British Journal of Nutrition (2023), 129, 1598–1606 doi:10.1017/S0007114522001568

The social cost of high sodium diet in Singapore

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(Submitted 26 January 2022 – Final revision received 30 April 2022 – Accepted 11 May 2022 – First published online 26 May 2022)

Abstract

High sodium (Na) diet is one of the leading behavioural risks of disease identified in the Singapore Burden of Disease Study. We aim to estimate the cost attributable to a high Na diet in Singapore in 2019 from a societal perspective by employing a prevalence-based approach in cost-of-illness studies. We extracted national-level healthcare data and population attributable fractions by sex and age. Costs included direct and indirect costs from inpatient treatment and productivity losses. In 2019, the annual societal cost attributable to a high Na diet was conservatively estimated to be USA$262 million (95 % uncertainty interval (UI) 218, 359 million). At least USA$67·8 million (95 % UI 48·4, 120 million) and USA $194 million (95 % UI 153, 274 million) could be saved on healthcare and indirect costs, respectively, if the daily Na intake of Singaporeans was reduced to an average of 3 g. Overall, males had higher costs compared with females at USA$221 million (95 % UI 174, 312 million) and USA$41·1 million (95 % UI 33·5, 61·7 million), respectively. Productivity loss from foregone wages due to premature mortality had the largest cost at USA $191 million (95 % UI 150, 271 million). CVD had the largest healthcare expenditure at USA$61·4 million (95 % UI 41·6, 113 million), driven by ischaemic heart disease at USA$41·0 million (95 % UI 21·4, 88·9 million). Our study found that reducing Na intake could reduce future healthcare expenditures and productivity losses. This result is vital for policy evaluation in a rapidly ageing society like Singapore, where the burden of diseases associated with high Na diet is expected to increase.

Key words: **Sodium diet: Population attributable fractions: Social cost**

Globally, the average salt consumption in 2010 was estimated at 9–12 g daily, twice of the WHO recommended daily intake of less than 5 g, approximately 2 g of sodium (Na)[1–3]. Na is a chemical element found in salt, where 1 g of salt contains approximately 0·4 g of Na[3]. There have been efforts to quantify the burden of disease attributable to dietary factors in the past decade. Among these efforts is the Global Burden of Disease (GBD) Study in 2017, where around one-third of the diet-related deaths and disability-adjusted life years (DALY) are attributable to high intake of Na (3 million deaths and 70 million DALY)[4]. For consistency with the GBD, we will use 'Na' instead of 'salt' throughout the paper.

In a review paper, studies have found positive associations between high Na intake and high blood pressure[5], and non-communicable diseases such as CVD[5,6] and stomach cancer[7,8]. These clinical outcomes due to high Na intake are mediated by various pathways such as increased blood pressure, damaged blood vessels and hormonal changes[9]. Additionally, the International Study of Sodium, Potassium, and Blood Pressure found an association between age with Na intake and increased blood pressure, where ageing could delay the rise in blood pressure due to excessive Na intake[10]. Coupled with a rapidly ageing population, the burden of CVD is expected to increase with a higher prevalence of unhealthy diet[11]. It is thus imperative for governments to mitigate the increasing burden and cost to both society and health systems.

Regional Na consumption estimate comparisons found that several parts of Asia (e.g. East, Pacific and Central) ranked top and had distinguishably higher daily Na intake than all other regions (e.g. Africa and America)[12]. Even though a high Na diet poses a significant burden from increased healthcare cost, and

Abbreviations: DALY, disability-adjusted life year; GBD, Global Burden of Disease; LFPR, labour force participation rate; Na, sodium; PAF, population attributable fraction; UI, uncertainty interval.

