# Prioritization of Intervention Domains to Prevent Cardiovascular Disease: A Country-Level Case Study using Global Burden of Disease and Local Data

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# Abstract

Aim: We aimed to combine Global Burden of Disease (GBD) Study data and local data to identify the highest priority intervention domains for preventing cardiovascular disease (CVD) in the case study country of Aotearoa New Zealand (NZ). Methods: Risk factor data for CVD in NZ was extracted from the GBD using the “GBD Results Tool”. We prioritized risk factor domains based on consideration of the size of the health burden (disability-adjusted life years [DALYs]) and then by two alternative ways: (i) strength of the evidence-base for domain-specific interventions being cost-saving (based on number of NZ publications); and (ii) the domain-specific interventions that delivered the highest health gains and cost-savings. Results: Based on the size of the CVD health burden in DALYs, the five top prioritized risk factor domains were: high systolic blood pressure (84,800 DALYs; 5400 deaths in 2019), then dietary risk factors, then high LDL cholesterol, then high BMI and then tobacco (30,400 DALYs; 1400 deaths). When considering strength of evidence-base around health economic benefits, we found that tobacco control could be considered to be the highest priority risk factor domain to intervene in (nine NZ publications showing cost-savings). But if policy-makers aimed to maximize health gain and cost-savings from specific interventions that have been studied, then they would favor the dietary risk domain (e.g., a combined fruit and vegetable subsidy plus a sugar tax produced estimated lifetime savings of 894,000 health-adjusted life years and health system cost-savings of US$11.0 billion). Other potential considerations for prioritization are: (i) the potential for total health gain that includes non-CVD health loss (i.e., again favoring tobacco control); (ii) potential for achieving relatively greater per capita health gain for Māori (Indigenous) to reduce health inequities; and (iii) consideration of co-benefits such as greenhouse gas reductions from dietary interventions. Conclusions: We were able to show how CVD risk factor domains could be systematically prioritized using a mix of GBD and country-level data. Tobacco control could be top ranked if policy-makers focused on the strength of evidence for health economic benefits. But if policy-makers wished to maximize health gain and cost-savings from any specific intervention/s, then they may favor dietary interventions e.g., food taxes and subsidies.


# Introduction

Ischemic heart disease (IHD) is the highest ranked cause of health loss in New Zealand (NZ), when considering death and disability combined [1]. The other key component of cardiovascular disease (CVD) is stroke, which is ranked fifth in importance for health loss (i.e., albeit behind low back pain, chronic obstructive pulmonary disease and falls). More specifically, IHD is the leading cause of death in the country, followed by stroke [1]. The total annual CVD burden for NZ is estimated at 11,900 deaths and 183,000 disability-adjusted life years (DALYs), or 15.1% of all DALYs [2]. In addition, CVD is an important contributor to health loss for Māori (Indigenous population) and it contributes to health inequities in NZ in terms of both ethnicity [3–5] and socioeconomic position [6].

CVD is also expensive with an estimated annual cost to the health system of US$2.3 billion [7] (~ NZ$3.3 billion). In addition, there is the annual loss of income to NZ citizens from CVD, estimated at US$427 million (15.6% of all disease-related income loss; and far ahead of cancer-related income loss at

US$122 million) [8]. The high costs of CVD to the NZ Government are a particularly important consideration when the country's health system is chronically fiscally constrained and has the recent added stressors associated with the Covid-19 pandemic.

CVD has also been given high priority by NZ stakeholders in a multi-criteria decision analysis to prioritise non-communicable diseases for research funding decision-making [9]. That is, coronary heart disease was in the top priority group, along with back and neck pain, and diabetes mellitus. Stroke was in the next highest priority group, along with "dementia and Alzheimer's disease". Furthermore, there is substantial scope for CVD prevention given that there are so many CVD prevention interventions available and which can be intensified [10] [11]. Many of these CVD preventive interventions can also contribute to health gain in other domains e.g., reducing tobacco use can reduce both CVD and a wide range of cancers. While it may be more rational for policy-makers to focus on major risk factors for health loss (such as diet and smoking) as opposed to disease domains (such as CVD), we suspect that the disease domain focus is one that is preferred by policy-makers as it is easier to explain to the public. For example, stating that "we plan to prevent heart disease" is more understandable than "we plan to control risk factors that cause the most health loss".

