Updated Cost-effectiveness Modelling of a Behavioural Weight Loss Intervention Involving a Primary Care Provider

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Abstract

Objective: We aimed to update our previous estimates around the cost-effectiveness of a behavioural weight loss intervention delivered by a Primary Care Provider (PCP) in a high-income country case study.

Methods: A literature search of the impact of behavioural weight loss interventions involving a PCP on BMI was performed to source the 'best' effect size for use in modelling. This effect size was for a behavioural weight loss intervention delivered by general practitioners (GPs) and lay health trainers, which differs from the previously modelled intervention which was delivered by practice nurse. The effect size was combined with multiple other input parameters (e.g., likely uptake of intervention epidemiological and cost parameters for obesity-related diseases) in an established multi-state life-table model with 14 parallel BMI-related disease lifetables using a 3% discount rate. We calculated quality-adjusted life-years (QALYs) gained and health system costs over the remainder of the lifespan of the NZ population alive in 2011 (N=4.4 million).

Results: The behavioural weight loss intervention was estimated to result in a health gain of 860 QALYs (95% UI: 530 to 1,260) over the population's lifetime. This is a more certain result than our previous best estimate at 250 QALYs (-70 to 560). The incremental cost-effectiveness ratio was 2011 NZ$142,000 per QALY gained and was more favourable for Māori than non-Māori ($109,000 vs $150,000 per QALY gained). However, none of these results can be considered cost-effective compared to such a threshold as the level of GDP per capita (i.e., 2011 NZ$45,000).

Conclusions: This study provides clearer modelling level evidence that behavioural weight loss interventions delivered by PCPs generate net positive gains (relative to the more uncertain previous estimates with the same model). Nevertheless, the health gains are relatively small at the population level and the intervention is not considered to be cost-effective. Policy-makers wanting to obtain health gain and cost-savings from reducing obesity levels in the population may be better off focusing on strategies that address the obesogenic environment such as taxes on sugary drinks and junk food, food marketing controls and healthy school lunch programmes.

Introduction

High BMI is an important risk factor for disease globally (Lim et al., 2013). Individuals with obesity have higher rates of coronary heart disease (CHD), stroke, diabetes, osteoarthritis and various cancers (Forouzanfar et al., 2015). As with many other high-income countries, rates of obesity have risen in New Zealand (NZ);in 2011/12, 28% of adults had obesity, up from 19% in 1997 (Ministry of Health, 2010). A wide range of interventions aimed at decreasing BMI is needed to reverse this trend.

Dietary advice to reduce energy intake has been shown to be effective in helping people lose weight, with varying results (Hartmann-Boyce et al., 2014, Franz et al., 2007, Dansinger et al., 2007). In a meta-analysis of 46 trials, where dietary advice was provided by health professionals and non-professionals, BMI was -1.9 (95% confidence intervals (CI): -2.3 to -1.5) at 12 months in the treatment groups compared to usual care (Dansinger et al., 2007). In a second meta-analysis, diet interventions (delivered by a wide range of health professionals) focused on reducing energy in diets with behavioural strategies resulted in an average of 4.9 kg in weight loss after six months, compared to advice alone (Franz et al., 2007). A meta-analysis on the effect of brief behavioural weight management programmes for adults conducted in everyday contexts showed a non-significant change of -0.45 kg (95% CI: -1.34 to 0.43), at 12 months compared to the control group (Hartmann-Boyce et al., 2014). However, LeBlanc and colleagues conducted a relatively recent meta-analysis on the effect of behavioural weight loss intervention delivered by a Primary Care Provider (PCP) and reported a change of -1.45 kg (95% CI: -2.16 to -0.74), at 12 months compared to the control group (LeBlanc et al., 2018).

There is little research examining the cost-effectiveness of weight loss advice interventions in general (Gillett et al., 2012, Forster et al., 2011), and even less on advice delivered by a PCP (Cleghorn et al., 2020, Segal et al., 1998). For example, a modelling study estimated the dietary approaches to stop hypertension (DASH) to have an incremental cost-effectiveness ratio (ICER) of 2011 NZ$11,900 per disability-adjusted life-year (DALY) averted and a less intensive low-fat diet programme to have an ICER of 2011 NZ$12,900 per DALY averted (Forster et al., 2011). A diabetes prevention study found that a combined intervention of GP advice, diet and behavioural therapy cost the equivalent of 2011 NZ$ 1,430 to 3,710 for each additional year of life saved (Segal et al., 1998). A modelling study using the same model as the current modelling found that brief weight loss dietary counselling delivered by practice nurses in primary care generates relatively small health gains at the population level (250 QALYs, 95% UI: -70 to 560) and was unlikely to be cost-effective (2% if willingness-to-pay is set to the GDP per capita for each QALY gained (i.e., 2011 NZ$45,000))(Cleghorn et al., 2020).

Given this background, the primary aim of this study was to estimate the future impact of behavioural weight loss interventions involving a PCP on health gains and changes in the health system’s expenditure in New Zealand, using updated evidence. The ‘business-as-usual’ comparator was usual care, defined as care provided by a health professional, such as a general practitioner, which does not typically include dietary counselling for weight loss.

Methods

OVERVIEW

Main outputs from this modelling were incremental health gain in QALYs and health system costs in 2011 NZ dollars (NZ$) between the behavioural weight loss intervention and business-as-usual (BAU). Both health gain and costs were discounted at 3%, with 0% and 6% used in scenario analyses. This modelling takes a health system perspective, i.e. excludes co-payments by patients, and assumes that the intervention is fully funded by the health system. Benefits and costs were modelled over a lifetime horizon. The intervention was modelled as a one-off intervention over the course of a year in the target population of adults with overweight or obesity.

The intervention effect was captured in the model through changes in weight from the behavioural weight loss intervention leading to change in average BMI, and then through population impact fractions (PIFs, which link the change in BMI with relative risks for BMI-related diseases). PIFs then alter disease incidence, resulting in changes in QALYs and health system costs.

A diet multi-state life-table model (MSLT) was built from an established tobacco control MSLT model (using many of the same diseases), from which we have published work previously (Blakely et al., 2015, Pearson et al., 2016, Van der Deen FS, 2017, Cleghorn et al., 2018). The diet model has already been used to study a number of dietary interventions (Cleghorn C et al., 2018, Cleghorn et al., 2019, Drew et al., 2020), including a paper on dietary counselling by practice nurses (Cleghorn et al., 2020). The conceptual diagram of this diet model is shown in Figure 1 and is described further in an online technical report (Cleghorn et al., 2017).

The diet MSLT model was used to simulate the entire NZ population that was alive in 2011 over their remaining lifetimes. This model is structured as a main life-table with projected all-cause mortality and morbidity rates by sex and age for Māori (Indigenous New Zealanders) and non-Māori with 14 BMI-related diseases running in parallel (i.e., CHD, stroke, type 2 diabetes, osteoarthritis and ten BMI-related cancers: endometrial, kidney, liver, oesophageal, pancreatic, thyroid, colorectal, breast, ovarian and gallbladder). The proportion of the NZ population in each parallel disease state is a function of the disease incidence, case-fatality and remission.