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indirect cost from absenteeism and reduced productivity, few studies have estimated the cost attributable to a high Na diet in Asia, where Na intake is high. The cost-of-illness study using population attributable fractions (PAF) is widely used by studies to estimate the cost attributable to a known risk factor[13]. Examples of such studies are the analysis of healthcare spending attributable to modifiable risk factors in the USA[14] and a global analysis to estimate disease-specific and country-specific costs attributable to physical inactivity[15]. In Singapore, it has been applied to estimate the impact of smoking in 2014[16]. However, to the best of the authors' knowledge, no local study has evaluated the cost attributable to a high Na diet.

The Singapore Health Promotion Board adopts WHO's guidelines on Na consumption and makes an effort to reduce national Na intake through collaborations with multiple stakeholders and policymakers[17]. Since Singapore's War on Salt launched in 2011, collaborations between food manufacturers and nutrition experts have encouraged companies to develop healthier food and Na alternatives locally[17]. Products like sauces and processed canned meats that carry healthier choice labels are created to help consumers identify that these products contained at least 25 % less Na than similar products[18]. Despite efforts, the survey found that approximately 90 % of Singaporeans still exceeded the recommended daily Na consumption, with an average of 3·6 g in 2018[19]. This intake was higher than the findings in 2010 (3·3 g)[17] and was nearly twice WHO's recommended daily Na intake of 2 g[20]. Findings in 2010 also revealed that adults aged 30–49 years had the highest daily Na intake at 3·6 g, and males had higher Na consumption compared with females (4 g *v.* 2·8 g)[17]. Despite national efforts to reduce Na intake, many Singaporeans still exceed the recommended Na intake. As daily Na consumption differs by sex and age, it is crucial to evaluate the economic impact of high Na diet, inform public health policies and provide evidence for Na reduction interventions in the country. Thus, this paper aims to estimate the societal cost (direct and indirect) attributable to a high Na diet in Singapore, accounting for sex and age differences.

Methods

Study design

Using the prevalence-based approach in cost-of-illness studies, this paper aims to estimate the societal cost of a high Na diet in Singapore in 2019. The cost estimation used a top-down approach by incorporating aggregated sex and age group data with PAF of high Na diet to evaluate the costs attributable to a high Na diet. Following GBD's definition, a high Na diet is defined as having more than 3 g of urinary Na per day. Components of costs included direct costs from healthcare and indirect costs from productivity losses. Direct healthcare cost cumulates medical expenditures from inpatient hospitalisation bills for all diseases associated with a high Na diet. Indirect costs include costs arising from productivity losses when a patient was absent from work due to diseases associated with a high Na diet and the costs society incurs when an individual dies prematurely from a high Na diet.

Estimation of population attributable fraction

The PAF is a crucial parameter used in our study that was estimated by the GBD study 2017[11]. The methodology used by the GBD to estimate PAF was detailed in the study's appendix and will only be summarised in this paper. Defined in the study, PAF for a high Na diet represents the proportion of disease (e.g. hypertensive heart diseases, stomach cancer and ischaemic heart disease) that would be reduced in a population in a specific year (e.g. 2019) if the population had a mean urinary Na measurement of 3 g (uncertainty interval (UI) of 1–5 g). Na was measured by a 24-h urinary excretion, a gold standard to measure dietary Na intake[11]. Although it was quantified that an average of 95 % dietary Na is excreted in urine[21], for simplicity, our study will discuss results assuming that the amount of dietary Na ingested is equivalent to the amount of urinary Na excreted.

The PAF for high Na diet for each disease, age group and sex in Singapore in 2019 is formulated by GBD as follows:

$$PAF_{oas} = \frac{\sum_{x=1}^{u} RR_{oas}(x)P_{as}(x) - RR_{oas}(TMREL_{as})}{\sum_{x=1}^{u} RR_{oas}(x)P_{as}(x)}$$

where PAF_{oas} is the population attributable fraction for outcome o due to a diet high in Na for age group a and sex s. $RR_{oas}(x)$ is the relative risk as a function of exposure level x for a diet high in Na for outcome o, age group a and sex s on a plausible range of 1 to u. $P_{as}(x)$ is the proportion of population of risk group (prevalence), for age group a and sex s; $TMREL_{as}$ is the theoretical minimum risk exposure level (TMREL) for a diet high in Na for age group a and sex s, defined as a mean of 3 g (UI of 1–5 g) of urinary Na a day.

