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RESEARCH REPORT

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The estimated health impact of alcohol interventions in New Zealand: A modelling study

Tim Chambers[1] | Anja Mizdrak[1] | Sarah Herbert[2] | Anna Davies[1] | Amanda Jones[1]

[1]Department of Public Health, University of Otago, Wellington, New Zealand

[2]Northern Regional Alliance, Auckland, New Zealand

Correspondence
Tim Chambers, Department of Public Health, University of Otago, 23 Mein Street, Wellington 6023, New Zealand.
Email: tim.chambers@otago.ac.nz

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Abstract

Aims: To estimate the health impacts of key modelled alcohol interventions among Māori (indigenous peoples) and non-Māori in New Zealand (NZ).

Design: Multi-stage life-table intervention modelling study. We modelled two scenarios: (1) business-as-usual (BAU); and (2) an intervention package scenario that included a 50% alcohol tax increase, outlet density reduction from 63 to five outlets per 100 000 people, outlet hours reduction from 112 to 50 per week and a complete ban on all forms of alcohol marketing.

Setting and participants: The model's population replicates the 2018 NZ population by ethnicity (Māori/non-Māori), age and sex.

Measurements: Alcohol consumption was estimated using nationally representative survey data combined with sales data and corrected for tourist and unrecorded consumption. Disease incidence, prevalence and mortality were calculated using Ministry of Health data. We used dose–response relationships between alcohol and illness from the 2016 Global Burden of Disease study and calculated disability rates for each illness. Changes in consumption were based on the following effect sizes: total intervention package [−30.3%, standard deviation (SD) = 0.02); tax (−7.60%, SD = 0.01); outlet density (−8.64%, SD = 0.01); outlet hours (−9.24%, SD = 0.01); and marketing (−8.98%, SD = 0.02). We measured health gain using health-adjusted life years (HALYs) and life expectancy.

Findings: Compared with the BAU scenario, the total alcohol intervention package resulted in 726 000 [95% uncertainty interval (UI) = 492 000–913 000] HALYs gained during the life-time of the modelled population. Māori experienced greater HALY gains compared with non-Māori (0.21, 95% UI = 0.14–0.26 and 0.16, 95% UI = 0.11–0.20, respectively). When modelled individually, each alcohol intervention within the intervention package produced similar health gains (∼200 000 HALYs per intervention) owing to the similar effect sizes.

A.J. now works for Te Hiringa Hauora (Health Promotion Agency) in New Zealand. Her work on this project predated her employment at Te Hiringa Hauora.

Conclusions: Modelled interventions for increased alcohol tax, reduced availability of alcohol and a ban on alcohol marketing among Māori and non-Māori in New Zealand (NZ) suggest substantial population-wide health gains and reduced health inequities between Māori and non-Māori.

KEYWORDS
Alcohol, alcohol availability, alcohol marketing, alcohol tax, intervention, modelling, policy

INTRODUCTION

Alcohol consumption poses a substantial risk to health, having ranked seventh globally and fifth for the New Zealand (NZ) population as a cause of morbidity and mortality in 2016 [1]. The health impacts of alcohol include 25 diseases and injuries [1]. Individual drinkers suffer harms from alcohol but so, too, do others [2]. Indicative of alcohol's wider societal impacts, an estimated 10% of interpersonal violence and property damage offences are attributable to alcohol consumption [3]. In 2005/06, harms from alcohol had an estimated societal cost of NZ $5 billion [3% of gross domestic product (GDP)] [4], more than five times the alcohol tax revenue collected to address externalities [5].

The proportion of the NZ population drinking alcohol has remained relatively constant [6]. Māori, the indigenous population of NZ, are more likely than non-Māori to have hazardous drinking patterns [7], and therefore suffer a disproportionate burden of the ill-effects of alcohol intake [8]. Māori have long recognized the negative impact of alcohol as a result of colonization, and both government action and inaction has contributed to alcohol harms among Māori over time. Disproportionate alcohol harms to Māori are raised in Waitangi Tribunal claims [9, 10], which is a commission of inquiry that makes recommendations on claims brought by Māori on breaches of the guarantees made to Māori in Te Tiriti O Waitangi (The Treaty of Waitangi), NZ's founding document.

In 2010, the NZ Law Commission proposed 153 recommendations to improve alcohol laws in NZ [11], but progress has been slow [12]. Failure to implement the Commission's key recommendations is one aspect of the aforementioned Waitangi Tribunal claim [9]. A wealth of international evidence identifies the benefits from different alcohol interventions [13–16] and the World Health Organization's (WHOs) SAFER framework identifies highly effective strategies for governments to adopt [17]. The three most cost-effective alcohol interventions, termed 'best buys' by WHO, include tax, availability and marketing [17].

Despite the well-established epidemiological evidence highlighting the associations between alcohol affordability [13, 18], availability [14, 15, 19, 20] and marketing [21–23] with alcohol consumption and associated harms, there have been limited empirical evaluations of alcohol interventions. As such, researchers in the United Kingdom [24], Australia [25] and Denmark [26] have developed simulation models to estimate the potential health impact of alcohol interventions. Many modelling studies have focused upon a single alcohol intervention (usually tax) [27–29], while some have attempted to model a suite of interventions [30–32]. We aim to build upon this evidence by modelling multiple alcohol interventions in the NZ context.