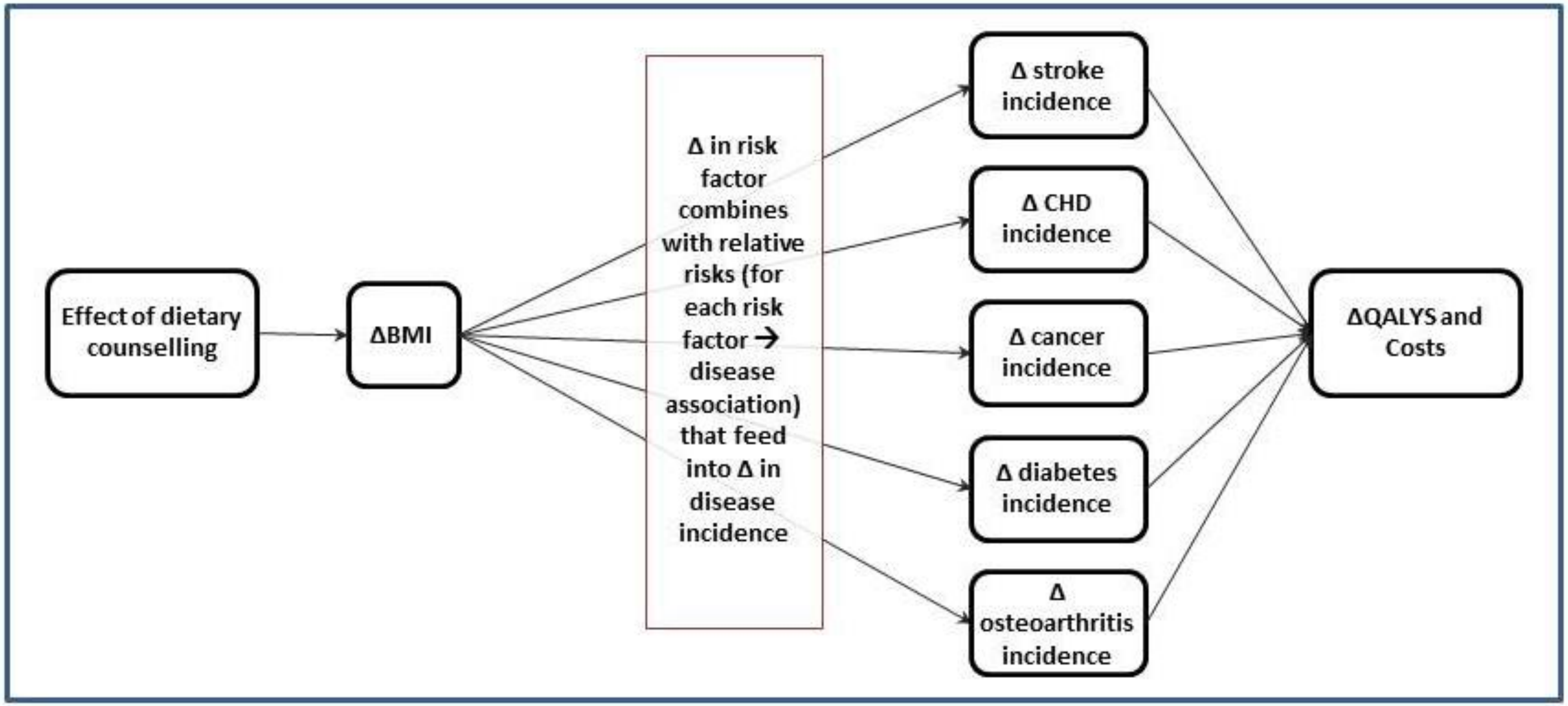

Figure 1 Conceptual diagram of the diet multi-state life-table model used in this modelling

BUSINESS-AS-USUAL (BAU) INPUT PARAMETERS

All input parameters, specified by sex, age and ethnicity unless stated otherwise, are shown in Table 2. Incidence, prevalence and case-fatality rates in 2011 are included for each disease. Remission was specified for cancers and set to zero for the chronic conditions of CHD, stroke, type 2 diabetes and osteoarthritis. Morbidity was quantified for each disease. This was calculated as prevalent years of life lived with disability (YLDs) from the NZ Burden of Disease Study (BDS), divided by the population count.

Individually-linked data for publicly-funded (and some privately-funded) health events occurring in 2006-10 was used to calculate sex and age specific health system costs in 2011 NZ$. These costs included hospitalisations, inpatient procedures, outpatients, pharmaceuticals, laboratories and expected primary care usage. Costs that were assigned in the model fell into the following three categories: (1) sex and age-specific annual cost of a citizen who does not have a BMI-related disease and is not in the last six months of their life; (2) disease-specific excess costs for people in the first year of diagnosis, the last six months of life if dying of the given disease, and otherwise prevalent cases of each disease in the model; and (3) the costs associated with the last six months of life if dying from a disease not in the model.

INTERVENTION PARAMETERS

Screening and referral rates

We used a range of data sources to calculate intervention screening and referral rates. The proportion of the population likely to receive this intervention and how this model input is calculated is presented in Figure 2.

The existing 'Heart and Diabetes Checks' programme in 2011 in NZ targeted Māori, Pacific and Indo-Asian men over 35 years and women over 45, European men over 45 and European women over 55 and people who have a family history of heart problems. On average, 90% (95% UI: 80% to 97%) of eligible adults had their diabetes and cardiovascular disease (CVD) risk assessed in the five years leading up to 2015 (New Zealand Ministry of Health, 2016). We used this figure as an estimate for the proportion of the target population that would be identified by GPs as eligible for the intervention.

The proportion of the target population that is likely to be referred to the weight loss intervention (60%, 95% UI: 35% to 82%) was estimated from a European survey of GPs (Brotons et al., 2003). This survey found that for a scenario of a 52 year old man with no other risk factors, 62% of GPs reported advising overweight patients to lose weight and 59% reported doing the same for a scenario of a 59 year old woman with no other risk factors.

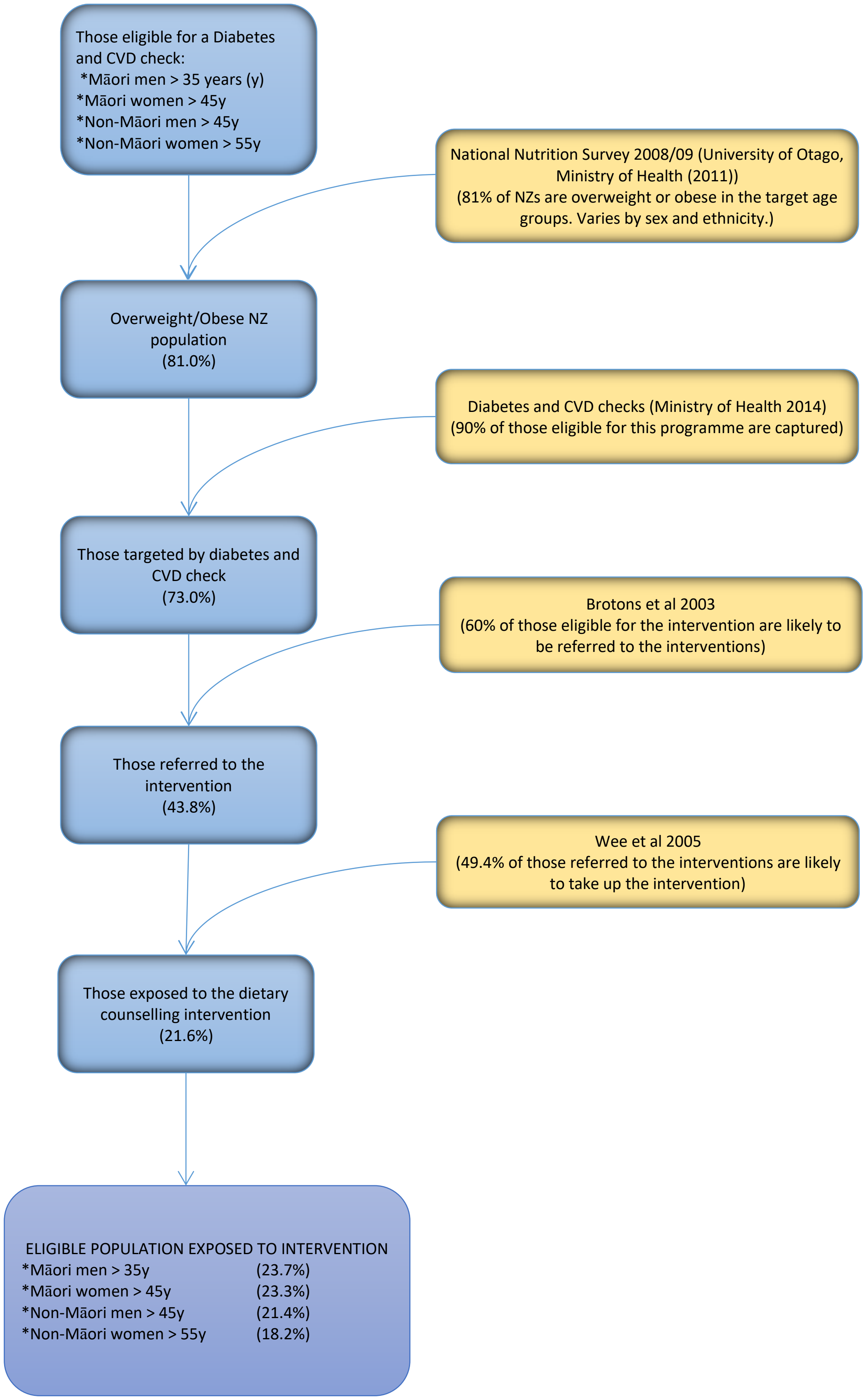

Figure 2 Flow diagram illustrating the targeting of the dietary counselling interventions in the New Zealand adult population as used in the model