The list of diseases associated with high Na can be found in online Appendix Table 1.

Data sources

PAF of high Na diet in 2019 for Singapore was retrieved from GBD online results tools[11]. These values were further categorised into three levels: (1) stomach cancer, (2) CVD and (3) chronic kidney diseases. Our study utilised 5-year interval PAF values for ages 20–79 and aggregated ages above 80 as a single age group. In the absence of PAF data for younger age groups, these age groups assumed values of the youngest available age group. Overall, PAF estimates of a high Na diet for various diseases are listed in online Appendix Table 1.

Inpatient hospital data, also known as Mediclaims data, were obtained from the Ministry of Health Singapore (not published). Mediclaims data contain national-level healthcare use data with detailed historical transacted bills sizes and hospitalisation information of all patient (Singapore citizens, permanent residents and foreigners) discharge information from Singapore's public and private hospitals. Data were then categorised according to International Classification of Disease (ICD10) codes diagnosed during a hospital stay. All disease-specific ICD10 codes attributable to high Na diet were extracted from the GDB[22] and merged with the Mediclaims data by sex and age. From the Mediclaims data, we obtained inpatient bills, length of hospital stays and total inpatient volume. For indirect cost estimation, we used

Table 1. Cost estimation formula

Category	Types		Formula
Direct cost	Healthcare cost		$\sum_{i=1}^{n_d}\sum_{s=1}^{2}\sum_{a=1}^{n_a} mean\ inpatient\ bill_{si} \times inpatient\ volume_{si} \times PAF_{isa}$
Indirect cost	Productivity losses	Cost from hospitalisation-related absenteeism*	$\sum_{i=1}^{n_d}\sum_{s=1}^{2}\sum_{a=1}^{n_a} mean\ daily\ wages_{sa} \times LFPR_{sa} \times mean\ LOS_{isa} \times inpatient\ volume_{isa} \times PAF_{isa}$
		Foregone wages due to premature mortality*	$\sum_{s=1}^{2}\sum_{a=1}^{n_a} number\ of\ deaths_{sa} \times LFPR_{sa} \times total\ expected\ future\ earnings_{sa} \times PAF_{(all\ causes)sa}$

PAF, population attributable fraction; LFPR, labour force participation rates; LOS, length of hospital stay.
Where $i = 1, \ldots, n_d$ and n_d represents total number of diseases; $s = 1$ and 2 representing male and female, respectively; $a = 1, \ldots, n_a$ and n_a represents total number of age groups with 5-year intervals starting from age 20 with the exception of ages above 80 which were aggregated as one group.
* Excluding ages 80 and above.

sex-specific mean income and labour force participation rates (LFPR) in the year 2019 from the Ministry of Manpower Singapore[23]. All data obtained and cost estimations were done by sex and age groups.

Direct healthcare costs

Using Mediclaims data from the Ministry of Health Singapore, the healthcare cost attributable to a high Na diet for each disease was estimated by multiplying the mean inpatient bill with the inpatient volume and respective PAF values. The total healthcare cost was then summed across all diseases. Only the primary diagnosis codes were used for hospitalisations with multiple Na-related conditions. The formula for the total direct healthcare cost attributable to a high Na diet for the analysis in this paper is presented in Table 1.

Indirect cost

Indirect costs were estimated using the human capital approach[24]. This approach assumes the opportunity cost attributable to a high Na diet from diseases and deaths was tied to an individual's productivity in society. This paper accounted for productivity loss from hospitalisation-related absenteeism and foregone wages due to premature mortality. Productivity losses were calculated for individuals between the ages of 20 and 79, who are economically active in the labour force. This cost cumulated represents an individual's present and future contribution to the society's production if he/she works in full health[13] by assuming future earnings as proxies for future productivity.

