Estimating the health benefits and cost-savings of a cap on the size of single serve sugar-sweetened beverages[☆]

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ABSTRACT

Sugar-sweetened beverage (SSB) intake is associated with tooth decay, obesity and diabetes. We aimed to model the health and cost impact of reducing the serving size of all single serve SSB to a maximum of 250 ml in New Zealand.

A 250 ml serving size cap was modeled for all instances of single serves (< 600 ml) of sugar-sweetened carbonated soft drinks, fruit drinks, carbonated energy drinks, and sports drinks in the New Zealand National Nutrition Survey intake data (2008/09). A multi-state life-table model used the change in energy intake and therefore BMI to predict the resulting health gains in quality-adjusted life-years (QALYs) and health system costs over the remaining life course of the New Zealand population alive in 2011 (N = 4.4 million, 3% discounting).

The 'base case' model (no compensation for reduced energy intake) resulted in an average reduction in SSB and energy intake of 23 ml and 44 kJ (11 kcal) per day or 0.22 kg of weight modeled over two years. The total health gain and cost-savings were 82,100 QALYs (95% UI: 65100 to 101,000) and NZ$1.65 billion [b] (95% UI: 1.19 b to 2.24 b, (US$1.10 b)) over the lifespan of the cohort. QALY gains increased to 116,000 when the SSB definition was widened to include fruit juices and sweetened milks. A cap on single serve SSB could be an effective part of a suite of obesity prevention and sugar reduction interventions in high income countries.

1. Introduction

Diets high in total sugar are associated with obesity, type 2 diabetes and dental decay (Te Morenga et al., 2013; World Health Organization, 2014; World Health Organization, 2015). Intakes of both free sugars and sugar-sweetened beverages (SSB) have been shown to be determinants of body weight in free living adults (Te Morenga et al., 2013). Sugar intake is high internationally with a 2015 review of sugar consumption showing that sugar contributed between 14 and 25% of adults total energy intake (Newens and Walton, 2016).

In 2015, the World Health Organization (WHO) published new guidelines for free sugars intake in adults and children (World Health Organization, 2015). The guidelines recommend a reduced intake of free sugars to < 10% of total energy with a further recommendation to reduce intake below 5% of total energy for additional health benefits. An important area to focus such interventions is SSB intakes due to their high contribution to total and free sugar intakes (Data and Statistics, Nutrition Survey, 2011), lack of beneficial nutrients, and potential acceptability as an intervention target (Studdert et al., n.d.).

Approaches to reducing SSB consumption used to date include taxation of SSB sales (Colchero et al., 2016) (HM Revenue and Customs, 2016) (Hagenaars et al., 2017) (Snowdon, 2014), banning SSB imports as in Tokelau (Rush and Pearce, 2013) and banning unlimited sugary drink refills as in France (BBC World News, 2017) (Nau, 2015). There

have been no cost-effectiveness evaluations in Tokelau and France on these policies to date while multiple modeling studies have estimated SSB taxes to be cost-saving (Long et al., 2015; Veerman et al., 2016). Upper limits or caps on the serving size of SSB have also been considered in many areas in the US, including New York City, where a 16 oz (473 ml) limit on sugary drinks served in food service establishments including restaurants, food carts and convenience stores (Department of Health and Mental Hygiene Board of Health, 2012) was intended to be implemented in 2013 (Kansagra et al., 2015). However, the policy was challenged by a lawsuit brought by organizations representing racial/ethnic minority groups and labor and business associations, resulting in New York City's highest court invalidating the policy in 2014 (Donaldson et al., 2015).