Fortunately, the NZ health system has made substantial progress in preventing CVD with such measures as ongoing enhancements to tobacco control (with even more substantive declines in smoking recently [12]). There has also been ongoing improvements in the provision of preventive pharmacotherapy. The assessing of absolute CVD risk for CVD risk management (i.e., prioritizing preventive pharmacotherapy and counselling by overall five year risk of a CVD event), has been promoted to clinicians for a long time [13], albeit with this approach still not always dominating in practice [14]. There is also evidence for successful campaigns to increase use of preventive pharmacotherapy e.g., use of lipid-lowering statins in Māori [15].

Given this background, we aimed in this study to prioritise CVD risk factor domains for NZ when considering the size of the health loss, the evidence for interventions, and potential health gains and health economic benefits of preventive interventions.

# Methods

We extracted risk factor data for CVD in NZ from the Global Burden of Disease (GBD) Study using the "GBD Results Tool" and using the disease category of "B.2 Cardiovascular diseases" [2]. This data source was selected on the basis of the high quality of the risk factor analysis as detailed in these recent publications [10, 11, 16].

These risk factor domains were then ranked based on consideration of the highest CVD-related health burden as measured by disability-adjusted life years (DALYs) i.e., a composite of health loss from premature death and disability. We then took the top five risk factor domains for CVD for further consideration, with just five being selected on the basis of encouraging a more strategic focus by policy-makers. Such a focus seems needed given that the NZ Government does not currently have any systematic strategic plan for non-communicable disease prevention or for CVD prevention, and does not routinely use health economic evidence for prioritising public health interventions (with prioritising by the agency PHARMAC for pharmaceuticals being an exception [17]).

We then further identified the top priority risk factor domains by two alternative ways: (i) strength of the evidence-base for domain-specific interventions being cost-saving or cost-effective (using the number of published health economic studies for NZ); and (ii) the domain-specific interventions that delivered the highest health gains and cost-savings. To inform such prioritization we conducted literature searches to identify relevant health economic studies. The search method used was identical to a previous search used to identify NZ-relevant studies published in the peer-reviewed journal literature between 1 January 2010 and 8 October 2017 (search details described elsewhere: [18]). In summary, we searched for NZ-related studies with the following metrics: cost per quality-adjusted life-year or disability-adjusted life-year or life-year (QALY/DALY/LY). For this updated search we expanded the search period to cover from 1 October 2017 to 31 December 2021.

We then used the number of peer-reviewed journal publications finding cost-saving interventions as a simple proxy for strength of evidence base around health economic benefits, and ranked the risk factor domains accordingly. This approach was taken on the grounds that health policy-makers often need local evidence (e.g., that takes into account local epidemiology and local health costs) relative to international evidence. Also policy-makers passing laws (e.g., for enhanced tobacco control or taxing sugar-sweetened beverages) may need particularly high levels of scientific evidence to counter opposition from commercial vested interests. But we also considered the specific preventive interventions within these studies to identify the estimated size of the possible health gain and cost-savings achievable.

# Results

Based on the size of the CVD health burden in DALYs, the five top prioritized risk factor domains out of all those detailed in the GBD Study were: high systolic blood pressure (84,800 DALYs; 5400 deaths in 2019), then dietary risk factors, then high LDL cholesterol, then high BMI and then tobacco (30,400 DALYs; 1400 deaths in 2019), (Table 1). For these five risk factors the same ranking order was apparent in terms of numbers of deaths. Nevertheless, given the overlapping 95% uncertainty intervals in both DALYs and deaths, this ranking can only be considered approximate.

Within the dietary risk grouping, the three CVD risk factors associated with the highest DALYs were: diet low in whole grains, then diet high in red meat, and then diet low in legumes (Table 1). All of these CVD risk factors had higher rankings than the ones of low physical activity and alcohol use.