This project aims to assess the potential health impacts of a suite of alcohol interventions targeting alcohol price (through taxation), availability and marketing among Māori and non-Māori in NZ.

METHOD

Model overview

The model uses a proportional multi-state life-table design [33] that divides the 2018 NZ population into 5-year age, sex and ethnicity (Māori/non-Māori) cohorts using the 2018 NZ Census population estimates. We simulated each cohort moving through disease states concurrently, over time, until the simulated population have all died. Diseases and injuries attributable to the NZ alcohol-related burden of disease were simulated. We modelled two hypothetical scenarios: (1) business-as-usual (BAU), which assumed no changes in alcohol consumption or policy settings; and (2) an intervention package scenario that included a 50% tax increase, a complete marketing ban and reduced off-licence outlet trading hours and density.

Modelled interventions

Our approach considered which interventions would bring the greatest health gain for Māori, the potential for impact and relevance to current policy settings in NZ. Table 1 outlines the current policy settings in NZ for our four modelled alcohol interventions that comprise our total alcohol intervention package. Table 1 also outlines the anticipated effect size for each intervention as a percentage decrease in per-capita alcohol consumption (a full explanation for intervention selection and effect size estimation is available in the Supporting information). In short, each intervention was estimated to decrease alcohol consumption by between 7.60 and 9.24% when applied individually and 30.3% when applied sequentially within the total alcohol intervention package.

The interventions were selected in consultation with Māori stakeholders (see Supporting information) and based on alignment with statements of claim in the Waitangi Tribunal against the Government, brought by Māori due to the differential harms suffered from alcohol [9, 10]. Our interventions are also aligned with current policy considerations in NZ. For tax, the 2010 Law Commission review of

TABLE 1 Interventions modelled with current policy, proposed intervention and expected effect size.

Intervention area	Current policy	Modelled intervention	Modelled effect size (95% CI)[a]	Source and original effect sizes
Taxation	∼15% of price	50% increase	−7.60% (−5.64 to −9.56%) Linear interpolation of Ministry of Justice modelling [34]	Ministry of Justice modelling of 82, 107 and 133% alcohol tax increases. Estimated decreases of 12.2, 15.8 and 19.5%, respectively
Availability, outlet density	63 outlets per 100 000	5 outlets per 100 000	−8.64% (−7.02 to −10.26%) Equivalent to ∼2% per 10 outlets per 100 000 people after applying decay effect [32, 35, 36]	Increase from 5 to 75 outlets per 100 000 population resulting in an estimated 16.4% (95% CI = 14.7–18.2) increase in consumption Formula for applying decay effect available in Supporting information and table of coefficients available in Stockwell [36]
Availability, outlet trading hours	112 hours	8:00 p.m. closing time and reducing weekly trading hours to 50	−9.24% (−7.34 to −11.14%) Equivalent to ∼1.5% per 9 h reduction after applying the decay effect [15]	Original estimate of 3.4% (95% CI = 2.7–4.1) decrease in consumption for each day reduction in sales (9 hours) [15] Decay effect results in each 9-hour increment has 0.65 the effect of the previous 9-hour increment [36]
Marketing, total ban	Self-regulation	Total ban	−8.98% (−5.06 to −12.9%) Same as original effect size	Estimate from regression model using data from 20 OECD countries [16] Original effect size −8.98% for total marketing ban
Total intervention package	The total intervention package modelled in the main scenario includes a 50% tax increase; outlet density reduction to five outlets per 100 000 people; outlet trading hours reduction to 50 h per week with a maximum closing time of 8:00 p.m.; a complete ban on all forms of alcohol marketing The effect sizes of all four alcohol interventions were applied to alcohol consumption sequentially. In total, alcohol consumption was reduced by 30.3% (95% CI = 26.5–34.1%)			

Abbreviations: CI, confidence interval; OECD, Organization for Economic Co-operation and Development.
[a]Change in per-capita alcohol use.

alcohol laws recommended raising alcohol tax by at least 50% [11], while the Ministry of Justice in 2014 modelled the impact of increases in alcohol tax of 82, 107 and 133% [34]. For availability, the Sale and Supply of Alcohol (Community Participation) Amendment Bill 2022 is currently before Parliament. If enacted in its current form, it would remove a clause that has prevented meaningful implementation of local alcohol policies (LAPs) by councils. LAPs provide council with the opportunity to set alcohol opening hours and implement outlet density or proximity restrictions which could facilitate substantial reductions from national rules [37]. For marketing, three government-initiated reviews completed since 2006 have recommended implementing a legislative framework to regulate all forms of alcohol marketing due to the major limitations of self-regulation [11, 38, 39]. One of the reviews recommended a total phasing-out of alcohol marketing [11], and one other recommended banning alcohol sponsorship of sport [39].

Measures of alcohol consumption draw from data in the nationally representative NZ Health Survey 2017/18 [6]. To account for under-reporting of true consumption [40], we scaled individual-level NZ Health Survey daily consumption to recorded population-level alcohol sales data [41]. We also adjusted for wastage, tourism-related consumption and unrecorded consumption from illicit sales and home brewing [1, 42] (more detail on the alcohol consumption estimation is provided in the Supporting information).