Despite the New York City policy being legally overturned some argue that similar policies can be legally pursued by other legislatures and that there are valid public health arguments to do so (Min, 2013; Roberto and Pomeranz, 2015). For example, a study which assessed the likely impact of the abandoned New York City SSB cap reported that with 80% coverage the policy would result in a daily 250 kcal decrease in energy intake, would affect 7.2% of children and 7.6% of adults daily, and would target those who were overweight (Wang and Vine, 2013). In addition, a study has modeled the health effects of a portion size cap in Australia for a 375 ml cap on all single serve SSB. This cap was estimated to result in health savings of 73,900 health-adjusted life-years (HALYs; 3% discount rate for a population of 22 million over the remainder of their lives) and cost offsets of AU$751 million. This was generated from a projected change in average consumption of SSB from 564 kJ/day (135 kcal) to 550 kJ/day (131 kcal) leading to a mean body weight reduction of 0.12 kg (Crino et al., 2017).

In New Zealand (population; 4.4 million people in 2011), the most recent adult nutrition survey found adults had a median usual daily intake of total sugars of 120 g for males and 96 g for females (University of Otago, Ministry of Health, 2011). New Zealand is a high-income country with a median household weekly income of NZ$1290 (US$867 in 2011) (StatsNZ, 2011), but despite this and similar sugar intakes between groups, there are large disparities in health (Ministry of Health, 2012), with Māori (Indigenous), and Pacific suffering a much higher proportion of the burden (StatsNZ, 2013). In 2011, 44% of Māori and 62% of Pacific were obese compared with 26% of European/other (Ministry of Health, 2012).

Given this background of high population sugar intakes and potential benefit but limited evidence for regulated reductions in SSB serving sizes, we aimed to use epidemiological macro-simulation multi-state life-table (MSLT) modeling to predict the total population health impacts and health system costs of reducing the size of single-serve SSB available for sale in New Zealand at all outlets, e.g. supermarkets, fast food chains, small stores, cinemas etc.

2. Methods

2.1. SSB intake data set

SSB intake data were obtained from the most recent New Zealand Adult National Nutrition Survey (NZANS) conducted in 2008/09 (acquired directly from the University of Otago's Life in New Zealand Research Group who conducted the survey; personal communication, Blakey, Smith and Parnell, 2014). Dietary data were from a single 24-hour dietary recall and are in grams per food group for each of the 4721 adult participants. This food group level data enabled us to identify and extract data for all SSB which met the definition for inclusion in the study. Data on the location of food purchases or consumption were not available through this dataset.

2.2. Intervention details

The modeled intervention applied a maximum cap to the container

size of single serve beverages consumed in bottles and a maximum cap to the serving size for drinks served in fast food/other restaurants and cafés. Both of these restrictions will be referred to as a maximum serving size from now on in this paper. Restrictions of a maximum serving size of 250 ml were applied to all SSB intake occurrences which were reported as a single item in the 24-hour recall and where intake fell between 250 ml and 600 ml, approximating all SSB of this size being replaced with 250 ml servings. The rationale for this was:

- Previous work defined one serve of an SSB as ≤600 ml (Poelman et al., 2015) and industry has agreed to a standardised serve size of 600 ml for beverages through the Health Star Rating development process (The FoPL Secretariat ADoH, 2017). Thus 600 ml is the maximum volume for a single serve beverage and volume purchases > 600 ml were likely for multiple serving occasions.
- The most common serving size for SSB (regardless of package size) available for sale in New Zealand supermarkets in 2016 was 250 ml (Eyles et al., 2016), and Coca Cola launched a new 'hand-bag' can of this size in 2016 (Daily Mail UK, 2016).
- The United States standard serving size for SSB is 240 ml (CRF - Code of Federal Regulations Title 21. Subchapter 5 Food for Human Consumption. Part 101 - Food Labelling, 2015).

The change in SSB intake was calculated as the difference between the new average intake of SSB for the specified intervention and the baseline average intake. Baseline dietary intake is averaged over all participants by sex by ethnic group. The change in SSB intake resulting from the intervention is calculated as a percentage of this baseline intake and is then applied to age specific SSB intake when this change is taken into the MSLT model to account for the different SSB intake by age. The associated change in BMI was calculated through the change in energy intake resulting from the change in SSB intake which was modeled to occur over 2 years using the method outlined in Hall et al. 2011 (Hall et al., 2011).

