the intervention as a shift in the BP distribution for the entire population. The LSSS policy took the form of a gradual system-wide implementation over a period of 5 years. The effectiveness of the policy was operationalised as linear (20% annually) increments to full effectiveness in year 5 and beyond. We assumed a population coverage equivalent to the current salt iodisation coverage levels (91.9%) in Indonesia. In addition, the policy was assumed to affect only discretionary salt consumption (i.e., added during cooking or at the table).

Study design, population, and data sources

We conducted a health impact assessment and cost-utility analysis from a health system perspective. We used a multi-cohort proportional multistate lifetable (Markov) model and applied a generalized cost-effectiveness analysis (GCEA) modelling approach.[18] Consistent with GCEA, we compared the implementation of a LSSS policy intervention to a 'do-nothing' comparator scenario, due to the absence of specific national sodium reduction interventions in Indonesia. In addition, salt substitutes are currently not widely used in Indonesia. The study population included all adult Indonesians (aged ≥20 years) alive in 2019 (total = 171.4 million, 49.9% female), disaggregated into multiple sex-specific five-year age group cohorts (i.e., 32 cohorts), and then by income quintiles. The impacts of the policy were simulated over 10 years, 20 years and over the population lifetime. Fig. 1 depicts the conceptual modelling framework.

Data on baseline BP distribution were from the 2018 Indonesian Basic Health Research Survey (RISKESDAS 2018). This nationally representative survey used multistage sampling to recruit 1,017,290 participants, for which objective BP measurements were obtained from 658,201 respondents aged 18 years and above from 34 provinces.[19] For this analysis, only data for those aged 20 years and above were used to derive baseline BP distributions in the model. This age cut-off was applied in our modelling because there is limited evidence on the causal link between BP and CVD events in younger people.[20] To estimate background trends in blood pressure, we used Indonesia-specific data from the Non-communicable Disease Risk factor Collaboration (NCD-RisC) for the years 2000–2016.[21] Generalized linear models were fitted to derive sex-specific and age-specific regression coefficients of the estimated annual change in BP. These were applied in the model to predict the future trends in BP, which were assumed to continue for the first ten years and

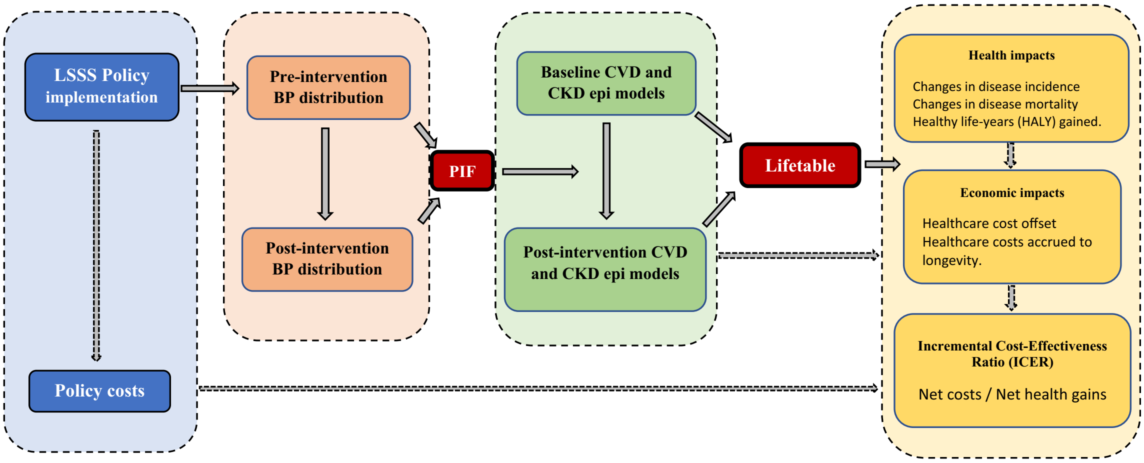

Fig. 1: **Overview of the conceptual modelling framework.** LSSS: low-sodium potassium-rich salt substitutes; BP: blood pressure; CVD: cardiovascular disease; CKD: chronic kidney disease; PIF: potential impact fraction method.

held constant thereafter. We modelled the effect of the LSSS policy on seven BP-related diseases (ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage, hypertensive heart disease, atrial fibrillation, and chronic kidney disease). Baseline incidence, prevalence, and mortality rates for these conditions, estimates of disease risk relative to change in BP from meta-analyses of cohort studies, population size and all-cause mortality rates were derived from the Global Burden of Disease study.[1,2] We used the DISMOD-II software to estimate corresponding case fatality rates using available data while imposing consistency in the overall disease epidemiology.[22]

Policy implementation costs included program costs and incremental reformulation costs (switching from regular salt to LSSS). We used the WHO NCD Costing Tool to estimate program costs.[23] This included policy development, monitoring and evaluation, human resources for law enforcement and program management, mass media and promotion, office capacity supplies and administration. To estimate reformulation costs, we used official 2019 data on salt production, importation, and consumption in Indonesia to estimate the cost of regular salt currently consumed. Using the price ratio of manufacturing salt substitutes in the east Asia region,[24] we calculated the incremental reformulation costs to LSSS alternatives.

Healthcare costs are based on data from the National Health Insurance (*Jaminan Kesehatan Nasional*) program managed by the Indonesian Social Security Agency for Health (*Badan Penyelengara Jaminan Sosial–BPJS Kesehatan)*.[25] We estimated the sex-specific and age-specific average healthcare costs for treating each prevalent case of CVD and CKD per year. Data on overall health expenditure was obtained from the Indonesian National Health Accounts 2019.[26] To account for the extra healthcare costs accrued to people living longer due to the LSSS intervention, we subtracted the age-group and sex-specific healthcare costs for the modelled cardiovascular and renal diseases from the total age- and sex-specific health expenditure estimates. These were then applied to the population alive in the lifetable to estimate the future costs for other unrelated diseases (details on input data in Supplementary File).

Health impacts and cost-effectiveness modelling

The proportional multistate lifetable Markov model is a macro-simulation model with a framework that contains the risk factor distributions combined with multiple disease-progression Markov models and a lifetable. It has the capacity to simultaneously handle comorbidity and competing mortality risks, hence its suitability for modelling chronic diseases.[27] Using demographic, epidemiological, and economic data, health and economic impacts of population-level interventions can be evaluated (See additional methods in Supplementary File).