Cost from hospitalisation-related absenteeism. Productivity loss due to costs from hospitalisation-related absenteeism was defined as the income lost due to hospitalisation. It was estimated by multiplying the mean daily wages by the LFPR and disease-specific mean length of hospital stay. These values were further multiplied by inpatient volume and PAF values. The formula used to estimate the total productivity loss due to costs from hospitalisation-related absenteeism is found in Table 1.

Foregone wages due to premature mortality. Productivity loss due to foregone wages from premature mortality of an individual was estimated by calculating his present value of lifetime earnings from the year of death to age 79 as a proxy of his total future expected earnings. The total productivity loss due to foregone wages from premature mortality in Singapore in 2019 was estimated across all diseases attributed to a high Na diet. This was done by summing the product of the number of deaths, total expected future earnings, LFPR and overall PAF values. The present value of lifetime earnings was discounted at a rate of 3 %, and an income growth rate of 3·3 % was set as the annualised real wage changes from the Ministry of Manpower Singapore in 2019[25]. The formula is presented in Table 1.

All reported costs are in US dollars (where USA$1 = SG$1·36[26]) for the year 2019. Point estimates in the model were deterministically estimated from mean values.

Sensitivity analysis

Uncertainties in the model were explored by stochastically simulating GBD and Mediclaims data using 10 000 independent draws. GBD's PAF values were drawn from a beta distribution, while inpatient cost, length of hospital stays and the number of deaths were drawn from a log-normal distribution. Wherever possible, the parameters of the distributions were obtained from data. Otherwise, they were estimated using published 95 % UI and a package named 'rriskDistributions' from R[27]. Details of parameters used in the sensitivity analysis can be found in online Appendix Table 2. Uncertainty of the model was characterised by the 95 % UI (2·5th percentile and 97·5th percentile) of the 10 000 draws. All analyses were done using R (version 3.6.3).

Results

Overall results

The societal cost attributable to high Na diet was estimated to be USA$262 million (95 % UI 218, 359 million) in Singapore (Table 2). Overall, males had a higher cost at USA$221 million (95 % UI 174, 312 million) compared with females at USA$41·1 million (95 % UI 33·5, 61·7 million). Productivity loss from foregone wages due to premature mortality had the largest proportion of the cost at USA $191 million (95 % UI 150, 271 million), followed by healthcare cost at USA$67·8 million (95 % UI 48·4, 120 million).

Direct cost

Total healthcare cost attributable to a high Na diet was estimated to be USA$67·8 million (95 % UI 48·4, 120 million), where males had around three times the cost of females (USA$51·8 million *v.* USA$16·0 million). This is approximately 25 % of the total cost.

Table 2. Overall cost of diet high in Na (Odds ratios and 95 % uncertainty intervals)

	Cost, USA$ in million					
	Male		Female		Total	
Cost breakdown	OR	95 % UI	OR	95 % UI	OR	95 % UI
Healthcare cost	51·8	32·5, 101	16·0	11·4, 28·9	67·8	48·4, 120
Productivity losses						
Cost from hospitalisation-related absenteeism	2·56	1·58, 4·92	0·460	0·325, 0·844	3·02	2·04, 5·46
Foregone wages due to premature mortality	166	124, 241	24·7	17·7, 39·5	191	150, 271
Total	221	174, 312	41·1	33·5, 61·7	262	218, 359

UI, uncertainty interval.

Table 3. Direct healthcare cost and disease breakdowns (Odds ratios and 95 % uncertainty intervals)