It was necessary to make a number of assumptions in modeling this intervention including:

- SSBs that were entered into the ANS 24-hour recall as a single item were assumed to be purchased in one bottle or beverage container and, if under 600 ml, were treated as single serve SSBs.
- Those consuming single serve SSBs between 250 ml and 600 ml changed to 250 ml, and no-one switched to consuming a larger serving.
- Individuals would not compensate for any change in energy intake due to changes in SSB consumption by changing intake of other foods or drinks in the base case. Evidence suggests increased intake of SSBs results in no significant compensation of energy intake by consuming less food during the day (Gombi-Vaca et al., 2016; Pan and Hu, 2011; Vartanian et al., 2007). Therefore, in reverse we assumed no energy compensation (but see the sensitivity and scenario analysis section for energy compensation scenarios).
- The differences in SSB consumption occurring in the short term due to the intervention persist over each individual's remaining life.

The definition of SSB used in the primary analysis ('base case' model) was all sugar-sweetened: carbonated soft drinks, fruit drinks, carbonated energy drinks, and sports drinks. The 'base case' model therefore excluded fruit juices and sweetened milks. Scenarios were also included with alternative definitions of SSB (See Table 3 for details).

Using the 'base case' model's definition of SSB, we modeled a range of sensitivity analyses and scenario analyses to test population effects for different groups and the impact of our model structure and assumptions on the results (See the sensitivity and scenario analyses section below for details). We also modeled a theoretical comparator of complete SSB elimination in order to judge the magnitude of this

intervention against its full potential.

2.3. Sensitivity and scenario analyses

- 0% and 6% discount rates.
- 20%, 50% and 100% of the reduction in energy consumed as a result of the intervention is replaced by other foods or drinks (only effects energy intake, no other dietary risk factors).
- A 475-ml cap on all single serve SSBs (the proposed New York cap on SSBs) (Donaldson et al., 2015).
- 20% reduction for all single serve SSBs (≤600 ml).

2.4. Cost parameters

Individually-linked data for publicly-funded (and some privately-funded) health events occurring in 2006–10 were used to calculate age and sex specific health system costs in NZ$ for 2011. These costs included hospitalizations, inpatient procedures, outpatients, pharmaceuticals, laboratories and expected primary care usage. Costs were sourced from the New Zealand Health Tracker database for all diseases except diabetes, which was sourced through the Virtual Diabetes Register (Kvizhinadze et al., 2016). Costs that were assigned in the model fell into the following three categories: (i) Sex and age-specific annual cost of a citizen who does not have a BMI-related disease and is not in the last six months of their life; (ii) Disease-specific excess costs for people in the first year of diagnosis, last six months of life if dying of the given disease, and otherwise prevalent cases of each disease in the model; (iii) Costs associated with the last six months of life if dying from a disease not in the model (Cleghorn et al., 2017). The intervention cost is the cost of a law (NZ$3.5 million) (Wilson et al., 2012) to introduce new legislation on maximum single serve SSBs. Net cost-savings were the sum of health system costs and intervention costs. Where costs were converted to United States dollars this was done using OECD purchasing power parity for 2011 (1.486 US$ to 1 NZ$).

2.5. Modeling

We used a multi-state life-table model to estimate the difference in quality-adjusted life-years (QALYs) and health system costs between the current New Zealand diet and the same diet where a 250 ml SSB cap has been implemented to reduce the serving size of all single serve SSB (as a strategy to reduce total and free sugar intake and total energy intake). The MSLT model was built from an established tobacco control MSLT model (using many of the same diseases), from which we have published work previously (Pearson et al., 2016; Van der Deen et al., 2017), which in turn was developed from the ACE-Prevention models used in Australia (Cobiac et al., 2009; Cobiac et al., 2010). See the technical report for BODE[3] intervention and diet MSLT models for further details (Cleghorn et al., 2017). The entire New Zealand population, alive in 2011 (N = 4.4 million), classified by sex, age and ethnicity (Māori and non-Māori) was modeled out to death or until year 2121 in the MSLT.