When considering evidence for interventions being cost-saving or cost-effective (or not) in the NZ setting for these five priority domains, a total of 22 relevant peer-reviewed publications were identified (published since 1 January 2010; Table 2). When using number of publications having cost-saving results as a proxy for strength of evidence-base around health economic benefits, tobacco control could be considered the highest priority risk factor domain (nine cost-saving publications) (Table 2). This was followed by high blood pressure (n=4), then dietary risk factors (n=3), then high LDL cholesterol (n=1) and then high BMI (n=0).

But in terms of the health gain and cost-savings from specific interventions that have been studied within these five highest risk factor domains, the highest impact intervention was a dietary one i.e., a combined fruit and vegetable (F&V) subsidy plus a sugar tax (Table 2). This produced estimated lifetime savings of 894,000 health-adjusted life years and health system cost-savings of US$11.0 billion (~NZ$16.4 billion). Behind this in impact were a sugar tax, then a salt tax with F&V subsidy, then a saturated fat tax with F&V subsidy, then a salt tax, and then a saturated fat tax. All these six dietary interventions were more impactful (greater health gain and cost-savings) than the highest impact tobacco control intervention: a sinking lid on tobacco sales.

Table 1: CVD burden in 2019 for NZ attributable to specific risk factors and ranked by number of disability-adjusted life years (DALYs; for all ages, both sexes; (95% uncertainty intervals), GBD data extracted using the “GBD Results Tool”)

| Risk factor* | CVD deaths | | DALYs (ranked) | |
|---|---|---|---|---|
| | Count | Proportion (%**) | Count | Proportion (%**) |
| High systolic blood pressure | 5400 (4210 to 6470) | 45.2 | 84,800 (71,400 to 97,700) | 46.3 |
| Dietary risk factors – all (see also below for specific components) | 3970 (3180 to 4810) | 33.3 | 62,400 (51,000 to 74,900) | 34.1 |
| High LDL cholesterol | 3330 (2300 to 4530) | 27.9 | 51,200 (40,000 to 64,600) | 28.0 |
| High body-mass index (BMI) | 1940 (1130 to 2850) | 16.3 | 40,100 (25,500 to 56,300) | 21.9 |
| Tobacco (including secondhand smoke***) | 1400 (1270 to 1520) | 11.7 | 30,400 (28,000 to 32,900) | 16.6 |
| High fasting plasma glucose | 2000 | 17.0 | 27,000 | 14.7 |
| Kidney dysfunction | 1200 | 10.1 | 15,400 | 8.38 |
| Non-optimal temperature (just too low for NZ data and not including excessive temperature as in heat waves) | 862 | 7.21 | 11,400 | 6.22 |
| Low physical activity | 673 | 5.63 | 7950 | 4.34 |
| Alcohol use | 103 | 0.87 | 4760 | 2.60 |
| Lead exposure | 258 | 2.16 | 3960 | 2.16 |
| Air pollution in the form of ambient particulate matter pollution | 172 | 1.44 | 3190 | 1.74 |
| **More specific risk factors – diet** | | | | |
| Diet low in whole grains | 1,010 | 8.48 | 16,000 | 8.73 |
| Diet high in red meat | 814 | 6.82 | 14,400 | 7.84 |
| Diet low in legumes | 878 | 7.35 | 13,600 | 7.44 |
| Diet high in trans fatty acids | 502 | 4.21 | 7,710 | 4.21 |
| Diet high in sodium | 377 | 3.16 | 6,920 | 3.78 |
| Diet low in dietary fibre | 377 | 3.15 | 5,720 | 3.12 |
| Diet low in fruits | 296 | 2.48 | 5,050 | 2.76 |
| Diet low in vegetables | 323 | 2.70 | 4,880 | 2.66 |
| Diet high in processed meat | 247 | 2.07 | 4,370 | 2.39 |
| Diet low in seafood omega-3 fatty acids | 201 | 1.69 | 3,030 | 1.66 |
| Diet low in polyunsaturated fatty acids | 192 | 1.61 | 2,990 | 1.63 |
| Diet high in sugar-sweetened beverages | 104 | 0.87 | 1,650 | 0.90 |
| Diet low in nuts and seeds | 137 | 1.15 | 1,620 | 0.88 |

