The broader health benefits of optimised dietary thresholds proposed for type 2 diabetes prevention in Aotearoa New Zealand: simulation modelling

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ABSTRACT

AIM: Optimised dietary thresholds for type 2 diabetes prevention exist; however, they likely have additional benefits beyond diabetes prevention. We have modelled the effects of the proposed dietary thresholds on Health-Adjusted Life Years (HALY), health inequities and health system cost in Aotearoa New Zealand.

METHODS: We created a national diet scenario using the optimised thresholds and compared it with current intakes using an established multistate life table. The primary model considered change in outcome from increasing intakes of fruits, vegetables, nuts and seeds while decreasing red meat and sugar-sweetened beverages. A separate secondary nutrient-based model considered change due to increasing whole grains and yoghurt while decreasing refined grains, potatoes and fruit juice. Both models considered the direct non-weight mediated associations between diet and disease.

RESULTS: In the primary model, adopting the dietary thresholds produced clear benefit to Aotearoa New Zealand in terms of HALY (1.2 million years [95%UI 1.0–1.5]), and a health system cost saving of $17.9 billion (95%UI 13.6–23.2) over the population life course. HALY gain was at least 1.8 times higher for Māori than non-Māori. The secondary model indicated further gains in HALY for all population groups and health systems costs.

CONCLUSION: These striking benefits of altering current dietary intakes provide strong evidence of the need for change. Such change requires government commitment to an overarching food strategy in Aotearoa New Zealand to build supportive food environments that enable healthy choices at affordable prices.

What we eat and the nutrients in food are important determinants of non-communicable disease risk.[1] There has long been convincing evidence on an increased risk of cardiovascular diseases in those with high intakes of dietary sodium and saturated fatty acids, and for a protective effect of dietary fibre, whole grains, vegetables, fruit and n-6 unsaturated fatty acids.[1–3] Dietary fibre and whole grains have also been associated with a reduced risk of type 2 diabetes and colorectal cancer.[4,5] More recently, red and processed meat intakes have been shown to be promotive factors in the development of colorectal cancer,[6] while nut, seed and legume intakes protect against cardiovascular disease.[7,8]

Escalating rates of type 2 diabetes worldwide[9] have prompted an in-depth evaluation of the role of dietary factors in this disease. O'Hearn and colleagues[5] have very recently utilised three global data sets to examine the relative importance of 11 dietary factors in 184 countries by considering both body weight mediated and direct non-weight mediated associations between diet and disease. Grain processing (whole grain intakes were protective, refined grain intakes were associated with increased risk) and red and processed meat intakes were found to be the major contributors to the global diet-related burden of type 2 diabetes incidence.[5] Based on this modelling of the global data, the authors concluded that 70.3% (68.8–71.8%) or 14.1 (13.8–14.4) million new cases of type 2 diabetes in 2018 were attributable to the 11 dietary factors studied.[5] For Aotearoa New Zealand this translated to 7,055 (6,459–7,615) potentially avoidable new diagnoses of type 2 diabetes in 2018.[5] These recent findings are compatible with advice from current guidelines[10] and the results of randomised controlled trials, which indicate that dietary interventions can more than halve the risk of progression from prediabetes to type 2 diabetes.[11]

While these results are striking, they do not acknowledge that a type 2 diabetes-protective diet would also have broader health benefits, likely in terms of cardiovascular health and the mitigation of some cancers. To better understand the true scope of health benefits with dietary change, we have used the same 11 dietary thresholds applied by O'Hearn et al.[5] to consider the broader health consequences of changing dietary intakes in Aotearoa New Zealand beyond type 2 diabetes incidence. Our aim in doing so is to provide local context to these recent global findings,[5] and further discussion on changing our food environment here in Aotearoa New Zealand to support healthier lives.