The LSSS policy effects are modelled to alter the age-specific and sex-specific baseline systolic BP distributions to obtain post-intervention BP distributions. These pre-intervention and post-intervention BP distributions together with relative risks were mathematically combined using the continuous 'distribution shift' potential impact fraction (PIF) method[28] to estimate changes in disease incidence. The PIF takes the systolic BP distributions (pre- and post-intervention) and the relative risk function for the dose response between BP change and CVD or CKD, and integrates them with respect to unit BP levels over a given range of plausible values. This quantifies the proportional change in disease incidence, assuming a theoretical minimum risk exposure level of 115 mmHg, which is the BP level below which there is minimum or no risk of BP-related events. The resulting change in incidence translates to changes in disease prevalence and subsequently mortality rates, which ultimately propagates to the lifetable where all-cause mortality rates are altered to re-estimate life years. These life years are adjusted for time spent in poor health due to the diseases modelled as well as sex- and age-specific background morbidity to estimate health-adjusted life years (HALYs). In addition, healthcare costs over time are estimated based on changes in diseases rates and the population alive each year. The model concurrently simulates a 'business-as-usual population' with current BP distribution and projected trends, and an identical 'intervention population' that additionally gets the LSSS policy implemented. Age-specific and sex-specific population cohorts are simulated in annual cycles over their remaining lifetime (until age of 100 years or death). The difference in incident cases, deaths, HALYs, and healthcare costs between the two populations is attributed to the LSSS policy.

The incremental cost-effectiveness ratio (ICER) was estimated by taking the quotient of the mean incremental net costs and the mean net health benefits (HALYs). The net costs included the policy implementation costs and the healthcare costs (savings from averted diseases and additional costs from unrelated diseases accrued to longevity from the intervention). We used the Indonesian Health Technology Assessment Guidelines,[29] which recommend the WHO benchmarks to specify an intervention as very cost-effective (ICER <1 x per capita GDP, Indonesian Rupiah [IDR] 58.7 million or US$ 4151.23 in 2019) or cost-effective (ICER <3 times the per capita GDP (IDR 176.2 million or US$ 12,453.69). All costs were estimated in local currency, inflated where necessary to 2019 using World Bank CPI, and then converted to US dollars (US$ 1 = IDR 14,147.67, July 2019). All future health and costs were discounted at 3% (25). This analysis is reported according to the CHEERS guidelines.[30]

Health equity analysis

Using monthly household expenditure in the RISKESDAS 2018 survey as proxy for income, the survey population was stratified into quintiles for which respective systolic BP distributions were derived. Evidence from published literature was used to scale the rates of disease incidence, prevalence, case fatality and all-cause mortality to account for baseline differences by income quintile. We used the relative concentration index (*CIx*) to quantify the relative distribution of health benefits (HALYs) by population income quintiles. The *CIx* is a relative measure of inequality that estimates how concentrated a (health) outcome is by sub-groups of a given variable.[31] A positive value denotes the inequality favours the most advantaged income quintile and the converse for a negative value.

Primary and sensitivity analyses

In the primary analysis, we modelled a gradual phase-in of the LSSS policy effect over 5 years. This was assumed to apply mainly to discretionary salt (73.2% of total salt consumed), with a population coverage similar to current salt iodisation levels (91.7%) in Indonesia.[7,19] In univariate sensitivity analysis, we modelled the following scenarios. First, alternate population coverage scenarios: a worst-case (50% national salt replacement coverage) and an optimistic best-case (100% national salt replacement coverage). Second, we evaluated the impact of different LSSS manufacturing prices with low-price and high-price ratio scenarios. Third, discount rates were varied: 0% and 5%. Fourth, we assessed alternate BP-lowering effects of LSSS from another meta-analysis.[32] Finally, we tested the impact of a longer policy phase-in period over 10 years.

Uncertainty analysis

Plausible statistical distributions were specified for uncertain model parameters. To capture the combined impact of this uncertainty, we conducted probabilistic sensitivity analysis (PSA) using Monte Carlo simulations whereby a random draw was made from each parameter distribution. We implemented 2000 iterations for the PSA, which resulted in convergence in the model outputs.[33,34] Estimates of the health benefits, costs and ICERs were obtained as the mean and 2.5th to 97.5th percentiles representing the expected value and uncertainty intervals. Analyses were implemented using Microsoft Excel with the Ersatz ver. 1.35 software add-in and R Studio ver. 4.3.0.[35,36]

Role of the funding source

The study was funded by a Griffith University Post-doctoral Fellowship. Griffith University was not involved in any stage of the conduct of the study. All authors were not precluded from accessing data in the study and they accept responsibility to submit for publication.

Results

Population health benefits

After 10 years of implementation, gradual uptake of the LSSS policy is projected to prevent over 330,000 non-fatal ischaemic heart disease (IHD) events (11.5% reduction), over 378,000 non-fatal ischaemic stroke events (10.7% reduction), 413,000 non-fatal haemorrhagic stroke events (14.4% reduction), 49,000 cases of subarachnoid haemorrhage (SAH, 16.1% reduction), 258,000 cases of hypertensive heart disease (HHD, 19.4% reduction), 110,000 cases of atrial fibrillation (AF, 8.3% reduction) and over 640,000 cases of chronic kidney disease (CKD, 8.2% reduction) in the Indonesian population. Corresponding fatal events averted were 45,000 for IHD (0.7% reduction), 31,000 for ischaemic stroke (3.1% reduction), 79,000 for haemorrhagic stroke (5.2% reduction), 4900 for SAH (2.4% reduction), 35,000 for HHD (1.2% reduction), 300 for AF (0.2% reduction) and 4100 for CKD (0.4% reduction). Over 20 years, the absolute number of averted events were nearly triple that of the 10-year projections (Table 1). Impacts were mostly greater in men (Table 1) and for people in the lowest income quintile (Supplementary Figures S3 and S4).

These changes in disease events would result in 883,500 HALYs (33.1 per 10,000 persons) gained over the first ten years. These benefits increase to 5.1 million HALYs (193.3 per 10,000 persons) over 20 years and about 24.6 million HALYs (921.8 per 10,000 persons) for the population lifetime. HALYs were marginally greater in men (Table 2).

Healthcare and policy implementation costs

We estimate that over US$ 2 billion could be saved in healthcare costs from BP-related disease in the first 10 years, rising to US$ 8.1 billion over 20 years and US$ 22.5 billion over the population lifetime. After accounting for healthcare costs from other diseases due to increased survival following the policy, the corresponding net savings in total healthcare costs were US$ 1.9 billion (US$ 7.3 per capita), US$ 7.3 billion (US$ 27.6 per capita) and US$ 15.7 billion (US$ 59.1 per capita) respectively.