Uptake rate
We then estimated what proportion of those referred to the weight loss intervention would be likely to take up this opportunity based on a study by Wee et al (Wee et al., 2005). This study assessed patients' readiness to lose weight and to change a number of weight-related behaviours. Wee et al. classified respondents into different stages for each behaviour: pre-contemplative and contemplative and then three advanced stages of change: preparation (thinking about changing in the next month), action (attempting change currently), and maintenance (changed behaviour and attempting to maintain change). In this study, 46% of adults with overweight and 53% of adults with obesity were at one of the three advanced stages of change to lose weight, improve diet and increase exercise. From these data we estimated that 49.4% (a weighted average of 46% and 53%; (95% UI: 40% to 59%)) of the overweight population referred to this intervention would be likely to take it up.

Effect size
The effect size used in this report is sourced from LeBlanc et al.'s 'Behavioural and pharmacotherapy weight loss interventions to prevent obesity-related morbidity and mortality in adults: an updated systematic review for the U.S. Preventive Services Task Force,' published as *Evidence Synthesis* Number 168 (LeBlanc et al., 2018). A shortened version of this work is reported in JAMA.[7] They present a meta-analysis for trials that involve a PCP (N=15) which was used for this modelling. This review was identified through a recent literature review conducted by Jones and colleagues to identify parameters suitable for health economic modelling of diet interventions (Jones AC, 2020).

Study overview
In LeBlanc et al.'s review, eligible studies were those that focused on weight loss in adults with overweight or obesity, or studies focusing on maintenance of previous weight loss. The review organised the interventions into three separate analyses (behavioural weight loss interventions, pharmacotherapy weight loss interventions, and weight loss maintenance interventions) and included multiple subgroup analyses to identify characteristics associated with programme effectiveness. Only interventions deemed 'primary care-relevant' met the study's inclusion criteria. The authors described these interventions as follows:

"We included interventions that were conducted in or recruited from primary care or a health care system or that we judged could feasibly be implemented in or referred from primary care. We included studies of commercial weight loss programs that are widely available in the community at a national level. We excluded studies that took place exclusively in or in conjunction with worksites, churches, or other settings that are not generalizable to primary care given pre-existing social ties that are not easily reproducible in primary care."(LeBlanc et al., 2018)

An overview of this review's characteristics can be found in

Table 1.

Table 1 Characteristics of the LeBlanc et al. (2018) review

REVIEW CHARACTERISTIC	DESCRIPTION
Study designs	Randomised or clinically controlled trials that report data at least 12 months following the start of the intervention
Population	Adults with overweight or obesity. The review excluded any study that selected participants based on the presence of a chronic disease in which weight loss or maintenance was a component of disease management (e.g., known CVD, T2DM)
Setting	Settings that were generalizable to primary care
Intervention	Behavioural weight loss interventions, pharmacotherapy weight loss interventions, or weight maintenance interventions. For the purposes of the modelling carried out in this report, only behavioural weight loss interventions are of relevance
Comparators	Any of: no intervention (e.g., wait list, usual care, assessment-only); minimal intervention (e.g., usual care limited to quarterly counselling sessions or generic brochures); attention controls (e.g., similar format and intensity but different content)

Adapted from Jones et al. 2020(Jones AC, 2020)

Intervention details

Among the studies included in the meta-analysis (LeBlanc et al., 2018) the degree of interaction with the PCP and the input from other providers varied across the interventions (see Table 10 in this report's Appendix). The types of trials included in the meta-analysis also varied widely in intensity and approach. The majority of the included studies relied on in-person sessions (either individual or group), with the PCP or lay health trainer equivalent (N=10). Five studies also included further intervention through a website (N=4), email (N=2) or phone contact (N=1), printed material (N=2) or exercise-related DVDs (N=1).

For modelling, the details on the trials included in the meta-analysis were used to devise an 'average' intervention to model. The intervention was modelled as a one-off, 12 month intervention that occurred within the baseline year (2011). The modelled intervention reflects an intervention that, on average, included GP involvement for an average of 45 minutes and lay health trainer involvement for an average of 300 minutes (5 hours). The modelled intervention also consists of an average of 14 sessions, a mix of individual sessions and group sessions with a GP or a lay health trainer (or equivalent). As the majority of the interventions were focused on counselling by health professionals we did not include any further costs for additional resources.

The target population for this intervention was NZ adults with excess weight, defined as having a BMI of 25-30 (varies by age and ethnicity, but an average of 34% of the NZ adult population) or obese, defined as a BMI of >30 (average 39% of the NZ adult population in 2008/09 (University of Otago and Ministry of Health, 2011)). For the model, we specified that adults with overweight and obesity would be recruited by their GPs through the existing national programme of 'Heart and Diabetes Checks' which already collects data on height, weight and waist circumference (Ministry of Health, 2014).

The meta-analysis showed a small weight reduction for interventions with 'PCP involvement' (mean difference -1.45 kg, 95% CI: -2.16 to -0.74) compared to the control groups. When this effect was averaged over the overweight and obese population within eligible age groups (i.e. allowing for coverage, etc.) this reduced to a change in BMI of -0.14 per person.

The rate at which the weight loss attenuated over time was based on Dansinger et al. (Dansinger et al., 2007) who found that BMI increased by 0.03 BMI units/month post-dietary counselling from an initial BMI decrease of 1.9 units. Evidence on how weight regain differs by magnitude of initial weight loss is currently limited, so we used this 0.03 BMI units/month as an estimate of how the modelled weight loss would decay post intervention. With such a small initial effect size the BMI decrease returned to zero approximately 5 months into the year after the intervention ended.

Table 2 Baseline input parameter table used in modelling a behavioural weight loss intervention involving a PCP

Baseline input Parameter	Source and application to model	Expected Value and 95% UI	Distribution
Baseline population count	Statistics NZ (SNZ) population estimates for 2011.	Nil uncertainty.	N/A
All-cause mortality rates	SNZ mortality rates for 2011.	Nil uncertainty.	N/A
Disease-specific incidence, prevalence, case-fatality rates (CFR) and remission rates	For each disease, coherent sets of incidence rates, prevalence, CFR, and remission rates (zero for non-cancers, the complement of the CFR for cancers to give the expected 5-y relative survival) were estimated using DISMOD II using data from NZ BDS, HealthTracker and the Ministry of Health.	Uncertainty: rates all +/- 5% standard deviation (SD).	Log-normal
Disease trends	Trends are applied to incidence, case-fatality and remission. These are switched on until 2026 and then kept constant for the remainder of the lifetime.	Uncertainty: +/- 0.5% absolute change. Diabetes: Uncertainty +/- 1.5% absolute change.	Normal
Total morbidity per capita in 2011	The per capita rate of years of life lived with disability (YLD) from the NZ BDS.	Uncertainty: +/- 10% SD.	Log-normal
Disease morbidity rate per capita	Each disease was assigned a disability rate (DR; by sex and age) equal to YLDs for that disease (scaled down to adjust for comorbidities) from the 2006 NZ BDS projected forward to 2011, divided by the disease prevalence. This DR was assigned to the proportion of the cohort in each disease state.	Uncertainty: +/- 10% SD.	Normal
Health system costs	Linked health data (hospitalisations, inpatient procedures, outpatients, pharmaceuticals, laboratories, and expected primary care usage) for each individual in NZ for the period 2006–2010 had unit costs assigned to each event, and then five health system costs (2011 NZ$) were estimated.	Estimated at SD = +/-10% of the point estimate.	Gamma
Time lags	It takes time for a change in BMI to impact on disease incidence. As there are no data on just how long these are we have used wide windows for time lags. For cancers the time lag was assumed to range between 10 and 30 years. For CHD, stroke, diabetes and osteoarthritis the time lag was assumed to be shorter and ranged between 0 and 5 years. Wide uncertainty is included in these estimates.	Uncertainty: +/- 20% SD of the minimum (10) and maximum (30) with no correlation	Normal
BMI TMREL	The Theoretical Minimum Risk Exposure Level (TMREL) is the level of risk exposure at which the dose response ceases. For BMI, a TMREL of between 21 and 23 was used from the latest Global Burden of Disease study (Forouzanfar et al., 2015).		Uniform
Adult height	Mean and SD of height from NZ Adult Nutrition Survey 2008/09 (University of Otago and Ministry of Health, 2011)	Uncertainty using reported SD.	Normal