Method

Simulation model parameters

We used a proportional multistate life table model (DIET MSLT), following established methods.[12,13] This model[14] has been used in previous projects to model interventions that are individually targeted,[15] modify the food environment[16] or are theoretical.[17,18]

Within the model, the 2011 Aotearoa New Zealand population (4.4 million) is divided into 5-year age group cohorts, modelled as four separate sex by ethnic populations, and simulated until death or the year 2121, whichever is the earlier.[14] Non-communicable disease outcomes (cardiovascular diseases, osteoarthritis, type 2 diabetes and colorectal, lung, oesophageal, head and neck, and ovarian cancers) were included in the model as they related to dietary factors.[1] Disease rates used in the multistate life tables of the DIET MSLT model were taken from a range of sources.[14] Relative risks for the associations between the relevant dietary factors (vegetables, fruit, sugar-sweetened beverages, nuts and seeds, red meat and processed meats) with non-communicable disease outcomes were obtained from the Global Burden of Disease study.[1] Only the direct effects of the dietary change were considered, and not those mediated by body weight due to differences in energy derived from the scenario diet and current intakes.

The current scenario was modelled in Microsoft Excel using Ersatz (EpiGear International), which enables calculation of uncertainty intervals around a point estimate. The scenarios were run with 2,000 iterations (Monte Carlo simulations) to produce 95% uncertainty intervals. Each of these simulations involved a random draw from the probability density function for the parameters specified with uncertainty within the model. Health-Adjusted Life Years (HALY) and health system costs were discounted at 3%.[19] Detailed modelling methods are available in the model's technical report.[14]

Scenarios modelled

We worked with the current Adult Nutrition Survey data (2008/09),[20] divided into 340 food and beverage categories, and showed as an average intake weight for four population groups (Māori women, Māori men, non-Māori women and non-Māori men). There were 122 food and beverage categories identified that related to the 11 optimal intake levels proposed by O'Hearn et al.[5] Intakes of these food and beverage categories were adjusted in the relative proportions that they were consumed per population group, so that the overall intake weight of each food group met the proposed weight, as shown in **Table 1**.

Of the other food and beverage categories, the average amounts of 148 categories were not modified, as these categories did not relate to the 11 proposed dietary thresholds shown in **Table 1** (e.g., egg, poultry or milk). The 70 remaining food and beverage categories were mixed dishes containing at least one of the food groups shown in **Table 1**. In a conservative approach we did not modify the amounts of mixed dishes, as we could not be confident in the ratios of each ingredient (e.g., "bacon and egg pie" would contain processed meat and refined wheat, but also egg). The most common dietary factors in mixed meals that were not modified were refined rice and wheat, processed meat and unprocessed meat.

Two scenarios were modelled. The primary model considered the direct associations between 6 of the 11 dietary factors with non-communicable disease outcomes (processed meat, unprocessed meat, sugar-sweetened beverages, fruits, non-starchy vegetables, nuts and seeds). The DIET MSLT does not include disease associations with yoghurt, starchy vegetables, fruit juice or refined and whole grains. This required a second scenario to be considered within a nutrient-based model that looked at fibre and sodium intakes when reducing refined grains, starchy vegetables and fruit juice while increasing whole grain or yoghurt intakes in line with the proposed thresholds. As the multistate life table methods assess multiple risk factors onto multiple diseases simultaneously, including the effect of increasing life expectancy on future disease incidence, it is

Table 1: Current and proposed optimal intake levels of 11 dietary factors.

Dietary factor (n categories modified)	Current intakes (grams)	Proposed intakes (grams)
Whole grains (8)	27.6	90
Yoghurt (5)	21.2	87.1
Processed meat (15)	37.6	0
Unprocessed meat (25)	64.9	14.3
Sugar-sweetened beverages (7)	183.3	0
Potatoes (9)	103.9	0
Refined rice and wheat (19)	121.7	0
Fruits (15)	150.1	300
Non-starchy vegetables (12)	119.8	300
Nuts and seeds (6)	4.5	20.3
Fruit juices (1)	46.1	0

*Current intakes are an adult population average from the Adult Nutrition Survey (2008/09) of 4,721 participants in Aotearoa New Zealand.

not possible to simply add the effects of these two scenarios together. Instead, the effects on outcomes from the two scenarios are distinct from each other.