Disease and injury data

Ministry of Health National Collections data from 2015/16 to 2017/18 were used to estimate disease incidence, prevalence and mortality for diseases and injuries. We used dose–response relationships between alcohol and illness from the 2016 Global Burden of Disease (GBD) study [1], which are conservative estimates of the overall negative impact of alcohol on health [43]. The GBD dose–response relationships also exclude some conditions associated with alcohol-related harm, particularly those for which evidence is still emerging, such as mental health conditions or illness due to others' alcohol consumption; for example, Fetal Alcohol Spectrum Disorder (FASD).

We included 15 alcohol-related disease and injuries (the full list and justification for exclusions are provided in the Supporting information). Disability rates, applied to each illness, account for time spent in ill health [44] and were calculated from NZ-specific GBD results by dividing years lived with disability by the population count of each illness in each age and sex strata [1].

Simulation analysis

Our simulation analysis used an incidence approach which links changes in alcohol consumption to disease incidence (e.g. the first onset of disease) at each year of simulation. Changes in disease incidence resulted in changes in disease prevalence and mortality. In turn, this influenced overall mortality and morbidity in the cohort.

We evaluated and compared modelled interventions using two main model outputs. We measured health gain using health-adjusted life years (HALYs); a population health measure permitting morbidity and mortality to be simultaneously described within a single number [45]. Health gain was also represented as life expectancy (LE), which is the median age at death for a particular population group (5-year age, sex and ethnicity groups) for the youngest cohort members (aged 2 years in 2018). Uncertainty intervals (UI) around results were estimated using a Monte Carlo analysis; the model was run 2000 times with input parameters sampled independently from their probability distributions. UIs capture uncertainty around disease rate inputs, alcohol consumption, relative risks and intervention effect sizes (see Supporting information for further details).

Our first scenario, BAU, assumed no changes in the level of alcohol consumption or to alcohol policy over time. The second scenario was an intervention package scenario that included a 50% tax increase, a complete marketing ban and reduced off-licence outlet trading hours and density, as outlined in Table 1. The differences in alcohol consumption between an intervention and the BAU determined the impacts of the intervention on health outcomes. These impacts were specific to ethnicity (Māori/non-Māori), age and sex. We also quantified impacts over time in 10-year increments during the full life-time of the population. To further examine the interventions' impacts on Māori-specific health inequities, we quantified relative per-capita health gains and age-standardized health gains (to eliminate confounding by age) [33]. The analysis plan was not pre-registered on a publicly available platform, so the results should be considered exploratory.

Software

The linkage of national collections data and the calculation of raw incidence, prevalence and mortality rates were conducted using SAS (SAS Institute Inc., Cary, NC, USA) and Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Disease rates were processed using the *disbayes* package in R to generate estimates of case fatality from mortality, incidence and prevalence data [46, 47]. The multi-state life-table model was implemented in Python version 3.6 (http://www.python.org).

RESULTS

BAU scenario HALYs and life expectancy

The BAU scenario represented our current policy settings. Our cohort represented the estimated resident population in the 2018 census (~4.9 million) with a total of 181 million HALYs (see Supporting information, Table S7 for a full breakdown by age, sex and ethnicity). The cohort had an average life expectancy of 78.9, with higher life expectancy among non-Māori (80.9) compared to Māori (73.6) and for women (82.7 and 75.4 non-Māori and Māori, respectively) compared to men (71.9 and 79.3).

Changes in alcohol consumption

Table 2 displays alcohol consumption in ethanol grams per day (per capita) by sex, age and ethnicity in the BAU scenario and the total intervention package scenario. In NZ, one standard drink is equivalent to 10 g of ethanol. In all scenarios, men consistently drank more than women at any given age or ethnicity. For both ethnicity and sex, higher per day consumption was observed in the 35–64-year age groups compared to other age groups. Younger Māori tended to have higher consumption than younger non-Māori, while Māori women aged over 65 years and Māori men aged over 55 years drank less than their non-Māori counterparts.

In the BAU scenario, all male age and ethnic strata have an average daily alcohol consumption that was higher than the Ministry of Health (MoH) low-risk drinking guidelines to reduce long-term health risks (Table 2) [48]. Table 2 shows the average daily alcohol consumption, meaning that most people may still drink under the MoH guideline. Average alcohol consumption among non-Māori women aged 45–64 years and Māori women aged 15–64 years was higher than the MoH guidelines in the BAU scenario.

The intervention package resulted in average consumption being below the MoH guidelines for all women except Māori aged 35–44, Māori men aged 35–64 and non-Māori men aged 45–74 years. Consequently, 12 of the 21 (57%) population groups with an average consumption above MoH guidelines now fall below the guideline. Further, only nine of the 28 population groups (32%) still have an average consumption above the MoH guidelines.

Changes in HALYS and life expectancy

Tables 3 and 4 outline the HALYs gained compared to the BAU scenario from the total alcohol intervention package during the life-time

TABLE 2 Alcohol consumption in grams of ethanol (10 g ethanol = 1 standard drink) by sex, age and ethnicity in business-as-usual scenario and full intervention scenario.