* Most of these risk factors are not independent of one another. For example, the blood pressure risk factor, the high LDL cholesterol risk factor and high BMI risk factor will be partly mediated via dietary risk factors. Nevertheless, a few of the risk factors (e.g., air pollution) may be largely independent of the other listed risk factors.
** This is the proportion out of the total of 11,900 deaths and 183,000 DALYs attributed to CVD in NZ in 2019 (with 79.6% of the total DALYs being attributed to named risk factors in the GBD).
*** Of the tobacco group, 11% of the deaths and DALYs were attributed to secondhand smoke exposure.
Values rounded to three meaningful digits.

[Table 2 About here]

# Discussion

### Main findings and interpretation

This case study analysis showed how CVD risk factor domains could be systematically prioritized using a mix of GBD and local data. It first used GBD data to identify the five major risk factor domains for CVD prevention in NZ. In descending order of importance in terms of health loss, these were: high systolic blood pressure, dietary risk factors, high LDL cholesterol, high BMI and tobacco. When these risk factor domains were then considered by level of local evidence for interventions (using number of published health economic studies for NZ), tobacco control was the domain that ranked the highest. This prominence of tobacco control fortunately coincides with this being a major new area of focus for the NZ Government with recent legislative plans for achieving its Smokefree 2025 Goal [45]. But a focus on tobacco control will not only prevent CVD, but also many other diseases including various cancers and chronic respiratory diseases. Indeed, if policy-makers took a broader “total disease” perspective around maximizing the reduction of health loss – then they would prioritise investing in tobacco control above all other risk factors as shown in Fig. 1. In addition, a focus on tobacco control would also potentially produce higher per capita health gain for Māori compared to non-Māori and so could contribute to reducing health inequities (Table 2).

But although some policy-makers may favor such a focus on tobacco for reasons of evidence-base for interventions (and potential impact on inequities), there are other relevant considerations. A key one of these is the likely size of the health gain and the size of the cost-savings from specific interventions that have been studied. Such a focus would give top ranking to the dietary risk factor domain which had the highest impact six interventions (the highest one of which was estimated to save 894,000 health-adjusted life years and produce health system cost-savings of US$11 billion).

Fortunately, these dietary interventions also produce higher per capita health gain for Māori compared with non-Māori [32], and so (like with tobacco control) could contribute to reducing health inequities. Furthermore, some dietary interventions (i.e., those reducing consumption of ruminant meats and dairy products) could also have the potential co-benefits of reducing greenhouse gas emissions [35] and other harmful impacts of livestock agribusiness (e.g., on erosion and flood risk, and on the quality of recreational and drinking water).

With all such preventive interventions, a lot will depend on how they are designed and presented to the public. For example, a tax on sugary drinks has majority public support when it is combined with using the revenue to further subsidize child health in NZ [46]. Nevertheless, some interventions are already likely to be very acceptable to a majority of the public, especially if the rationale is well explained. For example, setting maximal sodium levels in products such as bread have been successfully introduced in other high-income countries [47, 48].

### Study strengths and limitations

A strength of this work is that it shows how GBD and local data can be used for prioritization purposes in one high-income country. It also fills a clear gap given that the NZ Government lacks any systematic approach to prioritising interventions to reduce health loss. Furthermore, this country has relatively high quality epidemiological and health economic modeling data with BODE$^3$ models using consistent approaches. These BODE$^3$ model publications have also met the quality inclusion criteria in various systematic reviews (e.g., on sodium [49] [50]; dietary policies [51] and equity [52]). BODE$^3$ modeling has also been ranked highest quality out of 25 tobacco control models in a systematic review [53]. But despite these strengths, the following limitations of this study should be noted:

- The GBD Study for risk factor impacts for NZ lack (published) results by ethnicity. Nevertheless, these can be estimated with further epidemiological work if policy-makers requested it, and most of the health economic modeling studies in Table 2 have published results for both Māori and non-Māori (e.g., in a study on prioritising cancer control interventions [54]).
- The GBD Study might still not be that accurate in some of the risk factor domains. For example, there is still a lot of uncertainty around the precise health harm from air pollution and some recent work produces higher mortality impacts than the GBD Study (e.g., Vohra et al [55]). Another example is that the strength of evidence for sodium reduction may also have improved since the GBD Study last evaluated it (e.g., from various new studies [56-58]).
- The GBD Study does not include all CVD risk factors. For example, most obvious missing ones include upstream determinants like unemployment [59] and perceived job insecurity [60]. Poverty and

socio-economic inequities may also contribute to CVD in pathways other than the more well-established risk factors considered in Table 1. Various occupational risk factors for CVD are also not included, with these including for NZ: exposures to “dust, smoke or fumes, oils and solvents, awkward grip or hand movements, carrying out repetitive tasks, working at very high speed, loud noise, and working with tools that vibrate” [61].

- The number of health economic studies performed into the different domains in Table 2 may reflect idiosyncratic factors (e.g., personal agendas of the researchers). Nevertheless, many were done by the BODE[3] Program which purposefully aimed to take a broad approach so as to populate league tables [62], so that policy-makers could be better informed over a wide range of choices.
- Not all the health economic studies in Table 2 use similar methodologies with this limiting their comparability (this methodological issue for the NZ context is discussed further elsewhere [18]).

### Possible next steps

Given the wealth of methodologically compatible data from the GBD and health economic modeling work for specific countries such as NZ – there is now a need to start operationalizing this information to benefit society by reducing avoidable health loss, reducing health inequities, and making better use of health dollars. For the NZ situation, this may mean that the restructured NZ health system probably needs a specialized unit that focuses on combining epidemiology, health economics and prioritization of health sector interventions. This could be within the proposed Public Health Agency – potentially with the unit also shared with the proposed Māori Health Authority (although the latter could have its own such unit). Alternatively, such a unit could be in a university – with a long-term (e.g., 10-year plus) funding commitment from central government so that adequate expertise could be established and retained. But failing these developments it is still possible for officials to use the information in this type of analysis to at least begin incremental moves towards more systematic and rational prioritization that maximizes health gain for the best value for money.

# Declarations

# Ethics approval and consent to participate

Not applicable.

# Consent for publication

Not applicable.

## Availability of data and materials

The dataset supporting the conclusions of this article is included within the article.

## Competing interests

Not applicable.


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## Authors' contributions

N.W. designed the key aspects of the study, collated the data, performed the analyses, and wrote the first draft of the manuscript. T.B. and C.C. contributed to design aspects and made critical comments around data. All the authors (N.W., T.B, C.C., and N.N) contributed to revisions to subsequent drafts and reviewed the final manuscript.


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# Tables

Table 2: Top five risk factors for CVD health loss ordered by level of evidence for cost-saving interventions in the NZ context (using number of peer-reviewed publications published from 1 January 2010 to 31 December 2021 as a proxy for level of evidence for health economic benefit)