Table 3 Intervention input parameter table used in modelling a behavioural weight loss intervention involving a PCP

Intervention Input Parameters	Source and application to model	Expected Value and 95% UI	Distribution
Effect size	Weight loss in the intervention arm of the review had an average weight loss of -1.45 kg, 95% CI: -2.16 to -0.74) (LeBlanc et al., 2018) at 12 months.	-1.45kg (95% CI: -2.16 to -0.74).	Normal
Decay in BMI change post-intervention	Modelled BMI reduction decays back to the pre-intervention BMI at a rate of 0.03 units per month returning to approximately baseline levels the year after the intervention (Dansinger et al., 2007).	24% per year Uncertainty +/- 20% SD.	Exponential
Those targeted by diabetes and CVD check	90% of those eligible for a diabetes and CVD check are captured through this programme (New Zealand Ministry of Health, 2016): This model targets adults with overweight and obesity over 35 years for Māori men, over 45 years for Māori women and Non-Māori men, and over 55 years for Non-Māori women.	95% UI: 80% - 97%	Beta
Those referred to the intervention	60% of the above were assumed to be referred by GPs to practice nurses (Brotons et al., 2003)	95% UI: 35% - 82%	Beta
Those exposed to the intervention	49.4% of the above are likely to take up the intervention (Wee et al., 2005).	95% UI: 40% - 59%	Beta
Intervention costs	Total intervention costs were 2011 NZ$ 138,482,196 for the behavioural weight loss intervention (See Table 6 for details).	Modelled uncertainty set at 20% of the mean	Gamma
Relative risks for risk factors and disease incidence	See Table 4 and 5 for disease specific relative risks.		

Table 4 Relative risks of BMI-related diseases (non-cancers) from the Global Burden of Disease Study (for males and females, per 5 BMI units) (Forouzanfar et al., 2015)

	Age-group	CHD	Stroke	Type 2 diabetes	Osteoarthritis (knee & hip combined)
Male	25-29	2.274 (1.252 - 3.686)	2.620 (1.486 - 4.318)	3.546 (2.300 - 5.227)	1.677 (1.388 - 2.021)
	30-34	2.018 (1.291 - 3.107)	2.404 (1.547 - 3.599)	3.455 (2.500 - 4.692)	1.568 (1.305 - 1.882)
	35-39	1.724 (1.531 - 1.934)	2.134 (1.760 - 2.581)	3.349 (2.801 - 3.918)	1.592 (1.328 - 1.919)
	40-44	1.599 (1.417 - 1.785)	1.985 (1.675 - 2.337)	3.160 (2.689 - 3.700)	1.576 (1.312 - 1.876)
	45-49	1.567 (1.455 - 1.681)	1.862 (1.646 - 2.114)	2.864 (2.450 - 3.318)	1.510 (1.275 - 1.798)
	50-54	1.520 (1.416 - 1.631)	1.732 (1.518 - 1.964)	2.624 (2.222 - 3.038)	1.504 (1.265 - 1.797)
	55-59	1.466 (1.372 - 1.558)	1.599 (1.468 - 1.740)	2.417 (2.084 - 2.781)	1.521 (1.288 - 1.814)
	60-64	1.414 (1.324 - 1.505)	1.496 (1.363 - 1.637)	2.215 (1.866 - 2.611)	1.543 (1.294 - 1.830)
	65-69	1.364 (1.286 - 1.448)	1.406 (1.321 - 1.499)	2.046 (1.724 - 2.388)	1.558 (1.296 - 1.866)
	70-74	1.319 (1.241 - 1.400)	1.323 (1.238 - 1.411)	1.896 (1.596 - 2.229)	1.558 (1.301 - 1.883)
	75-79	1.274 (1.187 - 1.365)	1.239 (1.160 - 1.328)	1.740 (1.445 - 2.087)	1.558 (1.290 - 1.861)
	80+	1.170 (1.090 - 1.252)	1.069 (1.000 - 1.157)	1.461 (1.207 - 1.762)	1.588 (1.320 - 1.925)
Female	25-29	2.274 (1.252 - 3.686)	2.717 (1.543 - 4.538)	3.546 (2.300 - 5.227)	1.496 (1.285 - 1.748)
	30-34	2.018 (1.291 - 3.107)	2.514 (1.614 - 3.772)	3.455 (2.500 - 4.692)	1.466 (1.251 - 1.722)
	35-39	1.724 (1.531 - 1.934)	2.234 (1.806 - 2.754)	3.349 (2.801 - 3.918)	1.460 (1.255 - 1.712)
	40-44	1.599 (1.417 - 1.785)	2.035 (1.699 - 2.419)	3.160 (2.689 - 3.700)	1.501 (1.272 - 1.761)
	45-49	1.567 (1.455 - 1.681)	1.837 (1.633 - 2.072)	2.864 (2.450 - 3.318)	1.496 (1.268 - 1.776)
	50-54	1.520 (1.416 - 1.631)	1.761 (1.530 - 2.015)	2.624 (2.222 - 3.038)	1.541 (1.284 - 1.856)
	55-59	1.466 (1.372 - 1.558)	1.621 (1.480 - 1.775)	2.417 (2.084 - 2.781)	1.566 (1.313 - 1.886)
	60-64	1.414 (1.324 - 1.505)	1.502 (1.366 - 1.649)	2.215 (1.866 - 2.611)	1.565 (1.306 - 1.865)
	65-69	1.364 (1.286 - 1.448)	1.411 (1.323 - 1.507)	2.046 (1.724 - 2.388)	1.575 (1.304 - 1.892)
	70-74	1.319 (1.241 - 1.400)	1.323 (1.238 - 1.413)	1.896 (1.596 - 2.229)	1.562 (1.303 - 1.889)
	75-79	1.274 (1.187 - 1.365)	1.237 (1.159 - 1.322)	1.740 (1.445 - 2.087)	1.555 (1.288 - 1.856)
	80+	1.170 (1.090 - 1.252)	1.069 (1.000 - 1.160)	1.461 (1.207 - 1.762)	1.562 (1.305 - 1.882)

Table 5 Relative risks of BMI-related cancers from the Global Burden of Disease Study (per 5 BMI units) (Forouzanfar et al., 2015)

		Kidney cancer	Liver cancer	Oesophageal cancer	Pancreatic cancer	Thyroid cancer	Colorectal cancer	Gallbladder cancer	Endometrial Cancer	Breast cancer	Ovarian cancer
Males	All ages	1.24 (1.17 - 1.31)	1.29 (1.11 - 1.49)	1.39 (1.08 - 1.76)	1.07 (1.00 - 1.15)	1.22 (1.07 - 1.38)	1.18 (1.15 - 1.21)	1.16 (1.03 - 1.28)	NA	NA	NA
Females	All ages	1.32 (1.25 - 1.40)	1.18 (1.03 - 1.34)	1.35 (1.01 - 1.75)	1.09 (1.04 - 1.14)	1.14 (1.09 - 1.18)	1.06 (1.03 - 1.08)	1.34 (1.22 - 1.48)	1.61 (1.54 - 1.68)	1.02 (1.02 - 1.03)	1.04 (1.00 - 1.08)

INTERVENTION COSTS

Costs of the intervention were calculated as the time spent by the GP and lay health trainer (Table 6). The health system cost was the combination of the intervention costs and the difference in projected future health system expenditure resulting from changes in disease incidence due to the behavioural weight loss intervention (and including extra health system costs from any longer life attributable to the intervention).