		Business-as-usual scenario		Intervention package[a] scenario			
Sex	**Age (years)**	**Māori**	**Non-Māori**	**Māori**	**Reduction (g)**	**Non-Māori**	**Reduction (g)**
Female	15–24	**14.9**	10.8	10.4	4.5	7.5	3.3
	25–34	**15.4**	10.3	10.8	4.7	7.2	3.1
	35–44	**24.0**	13.9	**16.7**	7.3	9.7	4.2
	45–54	**21.6**	**18.6**	**15.0**	6.5	13.0	5.6
	55–64	**19.4**	**17.3**	13.5	5.9	12.0	5.2
	65–74	9.6	13.9	6.7	2.9	9.7	4.2
	75–99	6.1	13.0	4.3	1.9	9.1	3.9
Male	15–24	**26.5**	**26.2**	18.4	8.0	18.3	8.0
	25–34	**27.7**	**26.2**	19.3	8.4	18.3	8.0
	35–44	**34.8**	**28.9**	**24.2**	10.6	20.2	8.8
	45–54	**39.2**	**35.2**	**27.3**	11.9	**24.5**	10.7
	55–64	**37.2**	**40.1**	**25.9**	11.3	**28.0**	12.2
	65–74	**33.6**	**37.0**	**23.4**	10.2	**25.8**	11.2
	75–99	**27.0**	**22.4**	18.8	8.2	15.6	6.8

Note: Bold values represent a weekly consumption greater than the Ministry of Health recommendations to reduce long-term health risks [48] (women = two standard drinks per day with maximum of 10 per week, or 100 g per week divided by 7 days = 14.3 g per day; men = three standard drinks per day with a maximum of 15 per week, 150 g per week divided by 7 days = 21.4 g per day).

[a]Total intervention package consists of the combined effectiveness of a 50% increase in 2018 alcohol tax rates, reduction in outlet density to five outlets per 100 000 people, reduction in outlet trading hours to 50 per week with a maximum closing time of 8:00 p.m., and a complete marketing ban including sponsorship.

TABLE 3 Total health-adjusted life years (HALYs)[a] gained from alcohol interventions (intervention scenario) compared to business-as-usual scenario.

	Intervention package[b]		Taxation[b]		Off-licence outlet density[b]		Off-licence outlet hours[b]		Marketing ban[b]	
Population	**Total (000)**	**95% UI (000)**	**Total (000)**	**95% UI (000)**	**Total (000)**	**95% UI (000)**	**Total (000)**	**95% UI (000)**	**Total (000)**	**95% UI (000)**
All	726	(492, 913)	192	(115, 254)	218	(138, 283)	233	(145, 306)	226	(102, 333)
Non-Māori	555	(378, 696)	147	(89, 195)	167	(107, 218)	179	(112, 235)	174	(79, 256)
Māori	171	(112, 215)	44	(26, 58)	50	(31, 66)	54	(33, 71)	52	(23, 77)
Non-Māori females	167	(106, 221)	49	(29, 67)	55	(34, 75)	59	(37, 80)	57	(26, 86)
Non-Māori males	388	(269, 477)	99	(59, 128)	112	(73, 143)	120	(75, 154)	117	(53, 168)
Māori females	49	(28, 67)	14	(7, 20)	16	(9, 21)	17	(10, 24)	16	(7, 25)
Māori males	122	(83, 151)	31	(18, 39)	35	(22, 45)	37	(23, 48)	36	(16, 52)

Abbreviation: UI, uncertainty interval.

[a]Health-adjusted life years (HALYs) is a population health measure permitting morbidity and mortality to be simultaneously described within a single number.

[b]Intervention package includes the effect sizes of all four alcohol interventions applied to alcohol consumption sequentially; taxation is a 50% increase in 2018 alcohol tax rates; off-licence outlet density is a reduction to five outlets per 100 000 people from 63.1; off-licence outlet hours is a reduction to 50 hours per week from 112 with a maximum closing time of 8:00 p.m.; marketing ban includes a complete ban on all forms of alcohol marketing, including sponsorship.

of the cohort. The intervention package would result in 726 000 (95% UI = 492 000–913 000) HALYs gained, with an average of 0.18 (95% UI = 0.12–0.23) HALYs gained per-capita (note: 0.01 HALY = 3.65 days). Māori experienced greater age-adjusted per-capita HALYs gains of 0.21 (95% UI = 0.14–0.26) compared to non-Māori with 0.16 (95% UI = 0.11–0.20). Men gained twice the

TABLE 4 Per-capita health-adjusted life years (HALYs)[a] gained from alcohol interventions (intervention scenario) compared to business-as-usual scenario.