| Risk factor (top 5 from Table 1 but ranked by column [A] results) | Publications of cost-saving interventions* [A] | Publications of cost-effective interventions** (when not in group [A]) | **Details of the relevant NZ health economic publications** (with all specific health gain and cost values given being for lifetime impacts at an annual discount rate of 3%) |
|---|---|---|---|
| Tobacco (including secondhand smoke) | 9 publications | 0 publications | ***Cost-saving:*** (i) Two tobacco tax increase studies [19] [20]<br>(ii) Reduced retail access [21]<br>(iii) Five endgame interventions (including impact on access and supply etc) [22]. The highest impact intervention was a sinking lid on tobacco sales (282,000 QALYs gained and NZ$ 5.5 billion [~US$3.8 billion] in health cost-savings). Higher per capita health gains for Māori vs non-Māori were identified.<br>(iv) Pharmacy-only sales and pharmacist counselling [23]<br>(v) Promotion of the Quitline for smoking cessation [24]<br>(vi) Promoting smartphone apps for smoking cessation [25]<br>(vii) Two studies [26] [27] on permitting ready access to e-cigarettes (albeit this has now largely occurred in NZ).<br>***Not cost-effective:*** Exercise counselling intervention to enhance smoking cessation [28]<br>***Comment:*** All the cost-saving studies detailed above capture CVD-related health benefits but also the benefits of preventing 14 other tobacco-related diseases (e.g., various cancers and chronic respiratory disease). |
| High systolic blood pressure (BP) | 4 publications | 2 publications | ***Cost-saving:*** (i) Three publications each involving multiple different dietary salt reduction interventions (including salt substitution, salt tax, UK style interventions etc) [29-31]; (ii) salt tax [32].<br>***Cost-effective:*** (i) A “soft regulation” national policy for dietary sodium reduction that combines targeted industry agreements, government monitoring, and public education (international study with NZ data) [33].<br>(ii) Double therapy (an anti-hypertensive and a statin) and anti-hypertensive alone by clinician-assessed absolute risk level (cost-effective for nearly all risk levels in the middle-aged male age-group studied) [34].<br>***Comment:*** There is some overlap with these BP interventions with those in the dietary risk factor grouping (elsewhere in this table) given that some of the latter will lower sodium intake and increase potassium intake. |

| Risk factor (top 5 from Table 1 but ranked by column [A] results) | Publications of cost-saving interventions* [A] | Publications of cost-effective interventions** (when not in group [A]) | **Details of the relevant NZ health economic publications** (with all specific health gain and cost values given being for lifetime impacts at an annual discount rate of 3%) |
|---|---|---|---|
| Dietary risk factors | 3 publications | 1 publication | ***Cost-saving:*** (i) Various combinations of food taxes and subsidies [32]. The highest impact intervention (a combined fruit and vegetable (F&V) subsidy plus a sugar tax) saved 894,000 health-adjusted life years and saved US$11.0 billion in health system costs. Behind this in impact were a sugar tax, then a salt tax with F&V subsidy, then a saturated fat tax with F&V subsidy, then a salt tax, and then a saturated fat tax. Higher per capita health gains for Māori vs non-Māori were identified.<br>(ii) Adoption of climate-friendly eating patterns [35] (the model included multiple CVD risk factors list in Table 1 including: red meat, sugar-sweetened beverages (SSBs), and sodium as well as low intake of fruit, vegetables, and polyunsaturated fat). But the economic analysis did not include the intervention costs associated with achieving these dietary pattern changes and it was assumed that the whole population shifted eating patterns.<br>(iii) A cap on the size of single servings for SSBs [36].<br>***Cost-effective:*** A multicomponent through-school physical activity and nutrition program ("Project Energize") [37].<br>***Comment:*** There is some overlap with this dietary risk factor grouping in this table and interventions to reduce BP, lower LDL cholesterol and to lower BMI (as detailed elsewhere in this table). Some of the cost-saving interventions capture non-CVD health benefits (e.g., preventing diet-related cancers, diabetes etc). |
| High LDL cholesterol | 1 publication | 1 publication | ***Cost-saving:*** Saturated fat tax [32].<br>***Cost-effective:*** Double therapy (a statin and anti-hypertensive) and statin alone by clinician-assessed absolute risk level (at least in middle-aged males) [34].<br>***Comment:*** There is some overlap with this risk factor grouping and the dietary interventions detailed elsewhere in this table (many of which would reduce dietary intakes of saturated fat and increase intakes of poly-unsaturated fat). |

| Risk factor (top 5 from Table 1 but ranked by column [A] results) | Publications of cost-saving interventions* [A] | Publications of cost-effective interventions** (when not in group [A]) | **Details of the relevant NZ health economic publications** (with all specific health gain and cost values given being for lifetime impacts at an annual discount rate of 3%) |
|---|---|---|---|
| High body-mass index (BMI) | 0 publications | 1 publication | ***Cost-saving:*** Nil.<br>***Cost-effective:*** A multicomponent through-school physical activity and nutrition program ("Project Energize") [37].<br>***Not cost-effective:*** (i) Weight-loss dietary counselling by nurses in primary care [38]; (ii) Mass media promotion of apps for weight loss [39].<br>***Comment:*** There is considerable overlap with this BMI risk factor grouping and the dietary intervention grouping (as detailed elsewhere in this table). We did not include four health economic studies of physical activity interventions [40] [41-43], given that the evidence of the association between physical activity and BMI is not particularly strong. |

