Assessing the Cost-Effectiveness of Public Health Interventions to Prevent Obesity:
Overview Report

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Executive Summary

Obesity and overweight constitute a significant, and increasing, public health issue in New Zealand. The purpose of this research was to provide evidence on the relative cost-effectiveness of selected population-based initiatives aimed at preventing obesity and obesity-related chronic health problems in New Zealand.

This research was commissioned by the Health Research Council of New Zealand and the Ministry of Health. The research was undertaken by a collaborative group of researchers from the Health Services Research Centre at Victoria University of Wellington, Health Technology Analysts (a consultancy group based in Sydney, Australia), and Canterbury University. The research team was supported by a stakeholder reference group, which provided input throughout the project. The research took place between September 2009 and October 2010.

The first phase of this research was a wide ranging scoping search of the literature to identify population-based obesity-prevention interventions. A total of 95 relevant primary prevention interventions were found: 22 in New Zealand, 16 in Australia, 31 in the United States or Canada, and 26 from the United Kingdom, Europe or elsewhere in the world. The research team and the stakeholder reference group considered the results of the scoping search and selected 16 interventions that had been judged to be effective using a weight-based outcome. These interventions were then subject to full systematic review. Those selected covered both nutrition and physical activity interventions in a variety of age groups and settings (pre-school, school, tertiary education, community, primary care and workplace). The aim of the systematic review was to formally assess the evidence on the effectiveness of the selected interventions.

When the systematic review was completed, the research team and stakeholder reference group met again to consider the evidence and select 10 obesity-prevention scenarios to undergo cost-effectiveness analysis. A scenario is a particular obesity prevention intervention in a specific population or sub-population. In making their selection, the group considered relevance to the New Zealand population (including Māori and Pacific peoples) and policy setting; feasibility for implementation in New Zealand; the effectiveness of the intervention in preventing obesity; ability to produce population benefits; and a balance of intervention types, settings and ages. The 10 scenarios selected for cost-effectiveness modelling are shown in the table below.

Interventions selected for cost-effectiveness modelling following systematic review

Scenario Number	Study	Country in which Evidence was Collected	Setting	Intervention Type	Proposed Population for Modelling
1	APPLE (children)	New Zealand	Community	Activity/Education	General population
2, 3, 4	Be Active Eat Well (children)	Australia	Community	Nutrition/Activity/ Behaviour modification	General population, Māori, Pacific

5, 6, 7	General Health Screening (adults)	Denmark	General Practice	Education	General population, Māori, Pacific
8	Green Prescriptions (adults)	New Zealand	General Practice	Activity	General population
9	SNPI (School Nutrition Policy Initiative) (children)	USA	Primary school	Education (nutrition)/ Nutrition	General population
10	Switch-Play (children)	Australia	Primary school	Activity/Behaviour modification	General population

The cost-effectiveness for each of the scenarios was assessed using a lifetime model to estimate the incremental cost per quality adjusted life year (QALY), using a total health care budget perspective (i.e. accounting for all government incurred health care costs, but excluding individuals' out-of-pocket expenses) and a 3.5% annual discount rate. A summary of the cost-effectiveness of each of the scenarios using incremental cost-effectiveness ratios (ICER) is set out in the table below.

Summary of base case cost-effectiveness results (2010 New Zealand dollars)

Analysis	Population	Incremental cost	Incremental QALY	ICER
Switch-Play (general population, Analysis A)	Children	$128.38	0.027	$4824.18
General Health Screening (general population)	Adults	$89.10	0.014	$6179.51
General Health Screening (Pacific population)	Adults	$103.88	0.016	$6577.56
General Health Screening (Māori population)	Adults	$115.09	0.017	$6675.97
Switch-Play (general population, Analysis B)	Children	$104.62	0.003	$38,630.15
Be Active Eat Well (Māori population)	Children	$837.67	0.007	$123,536.19
Green Prescription (general population)	Adults	$206.59	0.002	$133,877.96
SNPI (general population)	Children	$101.31	0.001	$134,252.49
Be Active Eat Well (Pacific population)	Children	$834.41	0.005	$154,178.04
Be Active Eat Well (general population)	Children	$832.96	0.005	$168,391.38
APPLE (general population)	Children	$1392.65	0.007	$205,101.45

Note: Children refers to those aged less than 18 years; adults refers to all others

The results were tested in a number of sensitivity analyses, and data limitations and their implications are discussed.

Based on the approach taken, the evidence available at the time of writing and the assumptions utilised in the economic modelling of this research, the most cost-effective interventions for obesity prevention would appear to be a school-based programme for children and general health screening and advice for adults in a primary care setting. The reader should note, however, that all results hinge on a modest effect on BMI due to the intervention. Additionally, it should be noted that the maintenance of the BMI effect, in all cases, contributes substantially to the estimation of each intervention's cost-effectiveness. Similarly, the cost per participant plays a

key role. Given the inherent uncertainty in these estimates, the possibility of variation to the cost should be considered, particularly in the case of interventions in which scalability could reduce the costs and improve the cost-effectiveness. Finally, it could be expected that inclusion of benefits such as improved physical function, mobility, mental health and social interaction could similarly lead to improved cost-effectiveness should they be capable of being justifiably incorporated into future analyses.