	Intervention package[b]		Taxation[b]		Off-licence outlet density[b]		Off-licence outlet hours[b]		Marketing ban[b]	
Population	p/c[c]	95% UI	p/c[c]	95% UI	p/c[c]	95% UI	p/c[c]	95% UI	p/c[c]	95% UI
All	0.18	(0.12, 0.23)	0.05	(0.03, 0.06)	0.05	(0.03, 0.07)	0.06	(0.04, 0.08)	0.06	(0.03, 0.08)
Non-Māori	0.16	(0.11, 0.2)	0.04	(0.03, 0.06)	0.05	(0.03, 0.06)	0.05	(0.03, 0.07)	0.05	(0.02, 0.07)
Māori	0.21	(0.14, 0.26)	0.05	(0.03, 0.07)	0.06	(0.04, 0.08)	0.07	(0.04, 0.09)	0.06	(0.03, 0.09)
Non-Māori females	0.10	(0.06, 0.13)	0.03	(0.02, 0.04)	0.03	(0.02, 0.04)	0.03	(0.02, 0.05)	0.03	(0.01, 0.05)
Non-Māori males	0.22	(0.15, 0.27)	0.06	(0.03, 0.07)	0.06	(0.04, 0.08)	0.07	(0.04, 0.09)	0.07	(0.03, 0.1)
Māori females	0.12	(0.07, 0.16)	0.03	(0.02, 0.05)	0.04	(0.02, 0.05)	0.04	(0.02, 0.06)	0.04	(0.02, 0.06)
Māori males	0.30	(0.2, 0.37)	0.08	(0.04, 0.1)	0.09	(0.05, 0.11)	0.09	(0.06, 0.12)	0.09	(0.04, 0.13)

Abbreviation: UI, uncertainty interval.

[a]Health-adjusted life years (HALYs) is a population health measure permitting morbidity and mortality to be simultaneously described within a single number.

[b]Intervention package includes the effect sizes of all four alcohol interventions applied to alcohol consumption sequentially; taxation is a 50% increase in 2018 alcohol tax rates; off-licence outlet density is a reduction to five outlets per 100 000 people from 63.1; off-licence outlet hours is a reduction to 50 hours per week from 112 with a maximum closing time of 8:00 p.m; marketing ban includes a complete ban on all forms of alcohol marketing, including sponsorship.

[c]The number of age-adjusted HALYs gained per capita (p/c); 0.01 p/c HALYs = 3.65 days.

HALYs per-capita compared to women in both Māori (0.30, 95% UI = 0.20–0.37 compared to 0.12, 95% CI = 0.07 = 0.16) and non-Māori (0.22, 95% UI = 0.15, 0.27 compared to 0.12, 95% UI = 0.07–0.16) groups.

The trends by ethnicity and sex that were observed in the intervention package were also reflected within individual alcohol interventions. Each intervention was relatively similar in total HALYs gained (~200 000) and per-capita HALYs gained (0.05). Reducing alcohol outlet trading hours produced the highest gains in HALYs (233 000, 95% UI = 145 000–306 000 and 0.06, 95% UI = 0.04–0.08 HALYS total and per capita, respectively) and the 50% tax increase produced the lowest gains in HALYs (192 000, 95% UI = 115 000–254 000 and 0.05, 95% UI = 0.03–0.06 HALYs total and per capita, respectively).

Years of life expectancy gained were slightly higher than HALYs gained across the suite of alcohol interventions, suggesting that most life-years gained will be lived in good health (Table 5). For example, the intervention package resulted in 0.18 (95% UI = 0.12–0.23) HALYs and 0.24 (95% UI = 0.16–0.31) LE gained per capita, or 75% of life-years gained will be lived in good health. Māori and men experienced greater increases in overall life expectancy from alcohol interventions compared to non-Māori and women, respectively.

Changes in HALYs over time

Figure 1 provides an overview regarding when the modelled health gains from the alcohol interventions scenario were realized. After the interventions were implemented in 2018, most of the modelled health gains were realized between the period from 2048 to 2088. The majority of health gains would take a substantial proportion of time to be realized (> 20 years). This reflects the cumulative impact of alcohol consumption throughout the life-course on non-communicable diseases which make up the majority of the disease burden due to alcohol. Figure 1 highlights the disproportionate health gains likely to be experienced by men and Māori compared to women and non-Māori, respectively.

DISCUSSION

Few studies have estimated the impact of a suite of alcohol interventions [30, 32]. We estimated that our total alcohol intervention package could gain 726 000 (95% UI = 492 000–913 000) HALYs in NZ. A common practice in cost-effective analyses is to multiply the HALYs gained by the GDP per capita to establish cost effectiveness [49]. Interventions costing less than GDP per capita for each HALY have been defined as extremely cost-effective. Using the 2018 World Bank estimate of GDP per capita in NZ (~NZ$64 000), the intervention could cost up to ~NZ$46 billion during the next 100 years to be considered cost-effective. This estimate does not account for any costs associated with implementing or maintaining interventions, substitution effects or sensitivity analyses central to economic analyses. Thus, these figures help contextualize the magnitude of the potential health benefits.

The full intervention package was estimated to increase median life expectancy by 0.24 (95% CI = 0.16–0.31) years per capita or 87.6 days. The improvements in life expectancy are consistent with results from another study demonstrating the impact of completely eradicating tobacco use and obesity in NZ [50]. The authors estimated that eradicating tobacco use would improve median life expectancy by 0.50 years or twice the effect of our alcohol intervention package, while eradicating overweight and obesity would result in an increase

TABLE 5 Total and per-capita life expectancy (LE)[a] gained by the cohort aged 2 years in 2018 from alcohol interventions (intervention scenario) compared to business-as-usual scenario.