The modelled intervention includes GP involvement for an average of 45 minutes and lay health trainer involvement for an average of 300 minutes (5 hours). We assumed that this cost would be covered by the health system rather than being paid for by the patients. Costs to the individual practices for administrator time and resources were factored into the GP salaries.

For this intervention it was assumed that the GP and lay health trainer did not require training, only some time learning about the implementation of the specific intervention.

Table 6 Intervention costs used in the modelled intervention

Cost component	Details	Cost (NZ $2011)
GP time	GP time calculations were based on a BODE[3] report on 'Protocol for Direct Costing of Health Sector Interventions for Economic Modelling' (Foster et al., 2012). This report presents the average total cost per GP visit for enrolled patients by age (excluding GST). The average for all adults (18+) was $62.22 per consult, including overhead cost. This figure includes PHO management fees and health promotion payment and is weighted by the proportion of the population in each age group. Our calculations assume a normal consult of 10-15 minutes (12.5 minutes on average): $62.22/12.5*45=$223.99 for a 45 minute session.	It was assumed that GP would commit an average of 45 minutes to each patient. **$93,475,731** ($224 per patient; 417,321 targeted patients)
Lay health trainer time	Based on a WHO choices paper which presents global health worker salary estimates. The paper presented the average earnings index (multiple of GDP per capita) in high-income countries for "other health workers" to be 0.9 (Serje et al., 2018) NZ GDP per capita in 2011 was $45,000. $45,000 *0.9 = $40,500/year Assuming a 37.5 hour work week costs of a lay health trainer was estimated to be $20.77/ hour.	It was assumed that lay health trainers would commit an average of 5 hours to each patient. **$43,337,181** ($103.85 per patient; 417,321 targeted patients)
Total intervention costs		**NZ$ 136,812,912** SD= ±20%

MODELLING AND ANALYSIS

An Ersatz add-in (Barendregt, 2012) to Microsoft Excel was used to incorporate parameter uncertainty and run the multiple sex by age by ethnic cohorts through the model 2000 times each. Each iteration involved a random draw from the probability density function about the Table 2 and Table 3 parameters, specified with uncertainty. The main results produced by the model were incremental QALYs and net health system costs. Results for the base case are presented for the total population and by sex and ethnicity (for both Māori and non-Māori).

Incremental cost-effectiveness ratios (ICERs) were calculated by dividing the incremental costs to the health system by the number of QALYs gained. This was then compared to the GDP per capita for NZ ($45,000 in 2011) to assess whether the intervention was cost effective.

SCENARIO AND SENSITIVITY ANALYSES

Māori have higher background mortality and morbidity, resulting in a lesser 'envelope' for potential health gains, which disadvantages Māori in the analysis. Therefore, an equity analysis was conducted whereby non-Māori all-cause mortality and population morbidity rates were used for Māori (McLeod et al., 2014) (Table 7 and Table 8).

In the base case, weight loss occurred in the first year and then began a steep decay. In order to explore the impact of the decay rate used in the base case we ran a scenario analysis simulating a theoretical situation where all weight lost with the intervention was maintained over the subsequent course of the participants' lifetimes (Table 9).

We also ran sensitivity analyses varying the discounting rate from 3% (to 0% and 6%, Table 9).

Results

The total health gain for the NZ population estimated for the behavioural weight loss intervention was 860 QALYs (95% UI: 530 to 1,260; see Table 7). Net health system costs were an extra NZ$121.6 million [m] (95% UI: 94.7m to 152.8m; 2011 NZ$ real dollars). Based on the expected value results presented in Table 8, the ICER for the behavioural weight loss intervention was estimated to be 2011 NZ$142,000 per QALY gained.

Per capita QALY gains were 0.19 QALYs per 1000 adults in the population as a whole and 0.75 QALYs per 1000 adults in the target population. Per capita gains were 1.3 times higher for Māori (0.25/1000 people) than for non-Māori (0.18/1000 people) but 2.4 times as high when using age-standardisation (based on population age in 2011) assuming that the intervention achieved equal coverage within age-groups, was equally effective and had the same attenuation for Māori and non-Māori. For the target population (obese and overweight), age-standardised per capita gains for Māori were 1.4 times higher than those for non-Māori. The Māori-equity analysis increased modelled Māori health gains by 48 QALYs (29% over the default analysis) and gave a greater per capita ratio in the total population for Māori compared to non-Māori (1.7 crude ratio, 2.6 when age-standardised).

In a sensitivity analysis, when the model was rerun with no discounting, QALY gains increased to approximately 1,470 QALYs and costs decreased to 2011 NZ$117m (Table 9). In contrast, at a discount rate of 6%, these results were 570 QALYs and 2011 NZ$124m. In the scenario analysis when weight loss decay was switched off, simulating a theoretical situation where all weight lost with the intervention was maintained over the subsequent course of the participants' lifetimes, the QALY gains increased by 89 times to 78,100 and the intervention became cost-saving at 2011 NZ$1290m (all at the 3% discount rate).

Table 7 Modelled health gains and net health system cost-savings among NZ adult population alive in 2011 for the behavioural weight loss intervention*

	Non-Māori	Māori		Ethnic groups combined	
Starting age	**QALYs**	**QALYs**	**QALYs – equity****	**QALYs**	**Net costs (million)†**
Sex and age groups combined	690 (380 to 1,080)	170 (90 to 260)	210 (120 to 330)	860 (530 to 1,260)	$122 (153 to 94.7)
Men					
25-44 year olds (non-Māori not eligible)‡	0	28	34	28	$5.6
45-64 year olds	295	59	76	353	$35.2
65+ year olds	110	8	11	118	$18.5
All ages	405	94	120	499	$59.4
Women					
25-44 year olds (not eligible)‡	0	0	0	0	$0.0
45-64 year olds	149	63	80	211	$40.0
65+ year olds	137	10	14	147	$22.2
All ages	285	73	94	358	$62.2
Per capita (QALYs/1000 people & $)	0.18 (0.12)	0.25 (0.30)	0.32 (0.39)	0.19 (0.42)	$27.6 ($46.3)
Per capita: target population (overweight/obese & targeted age groups, QALYs/1000 people & $)	0.73 (0.21)	1.04 (0.54)	1.33 (0.69)	0.77 (0.75)	$110 ($104)

QALYs, quality-adjusted life-years; Results rounded to either two or three meaningful digits
*Results are modelled using 3% discounting and include QALYs for over 25 year olds as relative risks for the associations between risk factors and disease start at age 25 years.
**Includes the cost offsets and the behavioural weight loss intervention costs (see Table 6 for details), distributed pro rata across all people alive in 2011. Intervention costs were partitioned by age, sex, and ethnicity.
†QALYs calculated using non-Māori background mortality and morbidity rates (McLeod et al., 2014)
‡Non-Māori men 25-44 and all women 25-44 were not eligible for heart and diabetes checks and therefore this intervention

Table 8: Modelled health gains (QALYs) and net health system costs among the NZ adult population alive in 2011 for the behavioural weight loss intervention*(95%UI in brackets)

	QALYs	Net costs (NZ$ million) †	ICER (NZ$ per QALY gained)
Sex and age groups combined	860 (530 to 1,260)	$122 (94.7 to 153)	142,000
Males	500 (250 to 830)	$58.2 (43.5 to 73.6)	117,000
Females	360 (190 to 590)	$63.5 (49.5 to 78.7)	177,000
Non-Māori	690 (380 to 1,080)	$103 (80.5 to 130)	150,000
Māori	170 (90 to 260)	$18.2 (13.9 to 23.0)	109,000
Māori – equity‡	210 (120 to 330)	$18.1 (13.7 to 22.7)	84,100

QALYs, quality -adjusted life-years. ICER, Incremental cost-effectiveness ratio
Results rounded to either two or three meaningful digits
*Results are modelled using 3% discounting and include QALYs for over 25 year olds as relative risks for the associations between risk factors and disease start at age 25 years.
†Includes both the cost offsets and the behavioural weight loss intervention costs (see Table 6 for details), distributed pro rata across all people alive in 2011. Intervention costs were partitioned by age, sex, and ethnicity.
‡QALYs calculated using non-Māori background mortality and morbidity rates (McLeod et al., 2014)

Table 9: Sensitivity and scenario analyses about health gains and net health system costs among NZ adult population for the behavioural weight loss intervention*

Scenario	QALYs gained	Net costs (NZ$ million)	ICER (NZ$ per QALY gained)
'Base' case†	880	$121	138,000
Discount rate: 0% per annum	1,470	$117	80,000
Discount rate: 6% per annum	570	$124	216,000
No decay in weight loss benefit subsequently (3% discount rate)	78,100	$-1,290 (cost-saving)	dominant

QALYs, quality -adjusted life-years. ICER, Incremental Cost-effectiveness ratio.
Results rounded to either two or three meaningful digits.
*Expected value analysis, no uncertainty
† Includes both the cost offsets and the behavioural weight loss intervention costs (see Table 6 for details), distributed pro rata across all people alive in 2011
‡ Discount rate 3%, modelled BMI reduction decays back to the pre-intervention BMI at a rate of 0.03 units per month returning to approximately baseline levels the year after the intervention.