Simulation model outcomes

The primary outcome was change in health as measured by HALY. Secondary health outcomes were indicators of health inequities by ethnicity (Māori and non-Māori),[21] and costs or cost savings to the healthcare system[14] when each scenario was compared with current dietary intakes in Aotearoa New Zealand. Health inequity by ethnicity was considered by showing the health impact to Māori and non-Māori separately and in additional analyses where the higher background rates of mortality and morbidity for Māori were adjusted down to be the lower rates experienced by non-Māori in Aotearoa New Zealand.[21]

The healthcare system's costs or cost savings were calculated based on differences in rates of diet-related disease between Business as Usual (BAU) and the intervention.[14] Costs from hospitalisations, inpatient procedures, outpatients, pharmaceuticals, laboratories and expected primary care usage were used to calculate disease, age and sex-specific health system costs. Costs from individually linked data for publicly funded (and some privately funded) health events (2006 to 2010) were sourced from the New Zealand HealthTracker database for all diseases except diabetes, which was sourced through the Virtual Diabetes Register (VDR).[14]

Role of the funding source

This project was unfunded.

Results

Current dietary intakes in Aotearoa New Zealand provide an average of 1,954g food and beverages (other than water), and 8.6MJ of energy per day. The diet modified to meet the proposed intake levels of 11 food groups provided an average of 1,860g food and beverages (other than water), and 7.6MJ of energy per day. These differences in dietary volume and energy intake do not influence the observed health results, which only consider the direct non-weight mediated associations between diet and disease that are independent of energy balance.

The primary model of health outcomes due to six of the 11 proposed optimal intakes are shown in **Table 2**. The proposed optimal intakes scenario resulted in substantial HALY gains when compared with current intakes. HALY gain was higher for men than women (1.3 times), and higher for Māori than non-Māori (1.8 times). Per capita, HALY gains were higher again for Māori when their higher background rates of mortality and morbidity were adjusted for under the equity analysis (2.5 times), suggesting a reduction in health inequities with adoption of the proposed intakes.

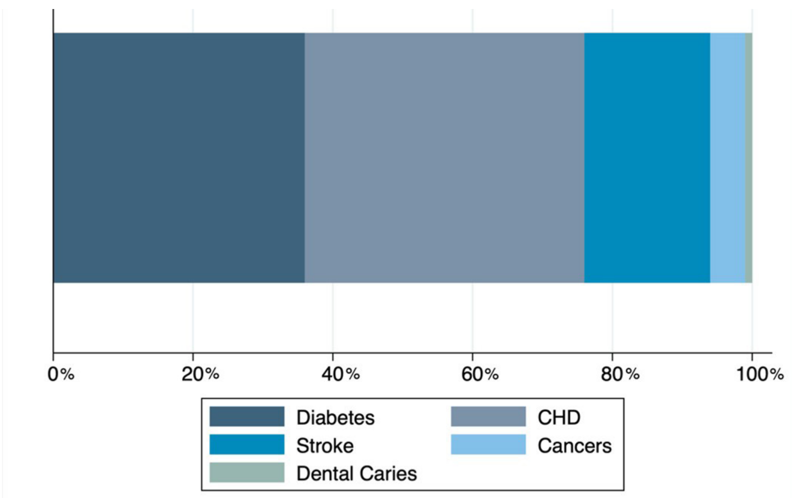
The secondary nutrient-based model considering the change in fibre and sodium content when meeting the proposed intakes of yoghurt, starchy vegetables, fruit juice, refined and whole grains are shown in **Table 3**. These results indicate a similar pattern of additional benefits, with health gains for Māori 1.3 times higher than for non-Māori when looking at age-standardised per capita health gain. This ratio increases to 1.9 times higher when using the equity analysis results.

Figure 1 shows the relative contribution of major non-communicable diseases included in the model to the HALY gain observed in the primary analyses. The major contributors to the HALY gain when moving dietary intakes towards the proposed thresholds were coronary heart disease, type 2 diabetes and stroke.