Population	Intervention package[b]		Taxation[b]		Off-licence outlet density[b]		Off-licence outlet hours[b]		Marketing ban[b]	
	LE[a]	p/c (95% UI)[c]	LE[a]	p/c (95% UI)[c]	LE[a]	p/c (95% UI)[c]	LE[a]	p/c (95% UI)[c]	LE[a]	p/c (95% UI)[c]
All	79.2	0.24 (0.16, 0.31)	79.0	0.06 (0.04, 0.08)	79.0	0.07 (0.04, 0.1)	79.0	0.08 (0.05, 0.1)	79.0	0.08 (0.03, 0.11)
Non-Māori	81.1	0.21 (0.21, 0.41)	81.0	0.06 (0.05, 0.11)	81.0	0.06 (0.06, 0.13)	81.0	0.07 (0.06, 0.14)	81.0	0.07 (0.04, 0.15)
Māori	73.9	0.32 (0.21, 0.41)	73.7	0.08 (0.05, 0.11)	73.7	0.1 (0.06, 0.13)	73.7	0.1 (0.06, 0.14)	73.7	0.1 (0.04, 0.15)
Non-Māori females	82.8	0.13 (0.29, 0.56)	82.7	0.04 (0.06, 0.15)	82.7	0.04 (0.08, 0.17)	82.7	0.05 (0.08, 0.18)	82.7	0.04 (0.06, 0.2)
Non-Māori males	79.6	0.28 (0.19, 0.36)	79.3	0.07 (0.04, 0.1)	79.4	0.08 (0.05, 0.11)	79.4	0.09 (0.05, 0.12)	79.4	0.09 (0.04, 0.12)
Māori females	75.6	0.18 (0.11, 0.25)	75.5	0.05 (0.03, 0.07)	75.5	0.06 (0.03, 0.08)	75.5	0.06 (0.04, 0.09)	75.5	0.06 (0.03, 0.09)
Māori males	72.4	0.45 (0.09, 0.18)	72.0	0.11 (0.02, 0.05)	72.0	0.13 (0.03, 0.06)	72.1	0.14 (0.03, 0.06)	72.0	0.13 (0.02, 0.07)

Abbreviation: UI, uncertainty interval.

[a] Life expectancy (LE) is the median age at death for a particular population group. This table represents the life expectancy of the age group aged 2 years in 2018.

[b] Intervention package includes the effect sizes of all four alcohol interventions applied to alcohol consumption sequentially; taxation is a 50% increase in 2018 alcohol tax rates; off-licence outlet density is a reduction to five outlets per 100 000 people from 63.1; off-licence outlet hours is a reduction to 50 hours per week from 112 with a maximum closing time of 8:00 p.m.; marketing ban includes a complete ban on all forms of alcohol marketing, including sponsorship.

[c] The number of age-adjusted LEs gained per capita (p/c) – 0.01 p/c LE = 3.65 days.

of 1.21 years of life [50]. In comparison to these eradication scenarios, in our alcohol intervention scenario alcohol consumption is still causing acute and chronic health outcomes [48].

Our results also show that health gains are only predominantly realized approximately 20 years after the interventions are implemented. This is consistent with previous studies estimating health gains during the life-course of other alcohol interventions [27]. However, we note that many of the non-health negative impacts of alcohol would probably be reduced much more rapidly from our modelled interventions, such as damage to property.

The BAU in the model assumes the continuation of 2018 alcohol consumption patterns and population mortality and morbidity into the future. We believe that this was the most reasonable approach at the time of modelling, given the uncertainties in future alcohol consumption and population health. Our intervention scenarios assume that all interventions are introduced at the same time and are maintained in perpetuity. Modelled health gains would have been lower if we assumed reducing background alcohol consumption and/or mortality and morbidity into the future. Modelled health gains would be higher if we projected increasing alcohol consumption and/or worsening health into the future.

Among all policies, Māori would experience greater benefits compared to non-Māori due largely to differences in baseline consumption, age structure and disease incidence. However, we did not account for the differential impact of our policies due to differences in drinking patterns or underlying exposure or responsiveness to policies, as discussed in the study limitations below. Therefore, results probably underestimate the health equity potential of these interventions for Māori.

Tax

Increasing the tax rate by 50% in NZ was estimated to gain 192 000 (95% UI = 115 000–254 000) HALYs. A 2008 modelling study in the Netherlands estimated that a fivefold increase in tax would result in ~624 000 HALYs gained compared to BAU during a 100-year period, with a cost saving of €3.3 billion or NZ$5.5 billion [27]. In 2014, the NZ Ministry of Justice estimated that an 82% increase in alcohol taxes would result in net savings to society of NZ$339 million in the first year and NZ$2.5 billion over 10 years [34]. Using the crude estimate above, the intervention could cost up to NZ$12.3 billion during the next 100 years and still be considered cost-effective.