The policy would require US$ 46 million in program costs and US$ 1.1 billion in reformulation costs in the first ten years, increasing to U$ 79.6 million and US$ 2.0 billion respectively over 20 years, and US$ 158.0 million and US$ 4.1 billion respectively over the population lifetime. The total implementation costs for this LSSS policy were estimated at US$ 4.5 per capita over 10 years, US$ 7.9 per capita over 20 years and US$ 16.0 per capita over the lifetime (Table 3).

Equity impacts across income quintiles

Across all time horizons, compared to their wealthiest counterparts (Q5), people in the lowest income quintile (Q1) were projected to have greater health gains after 10

Horizon–10 years	Men estimate (95% UI)	% change (95% UI)	Women estimate (95% UI)	% change (95% UI)	All persons estimate (95% UI)	% change (95% UI)
Non-fatal events						
Ischaemic heart disease	244,166 (210,932–271,005)	12.2 (10.5–13.5)	88,882 (69,354–104,504)	10.2 (8.0–12.0)	332,235 (294,907–365,150)	11.5 (10.2–12.7)
Ischaemic stroke	188,870 (159,763–213,222)	11.7 (9.9–13.2)	190,542 (144,059–229,021)	10.0 (7.5–12.0)	378,647 (322,924–428,422)	10.7 (9.2–12.2)
Haemorrhagic stroke	227,365 (201,375–248,891)	15.4 (13.7–16.9)	186,400 (155,068–213,241)	13.4 (11.1–15.3)	413,376 (369,115–454,332)	14.4 (12.9–15.8)
Subarachnoid haemorrhage	25,578 (22,973–27,890)	16.9 (15.2–18.5)	23,652 (20,309–26,638)	15.4 (13.2–17.4)	49,174 (44,520–53,740)	16.1 (14.6–17.6)
Hypertensive heart disease	149,146 (129,383–161,778)	21.3 (18.5–23.1)	110,230 (87,188–128,086)	17.5 (13.9–20.3)	258,542 (229,608–281,584)	19.4 (17.3–21.2)
Atrial fibrillation	60,048 (49,259–70,531)	9.0 (7.4–10.6)	50,658 (35,205–62,585)	7.6 (5.3–9.4)	110,416 (93,164–126,946)	8.3 (7.0–9.5)
Chronic kidney disease	327,335 (288,338–386,984)	8.3 (7.3–9.8)	315,849 (259,054–405,306)	8.0 (6.5–10.2)	643,700 (572,534–749,803)	8.2 (7.3–9.5)
Fatal events						
Ischaemic heart disease	35,068 (29,678–39,185)	0.8 (0.7–0.9)	10,826 (8236–12,834)	0.4 (0.3–0.5)	45,812 (39,772–50,948)	0.7 (0.6–0.7)
Ischaemic stroke	18,211 (13,417–22,115)	3.7 (2.7–4.5)	13,414 (7415–18,360)	2.5 (1.4–3.5)	31,368 (23,572–38,432)	3.1 (2.3–3.8)
Haemorrhagic stroke	40,596 (33,841–46,429)	5.5 (4.6–6.3)	39,194 (27,665–48,533)	5.0 (3.5–6.2)	79,481 (66,156–91,884)	5.2 (4.3–6.0)
Subarachnoid haemorrhage	2824 (2449–3128)	3.0 (2.6–3.3)	2094 (1667–2439)	1.9 (1.5–2.2)	4902 (4328–5478)	2.4 (2.1–2.7)
Hypertensive heart disease	17,916 (15,181–19,484)	1.2 (1.0–1.3)	17,832 (13,450–21,079)	1.1 (0.8–1.3)	35,589 (30,790–39,431)	1.2 (1.1–1.3)
Atrial fibrillation	148 (107–192)	0.3 (0.2–0.3)	170 (81–242)	0.2 (0.1–0.3)	317 (222–407)	0.2 (0.2–0.3)
Chronic kidney disease	2535 (2004–3041)	0.4 (0.4–0.5)	1666 (1116–2094)	0.4 (0.2–0.4)	4187 (3460–4910)	0.4 (0.3–0.5)
Horizon–20 years	**Men estimate (95% UI)**	**% change (95% UI)**	**Women estimate (95% UI)**	**% change (95% UI)**	**All persons estimate (95% UI)**	**% change (95% UI)**
Non-fatal events						
Ischaemic heart disease	644,570 (579,228–702,393)	13.8 (12.4–15.1)	235,216 (195,643–270,404)	11.5 (9.6–13.2)	878,265 (801,113–953,000)	13.1 (11.9–14.2)
Ischaemic stroke	485,052 (430,421–535,782)	13.3 (11.8–14.6)	489,486 (405,126–566,057)	11.3 (9.3–13.0)	972,890 (863,257–1,079,212)	12.2 (10.8–13.5)
Haemorrhagic stroke	567,824 (521,458–612,228)	17.6 (16.2–19.0)	472,377 (411,011–527,309)	15.1 (13.1–16.8)	1,039,695 (956,363–1,119,908)	16.4 (15.0–17.6)
Subarachnoid haemorrhage	61,024 (56,604–65,331)	19.4 (18.0–20.8)	57,657 (51,381–63,322)	17.5 (15.6–19.2)	118,343 (110,022–127,095)	18.4 (17.1–19.8)
Hypertensive heart disease	409,739 (370,424–438,082)	24.5 (22.2–26.2)	308,862 (263,356–349.817)	20.2 (17.2–22.9)	716,529 (655,257–769,172)	22.4 (20.5–24.0)
Atrial fibrillation	160,574 (139,100–181,341)	10.3 (9.0–11.7)	136,105 (107,047–163,058)	8.7 (6.8–10.4)	296,455 (259,933–331,865)	9.5 (8.3–10.6)
Chronic kidney disease	728,601 (656,908–819,066)	9.9 (9.0–11.1)	677,380 (575,347–799,698)	9.2 (7.8–10.8)	1,409,397 (1,274,857–1,564,581)	9.6 (8.6–10.6)
Fatal events						
Ischaemic heart disease	176,349 (158,916–193,342)	2.6 (2.3–2.8)	53,644 (45,134–60,995)	1.4 (1.2–1.6)	229,484 (210,324–248,820)	2.1 (2.0–2.3)
Ischaemic stroke	100,774 (84,192–116,402)	6.5 (5.4–7.5)	77,920 (55,455–98,094)	4.8 (3.5–6.1)	178,549 (148,168–206,750)	5.6 (4.7–6.5)
Haemorrhagic stroke	203,570 (182,384–222,880)	10.3 (9.2–11.2)	189,083 (157,156–217,937)	9.1 (7.6–10.5)	392,048 (350,482–431,081)	9.7 (8.7–10.6)
Subarachnoid haemorrhage	15,344 (13,925–16,561)	7.4 (6.7–8.0)	11,875 (10,332–13,268)	5.1 (4.5–5.8)	27,148 (24,937–29,461)	6.2 (5.7–6.7)
Hypertensive heart disease	93,273 (84,418–99,536)	3.8 (3.5–4.1)	91,554 (77,138–104,130)	3.6 (3.0–4.0)	184,473 (167,924–198,680)	3.7 (3.3–4.0)
Atrial fibrillation	486 (366–644)	0.5 (0.4–0.7)	648 (340–935)	0.5 (0.3–0.6)	1139 (797–1471)	0.5 (0.4–0.6)
Chronic kidney disease	12,620 (10,732–14,823)	1.2 (1.0–1.4)	8797 (6985–10,633)	1.0 (0.8–1.2)	21,425 (18,567–24,426)	1.1 (1.0–1.2)