The intervention was modeled as if it were put in place in the base year (2011) and kept in place indefinitely. The 'base case' model used 3% discounting and took a health system costing perspective. The effect of the intervention is through changes in SSB intake directly onto type 2 diabetes and ovarian cancer incidence (Forouzanfar et al., 2015) and the corresponding changes in energy intake modeled through to changes in body mass index (BMI) onto incidence of coronary health disease (CHD), stroke, type 2 diabetes, osteoarthritis and multiple obesity-related cancers i.e. endometrial, kidney, liver, esophageal, pancreatic, thyroid, colorectal, breast, ovarian and gallbladder (Forouzanfar et al., 2015) (See Appendix A for the relative risks for these associations). All disease input parameters were specified by sex, age and ethnicity unless stated differently (see Table 1).

3. Results

3.1. 'Base case' model

The modeled 250 ml SSB cap resulted in an average decrease of: 23.2 ml of SSB and 44.2 kJ (10.5 kcal) per person per day and a decrease of 0.22 kg or 0.08 BMI units per person modeled over two years. The total health gain was 81,300 QALYs (95% uncertainty interval (UI): 64500 to 101,000) with NZ$1.62 billion [b] (95% UI: 1.16 b to 2.21 b) (US$1.09 b) in cost-savings to the health system (Table 2). The majority of the discounted health gains occurred in younger age-groups (age at 2011) peaking in 40–49 year olds in non-Māori, and in 30–39 year olds in Māori. Absolute health gains were higher in men compared to women. Per capita gains were higher for Māori (160 QALYs/1000 people) than non-Māori (40.5 QALYs/1000 people).

3.2. Varying SSB definitions

Expanding or reducing the definition of SSB targeted by the 250 ml SSB cap altered the amount of health gain seen (Table 3). If only sugar-sweetened carbonated soft drinks were targeted then 58,200 QALYs were gained (67% of the health gains of the 'base case') and $1.18 b saved. If the definition was expanded from the 'base case' model to include fruit juices and sweetened milks, then the health gain increased to 116,000 (33% higher than the 'base case') and cost-savings increased to $2.33 b.

3.3. Scenario analyses

The 'base case' model produced 20.7% of the health gains of the theoretical scenario where all SSB are eliminated from the New Zealand diet (Table 4). Health gains and cost-savings associated with the less stringent 475-ml cap were substantially lower than for the 250-ml cap (7030 QALYs, 8.3% of the 'base case' model and cost-savings of $136 m). Health gains associated with the 20% serving size reduction were 74,100 QALYs (87.3% of the 'base case' model).

If energy intake compensation occurred the QALY gains would be reduced; for 20% compensation: 71700 QALYs; for 50%: 51800 QALYs, and 100%: 18400 QALYs (84.5%, 61.0% and 21.7% of the 'base case' model respectively). The majority of the health gains and cost-savings were therefore achieved through a reduction in BMI resulting from a decrease in energy intake from the reduced SSB intake.

Over 70% of QALY gains come from a reduction in diabetes incidence (Fig. 1), 19%, 11% and 7% from a reduction in CHD, stroke and osteoarthritis incidence. All cancers contributed < 1% to the overall QALY gains for the 'base case' intervention. Note that these percentages are calculated by switching off one disease at a time and comparing the QALYs gained to the 'base case' model. Due to competing mortality these percentages do not add exactly to 100% and just give an indication of the contribution the diseases make to the QALY gains generated by this intervention.

4. Discussion

4.1. Main findings and interpretation

In this modeling study, a 250 ml cap on all SSB for sale in New Zealand was found to be a highly beneficial and cost-saving health intervention. Health gains were estimated to be 21% of those possible if SSB were completely eliminated nationally (with no compensatory consumption of other drinks or foods) and were mainly due to a decrease in energy intake which slightly reduced the average BMI of the population.