Discussion

We have modelled the direct non-weight mediated associations between diet and disease to identify the broad and systemic health effects should dietary intakes in Aotearoa New Zealand change to meet recently suggested optimised dietary thresholds for 11 food groups. These thresholds were identified in a global risk assessment analysis of the impact of a suboptimal diet on type 2 diabetes of both direct and weight-mediated associations between diet and disease;[5] however, our analyses indicate far greater health benefits beyond type 2 diabetes prevention are likely should the national diet change towards these thresholds. Health gains were greater for Māori than non-Māori, suggesting these dietary changes may reduce health inequities, while the healthcare system's savings were around NZ$18 billion over the life course of the 2011 cohort, should the dietary changes be maintained. While the potential benefits of altering present dietary intakes are striking, they are also expected. Evidence of health benefits with improved dietary intakes has long existed; however, changing population intakes is not an individual responsibility, but instead requires strong and sustained government commitment. Such action has not been shown in Aotearoa New Zealand. What is needed is an overarching national food strategy in Aotearoa New Zealand to build supportive food environments that enable healthy food choices at affordable prices. Alongside health, a national food strategy in Aotearoa New Zealand should also encompass the environmental and economic aspects of food production.

Figure 1: Contribution of major non-communicable diseases to the HALY gain observed in the primary analyses.



*Cancer burden shown here relates to colorectal, lung, oesophageal, head and neck, and ovarian cancers.

Table 2: Health and health system cost savings when adopting 6 of the 11 optimal intake thresholds (processed meat, unprocessed meat, sugar-sweetened beverages, fruits, non-starchy vegetables, nuts and seeds).

	Non-Māori	Māori	Māori	Ethnic groups combined	
	Health gains: HALYs	Health gains: HALYs	Equity analysis health gains: HALYs	Health gains: HALYs	Net health system cost savings (NZ$ billion)
Total	900,100 (716,900 to 1,101,200)	289,600 (241,400 to 342,900)	409,400 (337,300 to 489,700)	1,189,700 (961,600 to 1,447,000)	$17.9 (13.6 to 23.2)
Men	522,500	155,500	218,100	678,000	$10.8
Women	377,700	134,100	191,300	511,800	$7.1
Per capita	241.3 (299.3)	429.6 (554.4)	607.2 (785.8)	270.1	$4,068

Results in brackets in the total population row are 95% Uncertainty Intervals. Per capita results are HALYs per 1,000 people and NZ$ per adult, with results in brackets presenting age-standardised data.

Table 3: Health and health system cost savings for fibre and sodium differences when adopting the other 5 of the 11 optimal intake thresholds (yoghurt, starchy vegetables, fruit juice, refined grains and whole grains).

	Non-Māori	Māori	Māori	Ethnic groups combined	
	Health gains: HALYs	Health gains: HALYs	Equity analysis health gains: HALYs	Health gains: HALYs	Net health system cost savings (NZ$ million)
Total	17,700 (6,600 to 30,400)	3,800 (1,300 to 6,500)	5,500 (1,800 to 9,900)	21,500 (9,400 to 36,000)	$241.8 (113.0 to 384.7)
Men	10,900	1,700	2,500	12,600	$140.9
Women	6,700	2,100	3,000	8,800	$100.8
Per capita*	4.7 (5.7)	5.6 (7.4)	8.1 (10.7)	4.9	$54.9

Results in brackets in the total population row are 95% Uncertainty Intervals. Per capita results are HALYs per 1,000 people and NZ$ per adult, with results in brackets presenting age-standardised data.

The current work highlights the difference between providing optimised dietary thresholds and a reference diet. Our results indicate a 1MJ on average reduction in daily energy intake when adopting the optimised dietary thresholds, a change in energy intake which would likely have unaccountable compensatory measures in eating behaviours. To avoid this uncertainty in the modelling, we only considered the directly mediated associations between diet and disease rather than body weight mediated associations. The nutritional completeness when adopting the optimised dietary thresholds and their viability to supply in current food systems were also not considered when proposed.[5] In contrast, a reference diet like the EAT-Lancet diet,[22] proposed in 2019, which appears similar to the optimised dietary thresholds (increased minimally processed whole grain, vegetable, fruit, nut, seed and legume intake, decreased red and processed meat and sugar-sweetened beverage intake) was modelled for nutritional completeness, including energy intake, as well as the systems change required to deliver such a diet at a population level.