UI: uncertainty interval.

Table 1: **Estimated blood pressure-related disease events averted over the first 10 and 20 years due to switching from regular salt to low-sodium potassium-rich salt substitutes in the 2019 cohort of adults in Indonesia.**

	Men estimate, in thousands (95% UI)	Women estimate, in thousands (95% UI)	All persons estimate, in thousands (95% UI)	Per 10,000 persons estimate (95% UI)	Change (%) from primary
Horizon–10 years					
Primary analysis	473.6 (404.5–523.2)	411.4 (316.4–482.3)	883.5 (774.7–976.7)	33.1 (29.0–36.6)	–
Sensitivity analyses					
50% coverage	267.5 (230.4–295.2)	231.8 (177.0–273.4)	497.6 (434.6–552.3)	18.6 (16.3–20.7)	−43.7
100% coverage	514.2 (437.4–566.0)	447.6 (348.9–525.6)	958.0 (839.4–1060.1)	35.9 (31.5–39.7)	+8.4
0% discount	585.5 (501.5–643.4)	511.5 (390.4–600.8)	1091.4 (952.3–1210.1)	40.9 (35.7–45.3)	+23.5
5% discount	412.3 (349.7–453.1)	358.4 (277.3–421.9)	768.1 (668.8–846.9)	28.8 (25.1–31.7)	−13.1
Alternate BP effects	289.7 (249.4–318.3)	250.3 (191.0–295.3)	538.3 (468.2–597.2)	20.2 (17.5–22.4)	−39.1
10-year phase-in	269.7 (230.7–298.5)	234.5 (181.9–276.7)	502.3 (440.0–556.5)	18.8 (16.5–20.8)	−43.1
Horizon–20 years					
Primary analysis	2852.7 (2576.6–3079.2)	2318.7 (1938.9–2631.9)	5158.6 (4684.2–5565.9)	193.3 (175.5–208.5)	–
Sensitivity analyses					
50% coverage	1618.6 (1457.0–1752.3)	1304.4 (1087.3–1489.4)	2919.5 (2649.5–3161.2)	109.4 (99.3–118.4)	−43.4
100% coverage	3082.0 (2769.4–3335.2)	2511.5 (2094.0–2862.5)	5580.8 (5079.0–6051.9)	209.1 (190.3–226.7)	+8.2
0% discount	4342.9 (3931.4–4688.4)	3526.3 (2948.6–4007.7)	7849.6 (7126.9–8498.9)	294.1 (267.0–318.4)	+52.2
5% discount	2171.2 (1933.6–2341.3)	1765.3 (1483.7–2009.4)	3932.4 (3576.1–4241.4)	147.3 (134.0–158.9)	−23.7
Alternate BP effects	1746.4 (1574.3–1883.5)	1410.3 (1177.1–1614.7)	3151.2 (2859.3–3411.7)	118.1 (107.1–127.8)	−38.9
10-year phase-in	2135.6 (1920.8–2309.3)	1748.9 (1450.9–1983.5)	3881.3 (3498.2–4196.9)	145.4 (131.1–157.2)	−24.7
Horizon–population lifetime					
Primary analysis	13,497.3 (12,730.5–14,200.4)	11,111.4 (9989.2–12,103.9)	24,604.3 (23,192.8–25,843.1)	921.8 (868.9–968.2)	–
Sensitivity analyses					
50% coverage	7617.8 (7137.4–8049.1)	6245.8 (5559.1–6833.2)	13,840.8 (13,046.5–14,623.4)	518.6 (488.8–547.9)	−43.7
100% coverage	14,572.3 (13,755.9–15,351.3)	12,045.1 (10,929.6–13,131.5)	26,601.7 (25,152.0–27,956.4)	996.6 (942.3–1047.4)	+8.1
0% discount	37,276.2 (34,941.3–39,422.1)	31,583.1 (28,317.3–34,585.8)	68,819.8 (64,799.8–72,634.0)	2578.4 (2427.8–2721.3)	+179.7
5% discount	7491.0 (7022.4–7892.7)	6083.8 (5454.8–6658.3)	13,567.9 (12,760.7–14,289.3)	508.3 (478.1–535.4)	−44.8
Alternate BP effects	8231.3 (7722.7–8685.1)	6735.9 (6053.3–7405.9)	14,948.7 (14,119.3–15,780.9)	560.1 (529.0–591.2)	−39.2
10-year phase-in	12,214.1 (11,494.3–12,936.7)	10,108.9 (9043.4–10,988.1)	22,312.5 (21,010.9–23,475.4)	835.9 (787.2–879.5)	−9.3

Primary analysis includes a gradual phase-in of the intervention effect over 5 years assumed to apply only to discretionary salt (73.2% of total salt consumed), with a population coverage similar to salt iodisation levels (91.9%) in Indonesia, and a 3% discount rate applied to both health benefits and costs. BP: blood pressure; UI: uncertainty interval.

Table 2: **Projected gains in health-adjusted life-years by sex, for the total population, and per 10,000 persons in the primary and sensitivity analyses over different time horizons.**

years (212,300 vs. 148,500 HALYs; concentration index (*CIx*) = −0.087, 95% confidence interval −0.104 to −0.069), 20 years (1.2 million vs. 0.9 million HALYs; *CIx* = −0.084, −0.100 to −0.067) and over the lifetime of the population (5.8 million vs. 4.3 million HALYs; *CIx* = −0.075, −0.088 to −0.062) (Fig. 2).