Health gains estimated in this study were greater (at 18.4 QALYs/ 1000 people), than those estimated for Australia by Crino et al. (Crino et al., 2017) who modeled a 375 ml portion size cap and found health

Table 1

Baseline input parameter table used in modeling the cap on the size of single serve sugar-sweetened beverages.

Parameter	Source and details	Uncertainty
Baseline population	Statistics New Zealand (SNZ) population estimates for 2011.	Nil uncertainty
All-cause mortality rates	SNZ mortality rates for 2011.	Nil uncertainty
Disease-specific incidence, prevalence, case-fatality rates (CFR) and remission rates	For each disease, coherent sets of incidence, prevalence, case fatality rate and remission rates (zero for non-cancers) were estimated using DISMOD II using data from NZ Burden of Disease Study (NZBDS), Health Tracker and the Ministry of Health.	Uncertainty: rates all ± 5% SD.
Total morbidity per capita in 2011	The per capita rate of years of life lived with disability (YLD) from the NZBDS.	Uncertainty ± 10% SD log-normal.
Disease morbidity rate per capita	2006 NZBDS (projected to 2011)	Uncertainty: ± 10% SD normal.
	Each disease was assigned a disability rate (DR; by sex and age) equal to YLDs for that disease (scaled down to adjust for comorbidities) from the 2006 NZBDS projected forward to 2011, divided by the disease prevalence. This DR was assigned to the proportion of the cohort in each disease state.	
Health system costs	Linked health data (hospitalizations, inpatient procedures, outpatients, pharmaceuticals, laboratories, and expected primary care usage) for each individual in New Zealand for the period 2006–2010 had unit costs assigned to each event, and then health system costs (NZ$2011) were estimated.	Estimated at SD = ± 10% of the point estimate, gamma distribution.
Intervention costs	The cost of a law (NZ$3.5 million) (Wilson et al., 2012) to introduce new legislation on maximum single serve SSBs.	95% UI: NZ$2.0 to NZ$6.2 million

Table 2

Health gain (in QALYs) and health system costs saved from a SSB single serve container cap to 250 ml among the New Zealand adult population alive in 2011 (3% discounting).

Starting age	Non-Māori QALYs	Māori QALYs	Ethnic groups combined QALYs	Net cost-savings (million)[a]
Sex and age groups combined	51,500 (39,800 to 65,600)	29,800 (24,400 to 35,400)	81,300 (64,500 to 101,000)	$1620 (1160 to 2210)
Men				
20–29 year olds	5840	3360	9200	$195
30–39 year olds	5910	2940	8850	$180
40–49 year olds	6750	2610	9360	$182
50–59 year olds	5140	1390	6540	$123
60–69 year olds	2500	391	2890	$51.8
70–79 year olds	581	62	643	$10.6
80+ year olds	77	4	81	$1.15
All ages	33,800	17,300	51,100	$1030
Women				
20–29 year olds	3340	2590	5940	$128
30–39 year olds	3460	2360	5820	$117
40–49 year olds	4000	2100	6100	$117
50–59 year olds	3180	1180	4370	$78.7
60–69 year olds	1680	356	2040	$33.3
70–79 year olds	434	66	500	$7.15
80+ year olds	68	5	73	$0.85
All ages	20,300	13,500	33,800	$674
Per capita (QALYs/1000 people & $)	13.8	44	18.4	$369

[a] Includes both the cost offsets and intervention cost, the latter being the cost of a law (NZ$3.5 million, 95% UI NZ$2.0 to NZ$6.2 million (Wilson et al., 2012)) to introduce new legislation on maximum single serve SSBs. The cost of a law was not partitioned by age, sex, and ethnicity.