Discussion

MAIN FINDINGS AND INTERPRETATION

The total estimated health gain from this modelled intervention in the NZ population was relatively small, at about 860 QALYs (95% UI: 530 to 1,260). Nevertheless, these results give more certainty than our previous best estimates of 250 QALYs (-70 to 560) for weight-loss dietary counselling by nurses in primary care (the parameters that differed between the previous and current modelling were the intervention effect size and intervention costs). The high intervention costs associated with this intervention ($137 million) meant that the cost per QALY gained (the ICER: $142,000) was substantially higher than the GDP per capita threshold that can be used for determining "cost-effectiveness" (i.e., 2011 NZ$45,000).

Per capita health gains were higher for Māori than for non-Māori as a result of a higher prevalence of elevated BMI, a higher burden of diseases modifiable through BMI changes, and the extended age range of intervention eligibility for Māori (e.g. from 35 years instead of 45 years for males as per current NZ guidelines for the programme of "heart and diabetes" routine checks – see *Methods*). It was assumed that uptake and effectiveness of the behavioural weight loss intervention was the same by ethnicity. If the update and effectiveness were lower for Māori, then the overall health gains for Māori would be less.

The relatively small health gain seen at a population level with this intervention is common for weight loss interventions and other treatment interventions that target individuals. The small effect size among participants of 1.45 kg found in the studies included in the meta-analysis by LeBlanc et al. (LeBlanc et al., 2018) reduced to a change in BMI of only 0.14 units per eligible person in the NZ population with overweight or obesity. This small change in BMI translated to per capita QALY gains of 0.19 QALYs per 1000 adults in the population as a whole and 0.75 QALYs per 1000 adults for the target population.

STUDY STRENGTHS AND LIMITATIONS

A strength of this modelling is that the intervention was specified based on the characteristics of the studies included in the meta-analysis used for the modelling effect size (LeBlanc et al., 2018). LeBlanc and colleagues calculated a number of pooled estimates for a range of studies. We used the effect size that was estimated for a subset of studies that involved some degree of PCP involvement. The majority of these studies had GP involvement but the bulk of the intervention was delivered by a lay health trainer (or equivalent). The specified intervention reflects the amount of contact time of the providers had with the participant; this contact time is also reflected in the costing that we conducted for the modelling.

A challenge of dietary counselling for weight loss studies, including meta-analyses of these studies, is the substantial variation in how this type of intervention is designed and delivered. In LeBlanc et al.'s report, the authors' conclusions in reference to their entire review of behaviour-based weight loss intervention analyses included comments on study heterogeneity and the characteristics that were associated with greater or lesser intervention effectiveness (LeBlanc et al., 2018):

"It is nearly impossible to determine to what extent specific population and intervention characteristics were driving intervention effects given the within- and between-study heterogeneity in population, intervention, and broader study characteristics. Few interventions included interaction with a PCP, and among those that did, the level of PCP interaction was variable. In addition, no two studies had exactly the same intervention messaging, schedule, or mode delivery, although many built off of learnings from earlier trials (e.g., the Diabetes Prevention Programme). We applied a priori subgroup analyses and meta-regression in an effort to identify whether any particular intervention modes or characteristics were driving larger effects. We did not find that the main intervention mode (group vs individual vs technology vs mixed), the involvement of a PCP, or the duration of the intervention significantly affected the direction or magnitude of the benefit." (LeBlanc et al., 2018)

We assumed all the intervention and costs occur in one year and that these costs were met by the health system for ease of modelling. This modelling scenario is somewhat hypothetical as it may not be entirely feasible to rapidly upscale this behavioural weight loss intervention and deliver the intervention in just year one (without some spill-over into year two), and similarly it would be unlikely to completely "be turned off" again after one year. If this intervention was repeated annually, this would cover many of the same individuals so the pool of eligible individuals would decrease over time, but would capture those that are newly screened. Some individuals who refused the intervention in the first year may decide to take it up in subsequent years. It is likely that this approach would increase health gains but it is difficult to estimate the impact on the cost-effectiveness of the intervention.

This intervention has proposed using the 'Heart and Diabetes Checks' (Ministry of Health, 2014) national programme currently running in NZ to recruit adults with overweight or obesity to this intervention. This programme targets specific age-groups (see *Methods* for details) and captures 90% of its target population. This approach allowed for the modelled theoretical intervention to capture a high proportion of the target population, a level that may be difficult to successfully attract if the behavioural weight loss intervention were rolled out in NZ.

The intervention was modelled solely through a change in BMI but ignores other effects that the intervention might generate. The interventions included in the meta-analysis included advice to increase physical activity, but the change in metabolic equivalent of tasks (METs) is not captured in the meta-analysis or in the modelling. There may also be an improvement in other dietary risk factors such as, increased fruit and vegetable intake or reduced sodium and sugar intakes, which are not captured. Nor does the intervention include the possibility that some GPs or lay health trainers may provide advice to patients on using smartphone apps for dietary change or using pedometer functions on smartphones, for which there is growing evidence for effectiveness (Flores Mateo et al., 2015, Kang et al., 2009). Our results may therefore include an element of underestimation of the health benefit.

The base year for demographic, epidemiological, and costing specification is 2011, with trends out to 2026 – as per other comparison evaluations in the Burden of Disease Epidemiology, Equity and Cost-Effectiveness (BODE[3]) Programme. It was beyond the scope of this evaluation to update the entire model to a more recent base-year such as 2018. Had this been done, we anticipate the total health gain in QALYs would have increased slightly due to population growth and ongoing high obesity rates, but the general pattern of findings would be unlikely to change much.

POTENTIAL IMPLICATIONS FOR RESEARCH AND HEALTH AGENCIES

It is unlikely that future investment in behavioural weight loss interventions delivered by a PCP and a lay health trainer would be a good use of health funding. The modelled behavioural weight loss intervention produced small health gains and the intervention was deemed to not be cost-effective. Therefore, alternative strategies to reduce the prevalence of overweight and obesity should be employed. The health sector could invest more in other evaluated obesity-prevention and management interventions ahead of counselling ones (including those listed for Australia and New Zealand in an online league table of methodologically compatible interventions (University of Otago & University of Melbourne)). For example, Retat et al. (2019) found that physicians who referred people with high BMI to a commercial weight loss programme generated greater health gains and cost savings when compared to physicians who provided weight loss advice directly. There is also some evidence that is starting to favour other strategies that address the obesogenic environment (e.g., taxes on sugary drinks and junk food as used in Mexico (Colchero et al., 2017), food marketing controls (Dhar and Baylis, 2011) and healthy school lunch programmes (Spence et al., 2013) etc.). Indeed, modelling work conducted in Australia has found a range of obesity prevention interventions to be either cost-saving (11 interventions) or cost-effective (5 interventions). The interventions generating the most health gains and cost-savings were a volumetric tax on alcohol, taxing SSBs and restricting television advertising of unhealthy foods (Ananthapavan J, 2018).

CONCLUSIONS

This study provides modelling level evidence for the likely impact of behavioural weight loss interventions involving a PCP and a lay health trainer. This work improves upon our previous modelling work by using updated estimates and as such was able to clearly demonstrate that net health gains resulting from the intervention were small (as opposed to uncertainty about this in our previous study on dietary counselling delivered by practice nurses). Despite dietary counselling in primary care being commonly recommended within health systems, our evaluation suggests that this intervention generates a relatively small health gain at the population level and is unlikely to be cost-effective. Although per capita gains were higher for Māori than for non-Māori, based on the ICER results, the behavioural weight loss intervention was still unlikely to be cost-effective for Māori.