Similarly, net health expenditure savings were comparatively greater in the lowest income (Q1) compared to the highest income (Q5) populations after 10 years (US$ 445 million vs. US$ 339 million), 20 years (US$ 1.7 billion vs. US$ 1.3 billion) and over the lifetime of the population (US$ 3.4 billion vs. US$ 2.9 billion) (Fig. 3 and Supplementary Figure S5).

Cost-effectiveness analysis

In our primary analysis, we estimate that compared to status quo, the LSSS policy could result in net cost savings of US$ 1.9 billion in the first 10 years, US$ 7.3 billion over 20 years and US$ 15.7 billion over the population's lifetime. The incremental cost-effectiveness ratios were dominant in all time horizons, with the LSSS policy having a 99% probability of being cost-saving over 10 years, and 100% probability over 20 years and the population lifetime (Table 3 and Fig. 4).

Sensitivity analysis

Unsurprisingly, HALYs were influenced by discount rates. In addition, if only 50% of the salt was switched to LSSS, the HALYs gained reduced by 43%. Using alternate evidence on the BP-lowering effects of LSSS reduced the health benefits by about a third. Furthermore, when a 10-year phase-in (instead of 5 years) was applied, HALYs reduced by 43% in the first 10 years, but the impact was only marginal over the lifetime (Table 2).

Using LSSS had a 95–100% probability of being very cost-effective in all scenarios irrespective of time horizon (Fig. 4). Over 10 years, the probabilities of being cost-saving ranged from 0 to 42% in some scenarios, e.g., using a high price ratio for LSSS, a sub-optimal population coverage, alternate BP-lowering effects, and longer (10 years vs. 5 years) effect phase-in period. However, as the full scale of benefits accrue into the

Outcomes	10 years		20 years		Population lifetime	
	Estimate, in millions of US$ (95% UI)	Per capita, US$ (95% UI)	Estimate, in millions of US$ (95% UI)	Per capita, US$ (95% UI)	Estimate, in millions of US$ (95% UI)	Per capita, US$ (95% UI)
Healthcare costs						
Ischaemic heart disease	−492.8 (−564.2 to −414.5)	−1.9 (−2.1 to −1.6)	−2037.3 (−2252.0 to −1814.1)	−7.6 (−8.4 to −6.8)	−5806.5 (−6198.9 to −5386.9)	−21.8 (−23.2 to −20.2)
Ischaemic stroke	−393.7 (−454.6 to −325.6)	−1.5 (−1.7 to −1.2)	−1668.9 (−1.857.5 to −1.458.8)	−6.3 (−7.0 to −5.5)	−5149.3 (−5577.9 to −4728.8)	−19.3 (−20.9 to −17.7)
Haemorrhagic stroke	−562.6 (−634.5 to −489.7)	−2.1 (−2.4 to −1.8)	−2070.6 (−2261.3 to −1870.3)	−7.8 (−8.5 to −7.0)	−4414.9 (−4726.8 to −4115.7)	−16.5 (−17.7 to −15.4)
Subarachnoid haemorrhage	−76.0 (−85.4 to −66.8)	−0.3 (−0.3 to −0.3)	−293.2 (−323.0 to −266.1)	−1.1 (−1.2 to −1.0)	−662.0 (−713.3 to −616.6)	−2.5 (−2.7 to −2.3)
Hypertensive heart disease	−65.7 (−73.5 to −56.9)	−0.2 (−0.3 to −0.2)	−267.7 (−292.5 to −240.0)	−1.0 (−1.1 to −0.9)	−863.5 (−916.3 to −803.9)	−3.2 (−3.4 to −3.0)
Atrial fibrillation & flutter	−102.2 (−120.6 to −83.2)	−0.4 (−0.5 to −0.3)	−477.1 (−539.3 to −413.2)	−1.8 (−2.0 to −1.5)	−1828.4 (−1980.7 to −1661.5)	−6.9 (−7.4 to −6.2)
Chronic kidney disease	−335.8 (−410.4 to −290.5)	−1.3 (−1.5 to −1.1)	−1337.7 (−1560.7 to −1203.7)	−5.0 (−5.8 to −4.5)	−3767.6 (−4229.9 to −3457.2)	−14.1 (−15.8 to −13.0)
Total cost offset from major BP-related diseases	−2036.3 (−2228.8 to −1804.2)	−7.6 (−8.4 to −6.8)	−8169.9 (−8765.2 to −7516.4)	−30.6 (−32.8 to −28.2)	−22,524.8 (−23,765.5 to −21,248.8)	−84.4 (−89.2 to −79.6)
Total cost accrued to unrelated diseases	78.9 (62.7–93.8)	0.3 (0.2–0.4)	791.5 (670.9–897.6)	3.0 (2.5–3.4)	6762.7 (6278.5 to 7250.1)	25.3 (23.5–27.2)
Net total healthcare costs	−1957.3 (−2146.2 to −1734.4)	−7.3 (−8.0 to −6.5)	−7380.2 (−7928.1 to −6780.9)	−27.6 (−29.7 to −25.4)	−15,762.2 (−16,792.3 to −14,798.1)	−59.1 (−62.9 to −55.4)
Implementation costs						
Salt substitute policy program cost	46.2 (30.4–68.5)	0.2 (0.1–0.3)	79.6 (52.9–112.7)	0.3 (0.2–0.4)	158.0 (102.2–230.6)	0.6 (0.4–0.9)
Incremental salt reformulation cost	1194.8 (781.8–1723.9)	4.5 (2.9–6.5)	2028.5 (1350.0–2956.4)	7.6 (5.1–11.1)	4141.4 (2692.4–5984.9)	15.5 (10.1–22.4)
Total policy implementation costs	1214.4 (788.1–1798.7)	4.5 (3.0–6.7)	2107.1 (1421.8–3028.6)	7.9 (5.3–11.3)	4279.4 (2848.7–6117.1)	16.0 (10.7–22.9)
Overall net costs	−734.6 (−1198.7 to −114.1)	−2.8 (−4.5 to −0.4)	−5251.5 (−6170.5 to −4202.2)	−19.7 (−23.1 to −15.7)	−11,430.8 (−13,298.5 to −9512.5)	−42.8 (−49.8 to −35.6)
ICER, cost (US$) per HALY	Dom (Dominant to Dominant)		Dom (Dominant to Dominant)		Dom (Dominant to Dominant)	
Probability of being cost-effective	100%		100%		100%	
Probability of being very cost-effective	100%		100%		100%	
Probability of being cost saving	99.0%		100%		100%	

All costs are discounted at 3% in the primary analysis; Dom, Dominant. BP: blood pressure; ICER: incremental cost-effectiveness ratio; HALY: health-adjusted life year.