* That is, cost-saving from a NZ health system perspective at typically a 3% discount rate.
** With cost-effective being defined as up to the GDP per capita of NZ (NZ$45,000 in 2011 or ~US$31,000) as per the standard BODE[3] modeling approach for NZ analyses [44].

# Figures

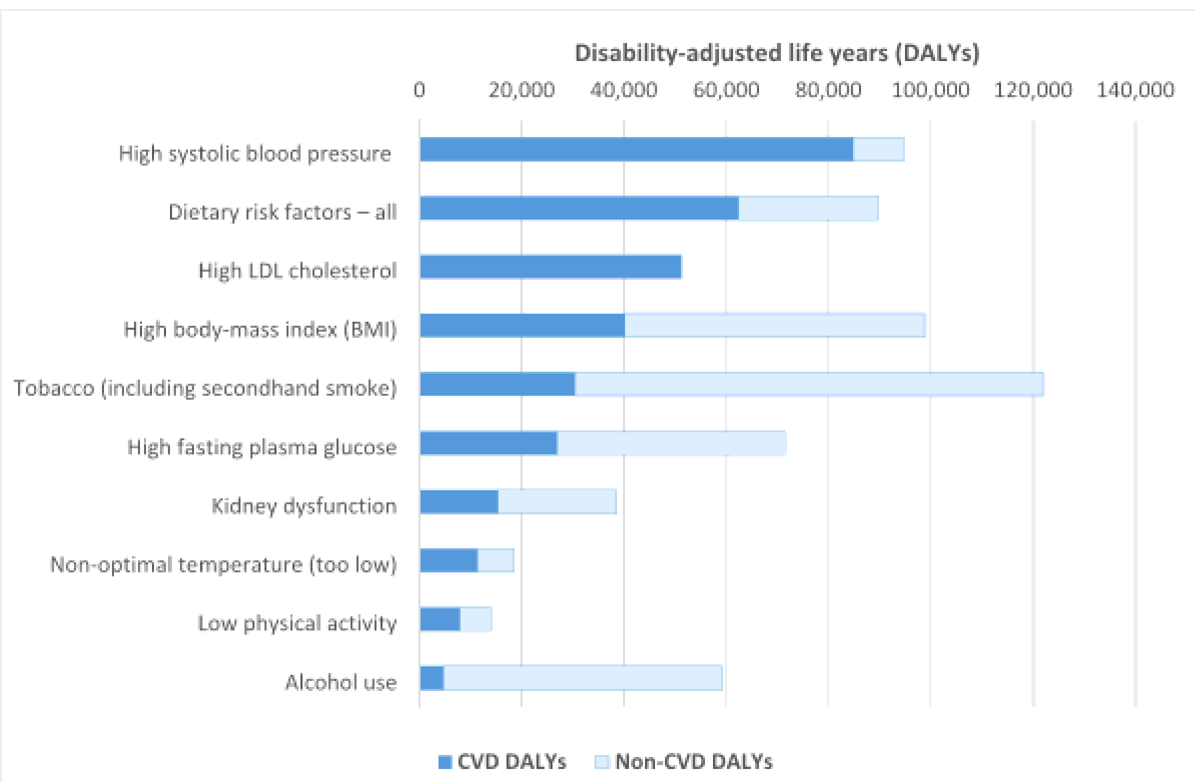


Figure 1

The top 10 risk factors for CVD in NZ ranked by attributable health loss but also showing non-CVD attributable health loss (GBD data for NZ extracted using the GBD Results Tool)