In addition to the clear health gains, there are numerous supporting arguments for increased taxation. First, the alcohol tax rates in NZ are low compared to some other Organization for Economic Co-operation and Development (OECD) countries, which places us out of step with our closest international comparators [51]. Secondly, alcohol taxes are often justified as externality-correcting taxes that account for the full cost of alcohol-related harm [34]. There is currently a NZ $4 billion deficit per year attributable to the societal harms associated with alcohol [4, 5], which is borne by taxpayers. Thirdly, the largest

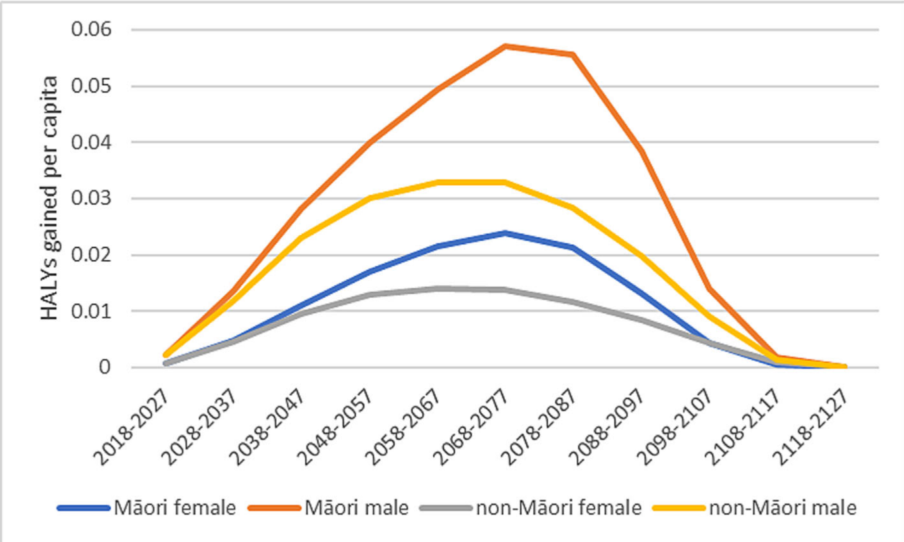

FIGURE 1 Health-adjusted life years (HALYs) gained per capita from the complete alcohol intervention package scenario compared to the business-as-usual scenario by decade.

review of NZ's alcohol laws in 2010 recommended raising alcohol tax by at least 50%, which has not been implemented by successive governments [11]. A 50% tax increase would probably increase the total retail price of different products by between 8% (for wine) and 38% (for spirits), translating to an absolute increase in price by between NZ $1.25 (bottle of wine) to NZ$11.32 (bottle of spirits) [7].

Availability

Reducing alcohol outlet trading hours produced an estimated 233 000 (95% UI = 145 000–306 000) HALYs gained over 100 years. However, this estimate should be interpreted with caution. Currently, there is very limited empirical evidence of the impact of reducing alcohol outlet trading hours, so our effect size relied upon the result of a meta-analysis of reduced days of operation [15], consistent with two previous modelling studies [32, 35]. Additionally, we have a poor understanding of the baseline total trading hours of alcohol outlets in NZ. The Alcohol Regulatory and Licensing Authority (ARLA) maintains the registry of alcohol licences in NZ. The registry has data on licensed trading hours, but the information is not entered in a standardized format and would require manual data cleansing and approaches to address missing data. These limitations in NZ are probably similar to those experienced internationally.

A substantial reduction in alcohol outlet density from 63 to five outlets per 100 000 population was estimated to result in 218 000 (95% UI = 138 000–283 000) HALYs gained. Again, these results should be interpreted with care, as the effect size was reliant upon results from one study, which has been used in two subsequent modelling studies [32, 35]. This effect size was our best available estimate, and is supported by a large body of evidence demonstrating a consistent link between increased physical availability of alcohol and alcohol consumption [14, 15, 19, 20].

In NZ, the Sale and Supply of Alcohol Act 2012 (SSAA) has not contributed to any substantial changes in alcohol outlet trading hours or density [52]. NZ has long permissible trading hours (7:00 a.m.–11:00 p.m. or 112 hours per week) and high outlet density (63 outlets per 100 000). An amendment to the SSAA to set new default national maximum trading hours and days of operation for off-licence outlets would offer an equitable and regulatory simple approach to reduce alcohol availability. Ideally, this would restrict alcohol sales after 8 p.m. [53] and remove sales on one weekend day [15].

Marketing

A complete ban on alcohol marketing was estimated to result in 226 000 (95% UI = 102 000–333 000) HALYs gained. Despite strong evidence on the relationship between alcohol marketing exposure and consumption [21, 54, 55], there is limited empirical evidence of the impact of alcohol marketing restrictions [56]. One analysis of the marketing ban in Norway estimated a decrease in total alcohol consumption of 7.4% [57]. In addition to this empirical evaluation, the existing epidemiological evidence and modelling studies provide a compelling case for strong marketing restrictions [17].

Three government-initiated reviews completed since 2006 have recommended implementing a legislative framework to regulate all forms of alcohol marketing due to the major limitations of self-regulation [11, 38, 39]. Additionally, there have been three previous attempts to bring alcohol marketing under a legislative regime, but none have made it past a third reading in Parliament [58–60]. To date, the only remaining sign of legislative restrictions on alcohol marketing is from the Sale and Supply of Alcohol (Harm Minimization) Bill that provides for an end to alcohol sponsorship of sport [61]. A previous study estimated that a partial marketing ban could result in decreased alcohol consumption of ~5% [16]. A 5% decrease in alcohol consumption, for example, from a ban on alcohol sponsorship of sport would result in 123 000 (95% UI = 21 000–219 000) HALYs gained (see Supporting information).