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Appendix

Table 10 Details of interventions included in LeBlanc et al.'s meta-analysis of trials with Primary Care Provider involvement (N=18 studies)*

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
(Appel et al.) 2011 (POWER Hopkins)	Intervention focused on behavioural self-management approaches designed to help participants set weight-related goals, self-monitor weight and weight-related behaviours, increase self-efficacy and support, and solve problems. Motivational interviewing was the primary approach to interactions with participants. At routine medical visits, GP encouraged participant to actively engage in the intervention.	Mixed 36	Total: 24 Core: 24 Support: 0	24 x group counselling sessions (90 min), 27 x individual counselling sessions (20 min), 15 x phone sessions (20 min), all with a lifestyle coach, weekly visits to website (that contained learning modules and opportunities for self-monitoring of weight, calorie intake, and exercise) and monthly email (provided tailored feedback)
		Phone with tech support 21	Total: 24 Core: 24 Support: 0	33 x telephone calls (20 min) with a lifestyle coach, weekly visits to website (that contained learning modules and opportunities for self-monitoring of weight, calorie intake, and exercise) and monthly email (provided tailored feedback)
(Aveyard et al., 2016)	Brief intervention lasting no more than 30 seconds in which GP offered to refer participant for free through National Health Service (NHS), to a weight loss program. GP asked them to make an appointment to return in a month. The appointments served as an opportunity for GP to re-refer those who accepted referral but did not attend, refer those who tried to lose weight on their own but did not do well, prescribe orlistat to those who have followed the treatment programme but not succeeded (in line with NICE guidance), and to reinforce GP's seriousness about participant weight change.	Group 14	Total: 3 Core: 3 Support: 0	1 x individual session with GP(<30 sec), 1 x follow up appointment with GP (NR min), 12 x optional weekly group sessions provided by e.g. Slimming World (60 min)

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
(Beeken et al., 2017) (10TT)	Participants received the 10 Top Tips leaflet which focused on simple diet and exercise behaviour, together with a simple logbook for self-monitoring of target behaviours and weight during the 3-month habit acquisition phase, and a wallet sized card with guidance on food labels. A single 30-minute session with a nurse or health care assistant within the baseline appointment was allocated to take patients through the leaflet using a flip chart and discuss habit formation. At 3 months, patients were mailed a second copy of the 10 Top Tips leaflet and were told they could request additional copies of the logbook.	Individual 1	Total: 3 Core: 3 Support: 0	1 x individual session with a nurse/health care assistant (30 min)
(Bennett et al., 2012) (Be Fit, Be Well [POWER])	Participants were prescribed 3 tailored goals to modify routine lifestyle behaviours; new goals were selected at 13-week intervals. For the duration of the study, participants maintained a hypertension medication adherence goal (to take their medication as prescribed daily). The tailored behaviour change goals, self-monitoring, and skills training were available via a website or interactive voice response which participants were encouraged to use daily. GP delivered at least 1 brief, standardized message about the importance of intervention participation. Participants were provided behaviour change "prescription" that included GP's electronic signature, as well as tailored information on community resources (e.g., public parks, walking groups, and farmers' market) and received a walking kit with a pedometer.	Phone with tech support 12	Total: 24 Core: 24 Support: 0	Web-based self- monitoring, 18 x counselling telephone calls (monthly in the first year, bimonthly in the second year)on self-monitoring data, problem solving and behavioural skills training (20 min), 12 x optional group sessions on interactive skills training, a physical activity component and promoting social support for behavioural change (min NR), GP delivered at least 1 message on the importance of intervention participation.
(Christian et al., 2011)	A computer-based assessment (<10 minutes) solicited information on usual dietary habits, weight- management history, and awareness of the role of diet and exercise in the prevention of diabetes to assess motivational readiness to increase physical activity and make dietary changes. The computer system then generated a tailored report providing feedback addressing participant-identified barriers to improving their physical activity and diet for both the	Tech 2	Total: 6 Core: 6 Support: 0	Computer-based self- management programme plus 2 x individual sessions with GP(min NR), given a 30-page planning guide that provided supplemental information on preventing diabetes and

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
	participant (who then listed 2-3 dietary and/or PA self-management goals) and the GP before a usual care appointment. Participants reassessed goals at 6 months and again reviewed their goal sheet with their physician, who reinforced patients' goals.			achieving goals.
(Cohen et al., 1991)	12 monthly visits (min NR) with the GP. At each visit the GP reviewed the patient's previous day food intake and weight and suggested dietary changes and help set short-term goals in preparation for the next visit. The goal of the dietary advice was to reduce the caloric content of the diet without radically changing the patient's lifestyle. Feedback to encourage weight loss was provided based on amount of weight lost or gained.	Individual 12	Total: 12 Core: 12 Support: 0	12 x individual sessions on dietary change (min NR) with GP
(Eaton et al., 2016) (Choose to Lose)	Twelve months of focused weight loss and lifestyle changes under the guidance of a registered dietitian, followed by a 12-month maintenance intervention. All participants met with their counsellor at baseline and set a weight loss goal of 10% over 6 months. They were given a structured meal plan dependent on their starting weight to support a 500 to 1,000 kcal reduced-calorie diet based on the diabetes prevention programme (DPP) guidelines. Participants were encouraged to add 10-min of moderate-intensity PA most days of the week and work up to 300 minutes/week by 6 months. They were given food and exercise self - monitoring diaries for the first 6 months. Participants met again with their counsellors at 6 and 12 months to review progress and set new goals as needed. In addition, they received 8 counselling phone calls (20-30 minutes) during year 1; 52 weekly tailored and non-tailored mailings for the first year and monthly in months 13 to 18 and bi-monthly in months 19 to 24. PCPs were updated about the patients' progress during the study to support management of related comorbidities, to give patients further accountability, and to promote adherence to the weight loss and physical activity regimen.	Individual + Phone 11	Total: 24 Core: 12 Support: 12	3 x individual sessions with counsellors (90 min), 8 x phone calls with counsellors (25 min), 12 printed materials (tailored exercise feedback reports), 2 exercise-related DVDs
(Jolly et al., 2011) (Lighten	Twelve weekly one-on-one counselling sessions with a nurse in general practice (first session = 30 min, remainder = 15-20 min) based around a problem solving approach. Weight loss goals were 5-10% of body weight, at a rate of 0.5-1 kg/week over 3-6	Individual	Total: 3 Core: 3	1 x initial session with a nurse (30 min), 11 x follow up sessions with a

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
Up)	months, followed by maintenance. Content comprised of weight and dieting history; exploration of goals & expectations of patients; eatwell plate; setting goals to reduce calorie intake & increase PA (to 30 min of moderate activity 5 days/week); planning strategies to deal with challenging situations; use of food diaries; and maintaining weight loss. Participants provided with resources as homework to discuss in sessions or use for personal reflection. Participants encouraged to reward themselves for success.	12	Support: 0	nurse (15 -20 min)
	Participants were given the choice of 1 of 6 different weight loss programs: NHS Size Down, Weight Watchers, Slimming World, Rosemary Conley, General Practice one-on-one support, and Pharmacy one-on-one support. 71% participants chose one of the commercial providers - Weight Watchers (29%), Slimming World (14%), Rosemary Conley (28%). 16% chose the Size Down program, 3% chose general practice, and 10% chose pharmacy support.	Group 12	Total: 3 Core: 3 Support: 0	12 x weekly group or one-on-one (participant chosen) sessions (min NR)
(Kanke et al., 2015)	At first consultation, participants were informed of their ideal body weight and weight loss goal and counselled on the positive effects of weight reduction for participants' respective pre-existing diseases. Subsequent consultations (every 1-2 months) involved routine measurements along with GP advice on general lifestyle changes for individuals who have obesity and personalized advice focusing on weight reduction, adjusted to each participant's circumstance and lifestyle.	Individual 12	Total: 12 Core: 12 Support: 0	6-12 x individual sessions with a GP (7 min)
(Kumanyika et al., 2012)	Use of Think Health!, a modified cultural adapted DPP-based programme delivered over 1 year. Counselling by PCP every 4 months (10-15 minutes). Counselling by Lifestyle coach monthly (10-15 minutes). Sessions addressed food and activity diaries and weight loss goals, healthy eating, increasing physical activity, negative thoughts/stimulus control, food environment/stress management/social cues. Goals set for 1,200-1,800 kcal/day based on weight and individuals were provided calorie counters. Activity goal of 30 min 5 days a week	Individual 17	Total: 12 Core: 12 Support: 0	4 x counselling sessions with a GP (10- 15 mins), 12 x individual sessions with a lifestyle coach (10-15 mins)