savings of 3.3 HALYs/1000 people (Australian Bureau of Statistics, 2012). This is likely to be due to a number of factors; firstly we modeled a lower SSB cap; 250 ml compared to 375 ml, with our 475 ml cap producing just 4.8 QALYs/1000 people. Secondly, our modeling included the effect of a change in SSB consumption directly onto diabetes and ovarian cancer incidence, which accounted for about 20% of the total QALYs, as well as indirectly through BMI onto 12 other diseases, whereas Crino et al. just included the effect of BMI onto nine diseases. Lastly, our 'base case' has a slightly wider definition of SSB which included fruit drinks (though both definitions excluded fruit juices).

The definition of SSBs is important. In this modeling study, when a narrow definition was taken (sugar-sweetened carbonated soft drinks only) the QALY gains are 58,200, but when expanded to include energy drinks, sugar-sweetened fruit drinks, sugar-sweetened sports drinks, fruit juices and sweetened milks QALY gains doubled to 116,000. The decision on which types of beverages to include in a portion size limiting intervention is therefore an important one. Definitions have varied internationally, for example the UK SSB tax excludes fruit juice and milk-based beverages but includes energy drinks (The Food Foundation, 2017) while Mexico's excise tax includes fruit juice (but not milk) if they were sweetened (Bonilla-Chacín et al., 2016; Colchero et al., 2017).

To put the results of this study into a wider context, Table 5 compares the results of the current study's interventions with other nutrition interventions that have been modeled using similar modeling methods by our research group. The 250 ml SSB cap gives substantial health gains and cost-savings compared to the two targeted weight loss interventions (these had a duration of one year only, compared to this intervention that was persistent) and approximately 30% of the intervention with the highest health gains; salt substitution in processed foods.

4.2. Study limitations and strengths

Due to lack of data on package size in the NZANS, we assumed that each SSB entry in the 24-hour recall recorded as a single item were from a single package and, if under 600 ml, were treated as single serve SSB. In some instances these may have been poured from a larger bottle. We also assumed that consumption for those consuming single serve SSB between 250 ml and 600 ml changed to 250 ml and that no-one switched to consuming a larger serving. In reality some consumers may purchase larger servings, e.g. 1 L, and actually increase their SSB intake. Both these assumptions may lead to an overestimation of the effect of the modeled SSB cap.

In the 'base case' model we assumed no energy compensation (Vartanian et al., 2007). However, we did explore the likely effects of energy compensation through scenario analyses, and found that the intervention was still beneficial to health and was cost-saving even with 100% compensation (due to the other mechanisms of SSB on increased diabetes risk).

Another limitation of this work is that the SSB intake data are from 2008/09, and SSB consumption in New Zealand may have increased since then. This modeling is based on intake data from a single 24-hour dietary recall, using multiple recalls allows for estimation of usual

Table 3

Health gain (QALYs) and health system costs saved from a cap on single serve SSBs, with varying definitions of SSBs, among the New Zealand population alive in 2011 (3% discounting).

	Cap on all single serve SSBs (≤600 ml) consumed to 250 ml			
	ΔSSB (ml/ day)	Δ BMI	QALYs	Net cost-savings (NZ$ billions)
Sugar-sweetened carbonated soft drinks only	−16.0	−0.05	58,200	$1.18
Sugar-sweetened carbonated soft drinks and energy drinks	−19.8	−0.06	64,800	$1.30
'Base case' model: Sugar-sweetened carbonated soft drinks, sugar-sweetened carbonated energy drinks, sugar-sweetened sports drinks	−23.2	−0.08	84,900	$1.70
As for 'base case', but with the addition of fruit juices	−29.0	−0.09	104,000	$2.10
As for 'base case', but with the addition of fruit juices and sweetened milks	−31.2	−0.11	116,000	$2.33

Table 4

Health gain (QALYs) and health system costs saved in various sensitivity and scenario analyses of SSB single serve package size reduction interventions among the New Zealand adult population alive in 2011 (3% discounting).