Strengths and limitations

This modelling study had a number of strengths. First, it incorporated 15 disability and injury rates from a global study on alcohol-related harm. Secondly, it used NZ alcohol consumption data that were stratified by age and ethnicity, so we were able to examine some of the health equity implications of different interventions. Thirdly, the study also benefited from a refined methodological approach that has been effectively applied and validated on modelling studies of tobacco, transport and diet [33, 50, 62].

One of the core limitations of this analysis is the uncertainty in our effect size estimates for different interventions. While there is strong evidence for the impact of price, marketing and availability on alcohol consumption [17], substantial variability in the precise effect sizes persist [63]. Further complicating effect size estimates is that most alcohol interventions are implemented concurrently with other policies, which makes isolating the effect of any particular intervention difficult. We believe the intervention effect sizes selected represent the best available measure for that intervention in the NZ context. However, to try to help communicate the magnitude of any uncertainty, we have created a figure that displays the estimated HALYs gained for any given reduction in alcohol consumption (see Supporting information). Thus, end users can determine the potential impact of interventions using a different set of assumptions that may either decrease or increase the estimated changes in alcohol consumption.

Another limitation is that we applied the intervention effect sizes uniformly throughout population groups, which probably underestimated the health equity potential of the modelled interventions. We anticipate that interventions would have differential effectiveness in certain population groups due to drinker type, age structure and variations in baseline exposures. First, while we raise health equity concerns around taxation, evidence suggests that heavy drinkers are the most price-sensitive [28]. In NZ, Māori are more likely to have hazardous drinking patterns [64], which means any resulting tax increase may result in disproportionate effectiveness due to drinker type. Secondly, younger people are more sensitive to price increases [65] and to the persuasive effects of alcohol marketing (and thus more responsive to an alcohol marketing ban) [54]. Given that Māori have a younger age structure than non-Māori, these interventions would probably have a disproportionate benefit for Māori. Thirdly, Māori are also disproportionately exposed to the drivers of alcohol consumption, including higher rates of alcohol marketing exposure [66] and alcohol outlet density and trading hours [67]. Thus, future research should examine the differential effectiveness of interventions among Māori specifically and, by accounting for drinker type, age structures and baseline exposure to the determinants of alcohol consumption.

Our alcohol consumption measure does not account for drinking patterns. We were constrained to the GBD approach, which assumes that heavy episodic drinking has no (independent) effect on alcohol-attributable harm. However, we know heavy episodic drinking is socially patterned with Māori and people living in deprivation experiencing higher rates [64]. As such, we may be underestimating the health equity potential of the proposed interventions if they are likely to have differential effectiveness by drinker type.

Another limitation was that we did not include the full suite of alcohol-attributable disease and injury conditions. We included all the conditions identified in the GBD study for which it was possible to obtain stable estimates of disease rates. Consequently, we excluded tuberculosis, epilepsy, oesophageal cancer, pancreatitis and alcoholic cardiomyopathy. These conditions represent a very small proportion of disease burden in NZ and are therefore a minor source of bias. Our modelled results do not include FASD, sexually transmitted diseases, violence or other social harms (e.g. relationship and work-place problems), for which the GBD does not provide relative risk estimates. These conditions impact upon both HALYs and life expectancy estimates. As a result, we have underestimated the total negative health impact of alcohol use.

CONCLUSION

Based upon conservative estimates of health benefits, our modelled interventions on tax, availability and marketing showed that there are substantial health gains available if the Government followed advice from previous government-led inquiries. Further, these interventions could reduce health inequities between Māori and non-Māori and thereby contribute to rectifying ongoing government failings to uphold the Treaty of Waitangi.

AUTHOR CONTRIBUTIONS

Tim Chambers: Conceptualization (supporting); data curation (supporting); formal analysis (supporting); investigation (lead); methodology (supporting); project administration (equal); resources (equal); validation (equal); writing—original draft (lead); writing—review and editing (lead). **Anja Mizdrak:** Conceptualization (equal); data curation (lead); formal analysis (lead); funding acquisition (supporting); investigation (equal); methodology (equal); writing—original draft (supporting); writing—review and editing (supporting). **Sarah Herbert:** Conceptualization (equal); funding acquisition (equal); investigation (equal); project administration (supporting); writing—original draft (supporting); writing—review and editing (supporting). **Anna Davies:** Conceptualization (supporting); data curation (lead); formal analysis (supporting); funding acquisition (supporting); investigation (supporting); methodology (supporting); writing—original draft (supporting); writing—review and editing (supporting). **Amanda Jones:** Conceptualization (lead); data curation (equal); formal analysis (supporting); funding acquisition (lead); investigation (supporting); methodology (equal); project administration (equal); writing—original draft (supporting); writing—review and editing (supporting).

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DECLARATION OF INTERESTS

A.J.'s involvement in this project predated her employment at Te Whatu Ora–Health New Zealand (previously Te Hiringa Hauora)—a government health promotion agency. The authors have no other conflicts of interest to declare. No authors have received funding from the alcohol industry.

DATA AVAILABILITY STATEMENT

Upon reasonable request.

ORCID

Tim Chambers https://orcid.org/0000-0001-5856-5600

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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