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
(Logue et al., 2005) (REACH)	Four semi-annual counselling sessions with dietician (10 mins) with written dietary and exercise prescriptions based on dietary and exercise recalls. Evaluated for anxiety, depression, and binge eating disorder every six months and completed a trans-theoretical model-based stage of change (SOC) assessment every two months. Mailed stage- and behaviour-matched workbooks corresponding to SOC profile. Monthly 15-minute phone calls from a weight loss advisor to review behavioural techniques based on their SOC. Access to public domain patient handouts and other materials (menu suggestions, mall walking maps, descriptions of local walking trails). Self-monitoring of the target behaviours was suggested but not reviewed. GPs received periodic reports of progress and training on the use of the SOC related materials.	Individual + Phone 14	Total: 24 Core: 24 Support: 0	4 x individual sessions with a dietician (10 min), 24 x phone calls with a weight loss advisor (15 min), plus personalized mailings
(Martin et al., 2008)	Participants had monthly visits (1/month for 6 months - 15 mins per visit) with their GP. Visits addressed weight loss, ways to decrease dietary fat, ways to increase physical activity, dealing with barriers to weight loss, healthy eating, and maintaining motivation. Personalised verbal recommendations and handouts summarizing the focus of each visit.	Individual 6	Total: 6 Core: 6 Support: 0	6 x individual sessions with a GP (15 min)
(Moore et al., 2003)	Primary care staff training consisted of three 90-min small group sessions held between 1 and 2 weeks apart over a 6 week period. All GPs and practice nurses were asked to attend all three sessions. The training covered the clinical benefit of weight loss and effective treatment options, including reduction of dietary energy intake, increased physical activity, and pharmaceutical intervention using best evidence. Practices then devised individual weight management protocols after being presented a model in which patients visited their GP about every two weeks until they had lost 10% of original body weight, then every 1-2 months for maintenance. Providers estimated patient's daily energy requirement and then prescribed a 500 kcal deficit. Diet sheets and supporting written resources were given to patients.	Individual 8	Total: 12 Core: 12 Support: 0	Providers: 3 x group training sessions (90 min), Patients: Average of 8 individual sessions with a GP (min NR)

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
(Nilsen et al., 2011)	Brief intervention given at pre-randomisation advising to make small changes in lifestyle and weight; to increase consumption of fruit and vegetables; to exercise get at least 30 minutes a day; to lose at least 5% of weight; to reduce sugar and saturated fat consumption; to use oil as main source of f at; and to consume cod- liver oil daily. After randomisation, participants consulted with the study physician, who utilized the elements of motivational interviewing techniques, at 6, 12 and 18 months. Participants also attended small group sessions (≤10 participants) one day (5 hours per day) each week for 6 weeks and one group session at 16 weeks. Group sessions emphasized educating participants on how to avoid diabetes and CAD with factual information about nutrition and physical activity, habit change, action plans, risk situations, and coping strategies. A variety of physical training was also offered. An individual 30-minutes consultation with a nurse or ergonomist completed the intervention one month after the last group session.	Group 10	Total: 18 Core: 5 Support: 13	1 x individual sessions with a GP (30 mins), 7 x group sessions with an interdisciplinary group (300 mins), 1 x individual sessions with a nurse or ergonomist (30 mins)
(Rodriguez -Cristobal et al., 2017)	GP visits every three months with advice on lifestyle changes, physical activity, hypocaloric diet (1,200-1,500 kcal), and anthropometric measurements. Participants received 60-minute nurse-delivered group motivational intervention session every 15 days, at the initial weeks 1-12 of the intervention, following LEARN (Lifestyle, Exercise, Attitudes, relationships and Nutrition) programme and then monthly at weeks 13-32, following the instructions of the Weight Maintenance Survival Guide programme.	Group 32	Total: 24 Core: 6 Support: 18	4 x visits with a GP (min NR), 12 x group sessions with a nurse(60 mins)
(Tsai et al., 2010)	Quarterly GP visits (weight management was ~2-3 min) and 1-2 pg. handouts developed by the Weight-Control Information Network or the National Institutes of Health) (provided to both Intervention and control groups). They also received a calorie counter, a pedometer, and sample meal plan. Participants received a series of 8 brief (15-20 min) individual sessions with a medical assistant @ weeks 0, 2, 4, 8, 12, 16, 20, and 24 in which DPP materials were used. Participants instructed to restrict dietary intake (1,200-1,500 kcal/day if <250 lb. or 1,800 kcal/day if ≥250 lb.), keep daily records of intake, and to gradually increase PA to 175 min/week. Patients were	Individual 12	Total: 12 Core: 12 Support: 0	4 x brief sessions with a GP(2-3 min), 8 x individual sessions with a medical assistant (15-20 min)

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
	weighed at each visit and food and PA records were reviewed.			
(von Gruenigen et al., 2012) (SUCCEED)	Participants attended 16 1-hour group sessions over six months (10 weekly followed by 6 biweekly) in which PA, nutrition, and improving diet quality and behaviour modification were discussed. Participants were weighed in private at beginning of each session and weekly food/PA records were reviewed. Intervention followed a step-wise, phased approach with short-term goals. Nutritional component included improving diet quality by increasing fruits, vegetables, lean protein, whole grains, and low-fat dairy intake, while reducing saturated fat, simple carbohydrates and low nutrient-high calorie foods. Additional topics addressed were grocery shopping, portion sizes, meal planning, food labels, and social eating. Focus was on lifestyle changes rather than caloric restriction. At first session, Dietician provided individualized weight loss goals. PA goals were 150 min/week for months 1-2, 225 min/week for months 3-4, and 300 min/week for months 5-6. Participants provided w/pedometers, 3 lb. hand and adjustable ankle weights, and heart rate monitors. Individual counselling with GP occurred @ months 3, 6, and 9 with the purpose of augmenting group sessions & providing individualized counselling. After 6 months, dietitian provided additional feedback/support via newsletters, phone, and email regarding dietary & PA suggestions.	Mixed 19	Total: 12 Core: 12 Support: 0	16 x group sessions with a dietician (60 mins) (months 1-6), 3 x sessions with a GP (min NR) (months 1-12), Print, telephone, and email support (months 7-12)
(Wadden et al., 2011) (POWER-UP)	Participants whose weight was less than 113.4 kg were prescribed a balanced diet of 1200 to 1500 kcal per day (1500 to 1800 kcal per day for participants who weight 113.4 or more), which consisted of approximately 15 to 20% kcal from protein, 20 to 35% kcal from fat, and the remainder from carbohydrate. All participants instructed to gradually increase their PA to 180 min/week and were given a pedometer, a calorie-counting book, and handouts from Aim for a Healthy Weight. Attended quarterly 10-15 min GP visits, at which they reviewed their health status and were provided handouts from Aim for a Healthy Weight. In addition, participants attended	Individual 16	Total: 24 Core: 24 Support: 0	8 x individual sessions with GP (5-7min), 24 x individual sessions with lifestyle coach (10-15min)

Author, year (study name)	Intervention description	Main mode of delivery / Total # of sessions in first 12 months	Duration (months)	Core components
	monthly visits with a lifestyle coach (LC), who delivered abbreviated DPP treatment. Participants attended 14 LC visits in year 1, followed by 12 LC visits in year 2. During month 1, this included 2 counselling visits to learn how record food and calorie intake in diaries provided. Visits began with a weigh-in and then a review of food intake, PA and other goals prescribed in monthly handouts.			

*Information extracted from table 4 and Appendix F, table 1 of LeBlanc's report (LeBlanc et al., 2018)