Scenario	QALYs gained	Cost-savings (billions)
'Base case' model[a]	84,900	$1.70
Discount rate		
0% per annum	306,000	$4.74
6% per annum	32,200	$0.77
Energy compensation[b]		
20%	71,700	$1.45
50%	51,800	$0.81
100%	18,400	$0.43
Alternative interventions		
Cap on all single serve SSBs (≤600 ml) consumed to 475 ml[c]	7030	$0.14
20% reduction in serving sizes for all single serve SSB[d]	74,100	$1.49
Comparator		
Complete SSB elimination, 'base case' SSB definition	410,000	$7.95

Presented analyses are run without uncertainty and the 'base case' model presented here varies slightly from the 'base case' model results presented in Table 2.

[a] 250-ml cap, SSB definition: Sugar sweetened: carbonated soft drinks, fruit drinks, carbonated energy drinks, sports drinks, 3% discounting, no energy compensation.

[b] A proportion of the reduction in energy consumed as a result of the intervention is replaced by other foods or drinks. These just reduce the change in energy intake by these percentages but do not model any increase in other dietary risk factors such as fruit and vegetable intake as a result of the increase in consumption.

[c] Chosen as the New York City cap on SSBs was 475 ml (Donaldson et al., 2015).

[d] Chosen as it was of interest theoretically and would be feasible for industry, but it is acknowledged that it is less politically feasible.

intake which would have been an advantage for this modeling. Further, the NZANS has been shown to underestimate overall energy intake (Gemming et al., 2014), as is common in dietary surveys. This MSLT model is based on adult consumption but models a change in consumption over the cohort's lifetime. This means that a change in SSB consumption in childhood is not captured but children become exposed to the intervention when they reach 25 years of age. It also does not model the effect onto tooth decay (for both children and adults). These limitations would have led to an underestimation of the health impact of the intervention.

4.3. Potential implications for research

Now that a modeled SSB serving size reduction policy has been suggested to be cost-effective, a further stage in developing an evidence base for such a policy is investigating this intervention in a real world
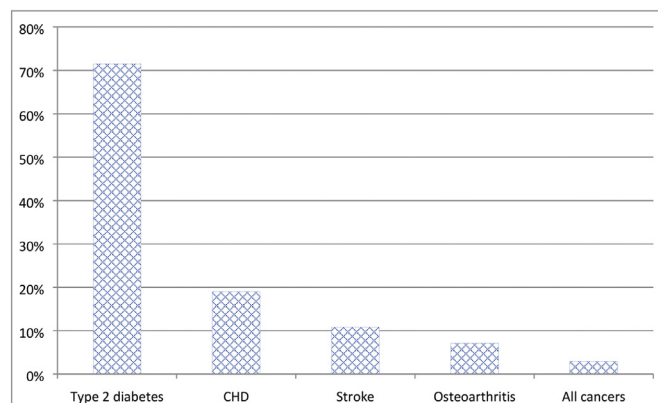

Fig. 1. Percentage of health gain (QALYs) from each contributing disease from a SSB single serve package size cap to 250 ml among the New Zealand adult population alive in 2011 (3% discounting).

setting. School settings and fast food outlets would be ideal locations to trial and evaluate such an intervention. Careful monitoring of energy compensation would be important in such evaluations, and could be informed by observational studies of SSB access (e.g., Taber et al. (Taber et al., 2015)), experimental studies and from studies of SSB taxes (e.g., where consumption shifts to other beverages such as milk and bottled water).

4.4. Potential implications for policy

While more research is desirable, jurisdictions wanting to test out real-world SSB maximum serving size regulations could consider these in context with other SSB control interventions. These include SSB taxes which are rapidly increasing in usage internationally (Backholer et al., 2017) and the use of mandatory warning labels on SSB with benefits suggested by modeling (Lee et al., 2018) and experiments (Bollard et al., 2016; VanEpps and Roberto, 2016).