***Table 3:* Estimated healthcare costs, policy implementation costs accrued and incremental cost-effectiveness ratios from implementing the low-sodium potassium-rich salt substitutes policy compared to using regular salt over different time horizons in Indonesia.**

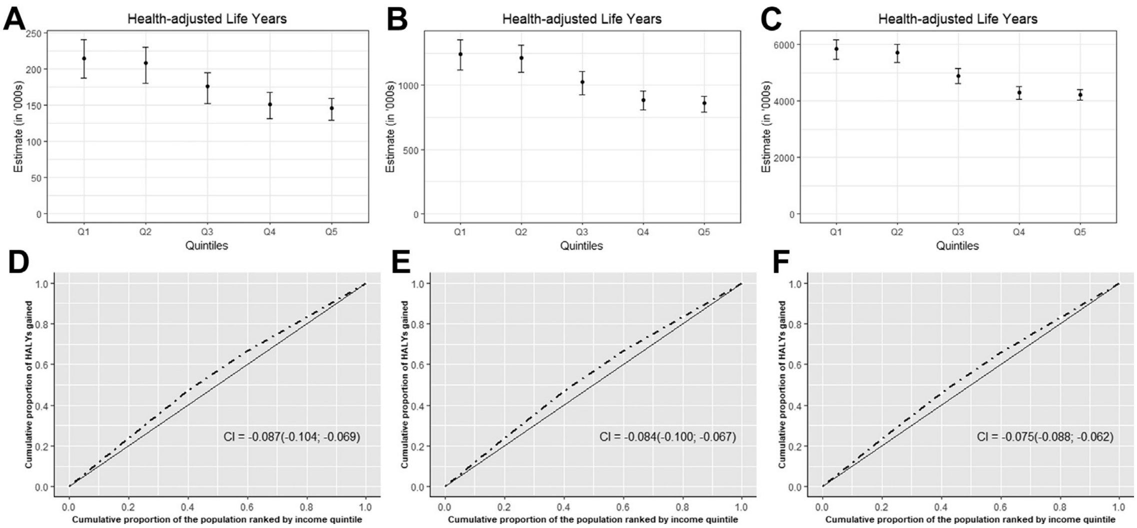

***Fig. 2:* Health-adjusted Life Years (HALY) gained by income quintile over 10 years (panel A), 20 years (panel B) and population lifetime (panel C) with corresponding concentration curves below depicting the relative inequality in the distribution of HALY gains in the 2019 Indonesian population after 10 years (panel D), after 20 years (panel E) and population lifetime (panel F).** Q1, quintile 1 (lowest income quintile), Q5, quintile 5 (highest income quintile). In panels A-C, the black dot represents the point estimate (mean HALY) while the error bars denote the uncertainty intervals. In panels D-F, the solid black diagonal line refers to the line of equality. The dot-dashed line denotes relative inequality with greater HALYs for those in the lower income quintiles. The CI refers to concentration index and the values in brackets are the 95% confidence intervals around the point estimate for the concentration index.

future, LSSS had a 100% probability of being cost saving in all sensitivity scenarios except for the high LSSS price scenario with a 62.6% and 71.4% probability of being cost saving over 20 years and the lifetime of the population respectively (Fig. 4 and Supplementary Table S21).

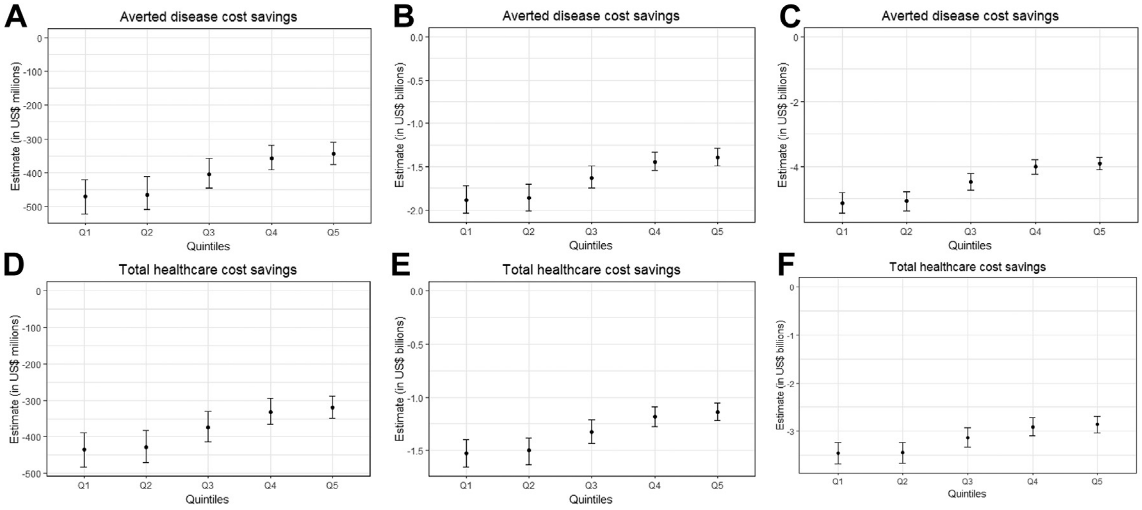

***Fig. 3:* Healthcare costs savings due to averted BP-related diseases by income quintile over 10 years (panel A), 20 years (panel B) and population lifetime (panel C) with corresponding net savings in total health expenditure after accounting for costs due to unrelated diseases as people live longer due to reduced events and mortality rates associated with the LSSS policy over first 10 years (panel D), 20 years (panel E) and the population lifetime (panel F).** Q1, quintile 1 (lowest income quintile), Q5, quintile 5 (highest income quintile). The black dot represents the point estimate (mean HALY) while the error bars denote the uncertainty intervals.