	Cost, USA$ in million					
	Male		Female		Total	
Type of diseases	OR	95 % UI	OR	95 % UI	OR	95 % UI
CVD	48·1	28·5, 97·4	13·3	8·85, 25·4	61·4	41·6, 113
Ischaemic heart disease	34·4	15·6, 80·8	6·59	2·68, 17·2	41·0	21·4, 88·9
Stroke	9·51	5·37, 19·5	5·07	3·09, 10·2	14·6	10·0, 25·8
Atrial fibrillation and flutter	1·57	0·627, 4·07	0·576	0·219, 1·59	2·15	1·08, 4·90
Peripheral artery disease	1·21	0·484, 3·12	0·346	0·125, 0·960	1·55	0·764, 3·58
Non-rheumatic valvular heart disease	0·754	0·324, 1·93	0·331	0·122, 1·01	1·09	0·571, 2·48
Endocarditis	0·273	0·121, 0·678	0·126	0·0611, 0·313	0·399	0·227, 0·865
Rheumatic heart disease	0·213	0·0998, 0·513	0·147	0·0553, 0·435	0·360	0·202, 0·777
Cardiomyopathy and myocarditis	0·108	0·0499, 0·280	0·0452	0·0224, 0·104	0·154	0·0897, 0·336
Hypertensive heart disease	0·0847	0·0371, 0·213	0·0443	0·0195, 0·121	0·129	0·0720, 0·282
Chronic kidney disease	2·83	1·57, 6·10	1·90	1·01, 4·40	4·73	3·11, 9·24
Stomach cancer	0·910	0·322, 3·21	0·787	0·256, 3·16	1·70	0·818, 5·32

UI, uncertainty interval.

Healthcare costs were mostly driven by CVD, USA$61·4 million (95 % UI 41·6, 113 million), followed by chronic kidney diseases, USA$4·73 million (95 % UI 3·11, 9·24 million) and stomach cancer, USA$1·70 million (95 % UI 0·818, 5·32 million) (Table 3). Main differences between sex were only observed in CVD, where males accounted for USA$48·1 million (95 % UI 28·5, 97·4 million), and females accounted for a quarter of the cost at USA$13·3 million (95 % UI 8·85, 25·4 million). When considering types of CVD, costs were highest for ischaemic heart disease at USA$41·0 million (95 % UI 21·4, 88·9 million), followed by stroke at USA$14·6 million (95 % UI 10·0, 25·8 million) (Table 3). Among individuals active in the labour force (aged 20–79 years), hospitalisation costs increased with age, and those aged 50 and above accounted for more than 90 % of the healthcare cost (Table 4).

Indirect cost

Males had a total of USA$2·56 million (95 % UI 1·58, 4·92 million) cost from hospitalisation-related absenteeism from diseases associated with a high Na diet while females had a total of USA$0·460 million (95 % UI 0·325, 0·844 million) (Table 2). The total number of workdays missed was 18 100 d (95 % UI 12 500, 32 900), where the number of missed workdays increased with age, with more than 80 % of total hospitalisation days from age group 50–79 (Table 4).

Foregone wages due to premature mortality amounted to a total of USA$191 million (95 % UI 150, 271 million) with males contributing USA$166 million (95 % UI 124, 241 million) and females USA$24·7 million (95 % UI 17·7, 39·5 million) (Table 2). This cost increased with age before a decrease from age 60. The age group with the highest foregone wages due to premature mortality was from ages 50–59 at USA$71·9 million (95 % UI 41·0, 123 million). The second highest foregone wages due to premature mortality were from age group 60–69 at USA$52·0 million (95 % UI 29·5, 89·3 million) followed by age group 40–49 at USA$42·4 million (95 % UI 23·2, 77·9 million) (Table 4). In all age groups, males had substantially higher foregone wages due to premature mortality compared with females.

The total cost (direct and indirect) was the highest for age group 50–59 at USA$89·5 million (95 % UI 56·1, 148 million) with males contributing at USA$77·1 million (95 % UI 43·7, 134 million) and females at USA$ 12·3 million (95 % UI 6·86, 22·9 million) (Table 4). The trend of cost across age groups for both sexes is similar, where there was an increase up to age 59.