Recent modelling of the adoption of the Eat-Lancet diet in Aotearoa New Zealand, alongside an Aotearoa New Zealand diet optimised for health and climate impact, showed similar health gains to the current study (1.4 million Quality-Adjusted Life Years [QALY]).[23] QALY and HALY gains can be interpreted similarly for these studies. Other recent studies have examined the potential benefits of red and processed meats' replacement with five different scenarios, with similar health gains seen when current red and processed meat intakes were replaced with minimally plant based meat alternatives (1.3 million QALYs).[18] Previous modelling has shown 1.0 million QALY gains when the Aotearoa New Zealand population was modelled to follow the current dietary guidelines, with these gains increasing to 1.5 million QALYs when the Aotearoa New Zealand population was also modelled to be vegan.[17] All previous analyses align in showing that population shifts away from the current diet and towards higher intakes of dietary fibre, whole grains, vegetables, fruit and n-6 unsaturated fatty acids and lower intakes of dietary sodium and saturated fatty acids will result in appreciable benefits to health in Aotearoa New Zealand.

The strengths of the current analyses are that they utilise optimal dietary thresholds recently identified in one of largest studies of their kind,[5] consider the benefits of dietary change on much broader health metrics than just type 2 diabetes incidence and rely on data relevant to Aotearoa New Zealand. The most important limitation is that the dietary intake data are derived from the 2008/09 Adult Nutrition Survey, our most recent nationally representative dietary assessment. As the global food supply has moved towards more processed and ultra-processed foods,[24] intakes of the 2008/09 Adult Nutrition Survey data may be closer to the proposed thresholds than actual current intakes, and therefore underestimate the health benefits of meeting them. Furthermore, the current DIET MSLT model does not incorporate the disease associations for yoghurt, fruit juice, starchy vegetables, whole and refined grains, so the effects of all 11 optimised dietary threshold could not be shown together. Instead, two scenarios are shown, where a second nutrient-based model was run to consider sodium and fibre changes when meeting optimised thresholds for yoghurt, fruit juice, starchy vegetables, whole grains and refined grains. Given the more recent understanding of the importance of whole grain intakes in human health,[4,25–26] and existing uncertainty on the effects of refined grain intakes,[27] this second scenario is a likely gross underestimation of the health benefits in Aotearoa New Zealand when changing grain intakes.

Aotearoa New Zealand has a long track record of nutrition recommendations that have been issued and updated by first the Department, and then Manatū Hauora – Ministry of Health. The most recent Eating and Activity Guidelines[28] would, if fully implemented, go some way towards achieving the targets which past modelling[17] has shown would achieve appreciably improved health and environmental outcomes. However, it is widely acknowledged that a sustainable food environment that ensures the availability, at affordable cost, of health promoting foods and discourages the consumption of dietary promotors of ill health is an essential requisite to achieve meaningful changes in population dietary habits. Regrettably, national policies likely to promote such an environment are absent in Aotearoa New Zealand.

We have demonstrated that the potential wide-ranging benefits of modifying present dietary intakes in Aotearoa New Zealand may be even greater than suggested previously, and that such changes could contribute to achieving equity in health outcomes. Our findings provide evidence for reinforcing and extending current dietary guidelines. However, the population dietary changes required for the realisation of these benefits are unlikely to be achieved without the creation of a sustainable food environment that ensures the availability, at affordable cost, of health promoting foods and discourages the consumption of dietary promotors of ill health. Successive governments have consistently held back from developing a national food strategy that includes the legislative and policy measures needed to change the current food environment. Investment now in such a strategy would have benefits for the environment and climate, in addition to health and the economy, for this, and subsequent generations.

COMPETING INTERESTS
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