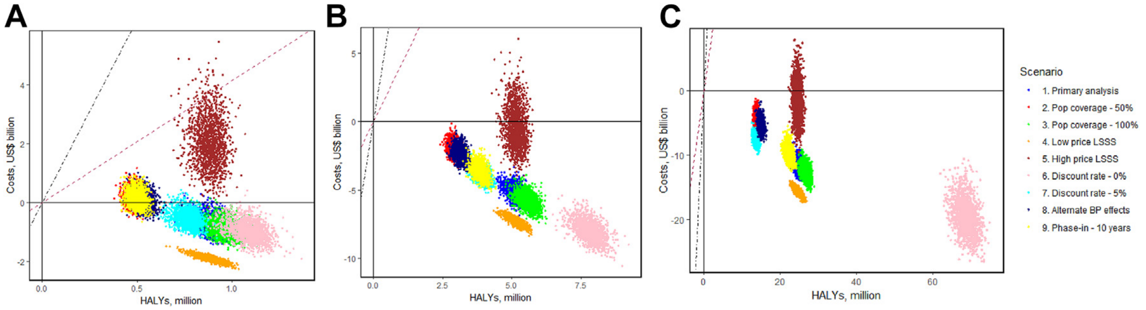

Fig. 4: **Cost-effectiveness planes depicting the decision uncertainty for implementing LSSS compared to regular salt consumption in Indonesia in the primary and sensitivity analyses in the first 10 years (panel A), 20 years (panel B) and population lifetime (panel C).** Primary analysis includes a gradual phase-in of the intervention effect over 5 years assumed to apply only to discretionary salt (73.2% of total salt consumed), with a population coverage similar to salt iodisation levels (91.9%) in Indonesia, and a 3% discount rate applied to both health-adjusted life years (HALYs) and costs. The maroon dashed line represents the willingness to pay threshold denoting an intervention as being very cost-effective in Indonesia based on 1*GDP per capita (US$ 4,151, as of July 2019) while the black dot-dash line represents the willingness to pay threshold denoting an intervention as being cost-effective in Indonesia based on 3*GDP per capita (US$ 12,453, in 2019).

Discussion

Our analysis demonstrates that use of LSSS could significantly reduce non-fatal and fatal events from multiple BP-related diseases in Indonesia, with substantial gains in healthy life years (~922 HALYs per 10,000 persons) over the lifespan of the cohort of adult Indonesians. The greatest health benefits are estimated to occur in those in the lowest income quintile. Implementing the LSSS policy was estimated to be a cost-saving intervention at 10 years, 20 years and over the lifespan of the adult cohort, owing to the substantial net healthcare costs savings (US$ 65 per capita) outweighing implementation costs (~US$ 16 per capita). While results were slightly sensitive to alternate assumptions such as higher price for salt substitutes and low population coverage, the intervention was nevertheless very cost-effective.

Despite the growing evidence on effectiveness of LSSS in reducing blood pressure, only a few studies have evaluated the long-term population health benefits of this strategy. Using comparative risk assessment (CRA) methods, LSSS were projected to prevent about 743,000 non-fatal cardiovascular events and 461,000 cardiovascular deaths each year in China.[37] Similar CRA analysis in India found that up to 559,000 new cardiovascular events and 214,000 cardiovascular deaths could be prevented in one year.[38] Contrary to the 'cross-sectional' type modelling used in the above studies, our study uses a multistate lifetable modelling approach which is a more dynamic analysis including a (prospective) time component simulating age-specific and sex-specific cohorts of the population over their remaining lifetime. In a study applying the latter simulation methods, we have previously shown that LSSS could avert 144,000 incident cardiovascular events and 84,000 deaths resulting in over 368,000 HALYs gained in Cameroon.[34] The differences in the magnitude of the benefits of LSSS on population health between prior literature and the current study could be explained in part by variance in population sizes, baseline disease risks and varying modelling methods. However, taken together, the evidence suggests a potentially sizeable impact that LSSS could have on population health.

Our study shows that a government-led LSSS policy has the potential to reduce cardiovascular health inequalities with larger benefits in the poor population, and relatively greater health benefits in men than women. These findings are likely explained in part by men and people with low-income in Indonesia having high (i) baseline BP and (ii) CVD or CKD incidence and case fatality rates.[39] Our literature search did not find studies in Asia or globally that had assessed the effect of LSSS across income quintiles of the population or socio-economic strata. However, two studies from the UK have assessed inequality impacts of other salt reduction strategies. A forecast analysis by Gillespie and colleagues,[40] showed that mandating the reformulation of food products to lower sodium-containing alternatives had a high likelihood of reducing health inequalities. Furthermore, a microsimulation study by Kypridemos and colleagues[41] demonstrated that while the salt reduction policies (public awareness campaigns, food labelling and voluntary reformulation of processed foods) implemented in the UK between 2003 and 2015 reduced CVD burden, they did not reduce inequalities in health. However, their modelling showed that further inclusion of structural and legislative policies (as opposed to voluntary initiatives) was more likely to reduce inequalities in CVD burden.[40,41]

Furthermore, our analysis suggests that LSSS are good value for money. After accounting for full intervention program and implementation costs and the extra healthcare costs from increased longevity due to the intervention, LSSS was a dominant strategy. That is, regardless of time horizon there were massive health gains and cost-savings. Even when only half of the population adhered to the strategy or the highest price of the salt substitute was considered, the policy was still very cost-effective. Our findings are largely consistent with prior modelling studies.[34,42] Using a different analytical approach, Li et al. conducted a within-trial economic evaluation of the Salt Substitutes and Stroke Study and demonstrated that over a 4.7-year follow-up period, compared to using regular salt, the use of salt substitutes resulted in an extra 0.054 Quality adjusted life-years (QALYs) per person on average in China. In addition, the intervention was cost-saving across all sensitivity analyses, except in the scenarios applying the median and highest market price of salt substitutes for which the intervention was rather cost-effective.[43]

Public health policy implications

As the burden of hypertension continues to grow in Indonesia alongside a non-reassuring care cascade with low rates of effective treatment, prevention is critical to curb the looming consequences.[4,44] Recent analysis of the WHO 'best-buy' interventions indicated that every dollar invested in these interventions for LMICs could yield a return of US$7 on average, with the highest returns generated by interventions targeting salt reduction.[45] The Government of Indonesia is committed to achieving universal health coverage in part through its National Health Insurance scheme which covers the NCD package of essential services (WHO-PEN) at primary, secondary and tertiary health facilities.[46] Despite these efforts, NCDs (predominantly CVD) continue to account for the largest share (>52%) of national health expenditure.[47] Our analysis shows that investing in primary prevention through LSSS could substantially reduce health expenditure, saving over US$ 1.8 billion (IDR 25.4 trillion) in the first ten years following implementation.