Discussion

This is the first study in Singapore to provide a cost estimate incurred to a society relating to high Na diet. In 2019, approximately USA$262 million (95 % UI 218, 359 million) could be saved if the average Na intake of Singaporeans is reduced to 3 g/d. This value consisted of USA$67·8 million (95 % UI 48·4,

Table 4. Total cost and hospitalisation days for age groups active in labour force – 20–79 (Odds ratios and 95 % uncertainty intervals)

			20–29		30–39		40–49		50–59		60–69		70–79	
Age groups			OR	95 % UI	OR	95 % UI	OR	95 % UI	OR	95 % UI	OR	95 % UI	OR	95 % UI
Healthcare	Hospitalisation days	Male	67·9	41·0, 157	423	225, 934	1780	742, 4990	4840	1970, 13 100	5910	2440, 16 200	1700	706, 4820
		Female	31·6	19·6, 73·2	115	60·1, 291	496	245, 1210	1 090 536, 2610)		1290	593, 3510	397	170, 1100
		Total	99·5	71·3, 198	538	330, 1100	2270	1200, 5600	5930	2970, 14 500	7200	3510, 18 200	2100	1060, 5280
	Healthcare cost*, USA$ in million	Male	0·170	0·104, 0·368	0·970	0·501, 2·29	4·87	2·06, 12·9	13·4	4·84, 40·5	18·9	7·28, 51·0	10·5	4·17, 30·9
		Female	0·0676	0·0434, 0·158	0·289	0·148, 0·723	1·09	0·551, 2·61	2·93	1·45, 7·10	5·05	2·42, 13·0	4·01	2·00, 9·85
		Total	0·238	0·172, 0·458	1·26	0·770, 2·65	5·96	3·11, 14·1	16·4	7·54, 44·4	24·0	11·5, 56·7	14·5	7·46, 35·4
Productivity cost	Cost from hospitalisation-related absenteeism, USA$ in thousand	Male	9·59	5·69, 22·4	104	54·7, 234	480	202, 1330	998	407, 2650	815	331, 2270	156	64·9, 443
		Female	4·74	2·88, 11·3	24·6	12·7, 62·2	104	51·4, 251	168	82·7, 403	131	59·3, 369	27·8	11·9, 77·3
		Total	14·3	10·2, 29·1	128	77·2, 269	584	300, 1470	1170	568, 2910	945	442, 2480	184	91·1, 476
	Foregone wages due to premature mortality, USA$ in million	Male	2·01	0·694, 5·13	13·3	5·62, 28·8	37·3	18·0, 71·7	62·7	31·9, 111	44·7	22·1, 80·4	6·55	2·53, 14·2
		Female	0·420	0·125, 1·22	1·44	0·497, 3·57	5·06	2·09, 11·0	9·25	4·01, 19·0	7·37	3·33, 14·8	1·18	0·422, 2·69
		Total	2·43	1·11, 5·71	14·7	7·16, 30·7	42·4	23·2, 77·9	71·9	41·0, 123	52·0	29·5, 89·3	7·73	3·61, 15·7
Total cost*	Cost, USA$ in million	Male	2·19	0·902, 5·32	14·3	6·79, 30·2	42·7	23·1, 77·6	77·1	43·7, 134	64·4	37·8, 112	17·2	8·98, 38·4
		Female	0·492	0·207, 1·31	1·75	0·815, 3·96	6·25	3·26, 12·5	12·3	6·86, 22·9	12·6	7·44, 23·3	5·22	3·02, 11·4
		Total	2·69	1·39, 5·98	16·1	8·66, 32·3	48·9	29·6, 85·4	89·5	56·1, 148	77·0	50·0, 126	22·4	13·8, 45·2

UI, uncertainty interval.
* Cost for ages above 80 not presented here

120 million) from direct healthcare costs and USA$194 million (95 % UI 153, 274 million) from indirect productivity losses. Policies to reduce Na intake could thus potentially reduce future healthcare expenditure.

Cost attributable to a high Na diet varied by sex and was skewed towards males in our study. CVD had the highest attributable direct hospitalisation cost, while age group 50–59 had the highest indirect cost. Although ages 50–59 accounted for the largest proportion of the cost, diseases caused by high Na diet happen before these ages, when unhealthy diet and lifestyle habits were cultivated[28]. Additionally, it has also been suggested that childhood dietary patterns may impact morbidities in later years[29].