Some of these interventions could be combined into packages (all passed by the same law), e.g., a SSB volume cap may be impacted less by substitution issues if combined with mandatory warning labels on all SSBs. Nevertheless, there should ideally be a prioritisation process by policy-makers that considers: the scientific evidence, the modeled health gain and impact on health inequalities, the potential health cost-savings, and the likely political feasibility.

5. Conclusion

This modeling work suggests that substantial health gains and costs savings could be gained through restricting the size of single serve SSB. Health gains are likely to be even greater than these modeled results as an SSB cap would be likely to have a positive effect on children's dental health, rates of obesity and adolescent diabetes. Having a wide

Table 5
Population level results for the health gain and costs of the presented SSB cap interventions, compared with previous nutrition interventions using the same or a similar model for the New Zealand setting (ordered by health gain).

Modeled intervention	Health gain (QALYs for remainder of the cohort's life)	Health system cost-savings (NZ$, billion (b) or millions (m)) for remainder of the cohort's life
Salt substitution (at the 59% level with potassium and other salts for processed food) (Nghiem et al., 2016)	294,000	$1.50 b
Achieving a 35% reduction in dietary salt intake via implementation of mandatory maximum levels of sodium in packaged foods plus reduced sodium from fast foods/restaurant food and discretionary intake (Wilson et al., 2016)	235,000	$1.26 b
Sinking lid on the salt supply to the New Zealand market (to achieve an average adult intake of 2300 mg sodium/day) (Nghiem et al., 2015)	211,000	$1.11 b
Tax on the salt in New Zealand market (to achieve an average adult intake of 2300 mg sodium/day) (Nghiem et al., 2015)	195,000	$1.00 b
This study: Cap on all single serve SSBs (≤ 600 ml) consumed to 250 ml	84,900	$1.70 b
This study: 20% reduction in serving sizes for all single serve SSBs	74,100	$1.49 b
Achieving targets for reducing salt in bread (typically a 37% reduction in most bread types) (Wilson et al., 2016)	8400	$35.7 m
This study: Cap on all single serve SSBs (≤ 600 ml) consumed to 475 ml	7030	$136 m
Dietary counseling by practice nurses for weight loss (intervention duration 1 year; weight loss attenuates rapidly over 2 years) (Cleghorn et al., 2018)	320	− $32.3 m
Dietary counseling by dieticians to reduce dietary salt (as per current practice in New Zealand) (persistent intervention) (Nghiem et al., 2015)	200	− $6.90 m
Smartphone apps for weight loss (intervention duration 1 year; weight loss attenuates rapidly over 2 years) (Cleghorn et al., 2018)	29	− $2.3 m

Based on simulations for the New Zealand adult population alive in 2011 modeled out to death or age 110. Discount rate: 3%. Numbers are rounded to two or three meaningful digits.

definition for SSBs, including sweetened fruit juice and sweetened milks will maximize this health gain. This intervention could be adopted directly by policy-makers or could be part of a suite of obesity reduction interventions (such as SSB taxes and health warning labels).

Contribution

CC helped conceptualize the intervention, transformed the existing tobacco MSLT to model dietary risk factors, modeled the intervention and wrote the first draft of the paper. TB contributed to the model build and study methods, and reviewed drafts of the paper. CNM secured funding for the project, contributed to study methods, and reviewed drafts of the paper. NW and BN contributed to the study methods and reviewed drafts of the paper. HE contributed to securing funding for the project, conceived of the idea, helped conceptualize the intervention, contributed to the study methods, and reviewed drafts of the paper.

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Competing interests

The authors declare no competing interests in relation to this work.

Appendix A. Supplementary data

Additional modeling methods are provided in the supplementary

file. This includes key details on the relative risks used, time lags from risk factor exposure to disease incidence and two supplementary tables showing the relative risks of BMI-related and sugar-sweetened beverage-related diseases from the Global Burden of Disease study. Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.01.009.

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