Low awareness, availability, cost, and safety have been identified as potential challenges that may affect scaling the use of LSSS across the population.[48,49] Culturally, the local Indonesian cuisine relies substantially on salt and salty flavours for taste enhancement leading to high preference for salty foods. Therefore, salt substitutes developed for this setting will need to closely mimic the texture and taste of regular salt to enhance acceptability.[50,51] In addition, the proliferation of processed and ultra-processed foods[52] requires attention as most of these foods are high in sodium. Industry reformulation with LSSS alternatives will need to strike the balance of simultaneously achieving acceptable taste and shelf-life.[53] However, evidence suggests that LSSS in which up to 25–30% of the sodium chloride is replaced with potassium chloride has similar taste, acceptability, and comparable shelf-life to regular salts,[54] and should be a starting point for implementation. Given the low awareness levels on health risks associated with excess sodium intake and the benefits of using LSSS, the government will need to invest in educational campaigns to improve awareness and consumer perceptions as part of measures to reduce population sodium intake.[51]

Indonesia is an archipelago with over 17,000 islands. Ensuring the availability of LSSS in remote areas or low-income communities may be a challenge and would require establishing effective supply chains and incentivising salt industries to produce affordable LSSS for optimal population coverage. Taxing products that are high in salt content could generate revenue to plough back as subsidies that improve affordability of LSSS. Finally, Indonesia has complex regulatory frameworks governing local salt production, imports, and distribution. Thus, switching the salt supply to LSSS alternatives may entail navigating complex bureaucratic processes.[55] Strong political commitment or preferably, a government-led policy as proposed in our analysis, will be critical to achieve optimal outcomes. Taken together, a multi-faceted approach involving collaboration between government agencies, industry stakeholders, healthcare professionals, and consumer advocacy groups is required to promote awareness, develop suitable LSSS alternatives, and facilitate behaviour change towards reducing sodium intake in the Indonesian population.

Safety concerns have been highlighted on the potential of LSSS to cause hyperkalaemia particularly in people with severe kidney disease. In a recent Cochrane review of 26 trials, moderate certainty evidence from five of the included randomised controlled trials (RCTs) indicated there was little or no difference in the risk of hyperkalaemia in people receiving salt substitutes compared to regular salt.[56] Thus far, there is insufficient evidence demonstrating this hyperkalaemia risk given that most of the RCTs on LSSS excluded persons at high risk of hyperkalaemia. There is need for more research exploring this hyperkalaemia risk while carefully navigating the existing ethical dilemma.[56,57] The Indonesian government's proposed strategy requiring manufacturers to label the nutrient content of food products could include specification of potassium content in LSSS products. This could alert at-risk persons to seek advice from their healthcare provider prior to using LSSS. Given that potassium intake is substantially low in Indonesia with almost none consuming up to the minimum daily requirements,[6] using LSSS is less likely to be a significant problem in this setting.

Our study has some limitations. First, due to the paucity of data, this study relied on the GBD study for epidemiological estimates and hence is susceptible to its inherent limitations.[2] Though multiple primary Indonesian data sources are used in generating GBD estimates for the country, there remain some areas of weakness such as incidence, case fatality and relative risk data. Thus, to strengthen the evidence-base that informs that GBD estimates for Indonesia, there is need for large-scale population-based longitudinal and burden of disease studies, estimating these epidemiological parameters as well as the causal relationships between risk factors and CVDs, and other chronic diseases in Indonesia. However, GBD uses robust analytical procedures and the available country data to produce consistent estimates of health outcomes globally. These estimates continue to be used by policy makers in Indonesia to guide health decisions.[2,15] Second, due to the absence of empirical evidence in the Indonesian setting, our analysis relies on meta-analyses of RCTs for the effectiveness of LSSS in reducing systolic BP. The overall GRADE assessment of the evidence for the systolic BP outcome was classified as low certainty, driven by small study populations and some RCTs with unclear risk of bias. There is need for large and robust RCTs in Indonesia to generate strong contextual evidence to refine future cost-effectiveness studies. In line with the above, our analysis uses multiple secondary data sources, including existing surveys, Indonesian government reports and published literature. While this is not uncommon in cost-effectiveness studies, we applied stringent criteria prior to using these data such as national representativeness, and published literature had to be based on Indonesian data or other similar Asian settings. We imposed plausible statistical distributions around all key input data and conducted probabilistic sensitivity analysis to capture the combined impact of this parameter uncertainty on the model results. Our reported impacts of LSSS are conservative given that our health system perspective does not capture the broader productivity impacts. Adding these societal benefits are likely to further enhance the economic credentials of this LSSS policy.[58] As our modelling focuses on the direct BP effects of LSSS, we did not include other diseases like stomach cancer which can be influenced by reduction in sodium intake. Our results therefore underestimate the full scale of benefits from this policy.

Our study has some key strengths. This is the first evaluation of the health impacts and cost-effectiveness of implementing LSSS in Indonesia. In addition, as national estimates can sometimes mask underlying health inequalities, we attempt to address this for the first time in the LSSS literature by exploring distributional impacts across income quintiles. Next, we maximised the use of Indonesia-specific data to parameterise our model. Blood pressure data were obtained from the RISKESDAS 2018 study, a nationally representative survey with objective measurements. Healthcare costs were derived from the National Health Insurance scheme which covers over 84% of the Indonesian population. We conduct multiple univariate sensitivity analyses to test the robustness of our results over different time horizons. Taken together, our analysis provides quantitative evidence of the decision uncertainty with implementing LSSS, which could inform strategies for the prevention of NCDs in Indonesia.

Low-sodium potassium-rich salt substitutes are increasingly gaining traction as an effective approach to reduce average population blood pressures. A government-led policy to switch the current salt consumed to LSSS could avert substantial cases of non-fatal and fatal vascular events in Indonesia. Besides longevity, our modelling suggests the policy has the potential to reduce health inequalities and offers good value for money. For Indonesia and other low- and middle-income settings where most of the salt consumed is discretionary, LSSS should be prioritised as part of broader efforts to tackle high blood pressure and NCD burden.

Contributors

Conceptualisation: LNA, NK, JLV; Data curation: LNA, WPN, RM, TR, NK; Formal analysis: LNA; Funding acquisition: LNA; Methodology: LNA, NK, JLV; Project administration: LNA; Supervision: JLV; Validation: LNA, WPN, NK, RM, TR, SM, FD; Writing–original draft: LNA; Writing–review and editing: LNA, WPN, RM, TR, SM, FD, LJV.

Data sharing statement

The data used in this study can be obtained from the corresponding author upon reasonable request.

Declaration of interests

LNA received funds from Griffith University (institutional fellowship) to support this project. LNA has received consulting fees from The World Bank (direct payment) and is currently supported by an Australian National Health and Medical Research Council (NHMRC) Investigator Grant (GNT 2018082) and a Heart Foundation Honorary Fellowship. JLV receives salary from Griffith University and has received consulting fees from The World Bank (direct payment). Authors have declared no other conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lansea.2024.100432.

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