Our study found productivity loss attributable to high Na diet totals 18 100 d (95 % UI 12 500, 32 900) spent in hospital during the year, and 15 900 years (95 % UI 13 500, 21 400) lost due to premature death. These reduced workdays significantly impact employers and society. Thus, there is a large potential for reducing productivity loss and associated costs from new interventions in primary and secondary prevention of non-communicable diseases from a high Na diet. Given Singapore's rapidly ageing population, high Na diet is expected to create a huge impact on Singapore's economy due to the increased burden of disease.

Over the past decade, cost-effectiveness studies on dietary interventions at both national[30–35] and global levels[36] have provided evidence that Na reduction interventions have great potential to be cost-saving. A recent individual-based microsimulation study in Singapore found that reducing to 1·6 g of Na daily was optimal in averting CVD and DALY[37]. Despite promising results, these studies do not account for consumers' reactions and pricing strategies of the food industry[38–41]. An international review of eleven studies suggests that population-wide interventions on reducing Na intake were effective[42]. Possible policies included government collaboration with the food industry and a Na tax[40]. In Asia and Latin America with a larger participation of discretionary salt and sauces, salt reduction initiatives further included the reformulation of food products, limiting the Na content in processed foods, restrictions on importing foods high in Na, public education on the harmful effects of high Na intake, compulsory labelling of products high in Na and increased range of healthy foods with low Na[43,44].

Since the launch of the War on Salt in 2011, Singaporeans' average daily Na consumption has increased slightly from 3·3 g in 2010 to 3·6 g in 2018[19]. The contribution of Na on DALY in Singapore has also increased from 2014 to 2019 despite an initial drop after the War on Salt[45]. However, the contribution of Na on mortality has decreased during the same period[45]. Further research on the impact of the War on Salt may be warranted to evaluate its effectiveness.

Reduction of Na consumption is difficult because policies to reduce Na intake also face major challenges. Many policies only target consumers but not the wider range of interconnected factors, such as food production and distribution[46,47]. Most Na in Singaporean's diet (60 %) comes from table salt and sauces, especially stir-fried food. Processed food such as fish balls, fish cakes, bread and noodles are estimated to contribute another 37 % of the population's Na intake[17]. Such foods are widely served at affordable and convenient food establishments where Singaporeans frequent, such as hawker centres and food courts[48]. In 2022, the Health Promotion Board Singapore has re-evaluated its Na-related policies and launched a collaboration with food suppliers to encourage the use of lower-Na alternatives[49]. The Healthier Ingredient Development Scheme provides grant support for suppliers to use lower-Na alternatives. Additionally, campaigns will also be conducted to the public to raise awareness of the dangers of excessive Na intake[49]. In line with suggestions from review studies, providing financial support to encourage food suppliers to reformulate their food products with lower-Na alternatives and providing public education on the effects of high Na consumption are potential policies government could support to reduce Na consumption.

Understanding the impact on healthcare spending and productivity losses attributable to high Na diet, a modifiable risk factor can help to guide public health intervention programmes in Singapore. Our study identified the age groups and sex with the greatest impact to allow policymakers to streamline interventions at the right population to obtain optimal benefits. Given that the greatest contributor to early death and disability in Singapore was CVD (14·7 % of total DALY)[50], targeting the causes of CVD early can help lessen the burden on Singapore's healthcare system. A separate simulation study projected the lifetime hospitalisation spending of older adults to be USA$24 400 (30·2 %) higher among people with disabilities[51].

Comparison with other countries

To the best of the authors' knowledge, few studies evaluated the societal cost attributable to high Na diet, and none in Asia. In 2013, the Brazilian health system estimated around USA$103 million could be saved in public hospitalisation costs if Brazilians reduced their average Na intake to 2 g/d[52]. A further study estimated USA $752 million from productivity losses of foregone wages due to premature deaths from CVD attributable to excessive Na intake in 2017[53]. The study also estimated the hospitalisation cost to their health system attributable to a high Na diet for CVD to be USA$76·2 million. Compared with the direct healthcare cost from CVD in our study, the CVD cost to gross domestic product ratio was approximately 4·4 times higher in Singapore compared with Brazil[54]. This comparison suggests that direct healthcare costs accrued due to a high Na diet in Singapore could indicate a rising public health concern. In line with the USA study[14], males contributed to a larger proportion of healthcare expenditures for modifiable risk factors than females. Similarly, the authors also found that CVD (i.e. ischaemic heart disease) had the largest spending attributable to modifiable risk factors compared with other diseases.

Strength and limitations

This is the first paper in Singapore to quantify the cost of a high Na diet, where approximately 90 % of Singaporeans still exceeded the recommended daily consumption. The method presented in this paper is adaptable in different settings using nationally aggregated data and publicly available PAF values from GBD's online results tools. This approach can be

considered for various diet behaviours in a country and different diseases of interest. Similar to the published study in the USA[14], such methods can compare different risk factors to identify the main contributors of healthcare spending in a country. However, the estimates are directly comparable across countries only if the components of costs were measured similarly.

The main limitation of this study includes the underestimation of the costs. The cost estimate in this paper is conservative as it is solely dependent on three main components (1) healthcare cost from inpatient bills, (2) cost from hospitalisation-related absenteeism and (3) foregone wages due to premature mortality. Due to a lack of data, other cost components such as outpatient hospital bills, medication, primary healthcare costs that are incurred regularly and non-healthcare costs arising from caregiver costs, transportation and sick leaves at primary care facilities and outpatient care were not considered. Our model was also limited by the lack of income data and LFPR data for ages above 79. Although excluding these age groups would underestimate the cost, it will not substantially affect the results as population above age 79 had much lower income and LFPR. Additionally, due to the lack of data, our model also assumed that diseased individuals had similar income as healthy individuals, and both groups had the same likelihood to be in the labour force. In the estimation of PAF of diet in high Na, GBD considered systolic blood pressure as a full mediator for the effects of Na. This meant that excess Na consumption leads to an increase in systolic blood pressure, which, in turn, increases the risks of various diseases[5]. In Singapore, primary healthcare is the first line of medical attention an individual seeks[55]. The exclusion of primary healthcare medical costs (i.e. drugs) for patients meant that our healthcare cost attributable to high Na diet was severely underestimated since long-term medication costs were excluded. For example, in Brazil, the treatment cost for drugs attributed to high Na diet was USA$110 million[53]. This is equivalent to more than half of the total cost attributable to a high Na diet. Also, adopting a human capital approach assumes that a worker is indispensable and could lead to overestimation of productivity losses if unemployment rates in a country are high[13].

Conclusion

In conclusion, the cost society incurred due to a high Na diet in Singapore in 2019 was estimated to be at least USA$262 million (95 % UI 218, 359 million). These estimates, although conservative, provide vital insights to purposefully design public health interventions and promotion programmes for modifiable risk factors such as a high Na diet.

Acknowledgements

We would like to thank Dr Stefan Ma and his team from the Ministry of Health Singapore for the helpful discussions that contributed to this work.

The research was supported by the Singapore Ministry of Health, Health Services Research Grant (HSRGMH18may-0002). The funding source had no role in the design and conduct of the study; collection, management, analysis or interpretation of the data; preparation, review or approval of the manuscript; and decision to submit the manuscript for publication.

Concept and design: C. C. Acquisition of data: K. B. T. Analysis and interpretation of data: J. K., G. A. and C. C. Drafting of the manuscript: J. K., G. A. and C. C. Statistical analysis: J. K., G. A., K. B. T. and C. C. Provision of study materials or patients: K. B. T. Obtaining funding: C. C. Administrative, technical or logistic support: K. B. T. Supervision: C. C.

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114522001568

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