 Appropriate implementation in the New Zealand setting will also be crucial for any programme adopted. Neither of the New Zealand programmes modelled appeared highly cost-effective, and it is notable that many New Zealand interventions have not been evaluated for outcome measures necessary for this type of modelling.

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List of Abbreviations

APPLE	A Pilot Programme for Lifestyle and Exercise
BMI	Body mass index
ICER	Incremental cost-effectiveness ratios
PA	Physical activity
QALY	Quality adjusted life year
SNPI	School Nutrition Policy Initiative

1. Background

Obesity and overweight constitute a significant, and increasing, public health issue in New Zealand. Premature mortality, morbidity, and poorer quality of life are all associated with higher body mass index (BMI). In the past two decades, the average level of obesity in OECD countries has risen eight percent[1], with considerable variation among countries. New Zealand ranked third among OECD countries for adult obesity in 2007[2]. Between 1977 and 2003, the prevalence of obesity in New Zealand increased from 11% to 22% among females and from 9% to 20% among males, which gives an average annual percent change of approximately 3% for both genders[3]. More recent data show that about one in four (27%) adults meet the criterion for obesity (BMI>30), with a further 36% being classified as overweight[4]. Māori and Pacific men and women are more likely than the general population to be classified as obese, as are those, particularly women, living in areas of highest neighbourhood deprivation[4].

While there was no increase in childhood obesity from 2002 to 2007, the reported rate of 8-10% for young males and females remains a significant concern, particularly given that early onset of obesity is associated with increased likelihood of obesity in later life and an increased prevalence of obesity-related disorders[5-6]. The ethnic disparities seen in adults are also apparent among children, with Māori boys and girls being 1.5 times more likely to be obese than those in the total population, and Pacific girls and boys 2.5 times more likely[4]. More concerning still, in a representative sample of New Zealand school children, Goulding *et al*. reported a 2.7% prevalence of extreme obesity overall, with considerable ethnic differences: 0.8% among New Zealand European; 5.1% among Māori; and 10.9% among Pacific children[7].

Internationally, the World Health Organization, governments and other organisations have recognised the need for comprehensive public health strategies to prevent obesity[8-10]. New Zealand introduced a national Healthy Eating Healthy Action Strategy in 2003, aimed at improving nutrition, increasing physical activity and reducing obesity[11]. Choosing interventions, however, to prevent obesity is difficult given that existing reviews of the obesity prevention literature have reported mixed results from a diverse range of studies[6 12-14]. To date, it is unclear what the most effective and cost-effective aspects of obesity prevention interventions are (e.g. whether it is more cost-effective to implement various approaches to reducing intake of energy-dense foods, school-based programmes, television or other social marketing campaigns, promotion of increased physical activity through structured programmes, environmental change such as cycle ways, or education). The Australian ACE-Obesity project evaluated the effectiveness and cost-effectiveness of 13 obesity interventions in children and adolescents and concluded the greatest health benefit was likely to be achieved by reducing television advertising of high fat and/or high sugar foods and drinks to children; laparoscopic adjustable gastric banding (a clinical rather than public health intervention, included to provide benchmark data); and a multi-faceted school-based programme with an active physical education component[15-16]. Sassi et al's analysis of the health and economic impact of obesity prevention strategies concluded most have favourable cost-effectiveness ratios compared with no systematic prevention and the treatment of chronic diseases once they emerge[17]. Analysis of public health strategy costs and outcomes will vary in settings with different levels of income, distributions of risk factors, health system characteristics and costs[18].

The purpose of this research was to provide information on the relative cost-effectiveness of selected population-based initiatives aimed at preventing obesity and obesity-related chronic health problems in New Zealand. In March 2009, the Health Research Council of New Zealand (HRC) released a request for proposals, *Assessing the Cost-Effectiveness of Public Health Interventions to Prevent Obesity*, jointly funded by the Health Research Council of New Zealand and the Ministry of Health. The primary objective was "to examine the effectiveness and cost-effectiveness of selected public health interventions to prevent obesity, thus providing economic information to assist policy and funding decisions. What are the best options towards which NZ health resources should be directed to reduce unhealthy weight gain?"[19] Researchers were expected to use the best available evidence to weigh up intervention options, while recognising assumptions, estimates and modelling might also be required where evidence was limited.

The Health Services Research Centre at Victoria University of Wellington, in conjunction with Health Technology Analysts (Sydney) and the University of Canterbury, tendered for and won the contract to conduct the research. The project began in September 2009 and ran for just over a year, with a stakeholder reference group providing advice and guidance throughout the research. The key focus of the research was public health interventions for the primary prevention of obesity which had been evaluated with evidence of their effectiveness. The total number of interventions able to be modelled for their cost-effectiveness was constrained by the available time and funding. We report here on the 10 scenarios which were selected and the results of the economic modelling. The findings of this research will inform policy makers about the relative merits of different investments, with a view to reducing the prevalence of a range of chronic health problems including diabetes, arthritis, cancer and obesity. This in turn will result in improved quality of life for New Zealanders and better value for money in health-care expenditure in New Zealand.

2. The Research Process

There were three main stages of this project: a scoping search and selection of interventions for systematic review; systematic review and selection of interventions for economic modelling; and cost-effectiveness analysis.

2.1 Stage 1: Scoping Search and Selection of Interventions for Systematic Review

The first phase of this research was a wide ranging scoping search of the literature, designed to identify a large number of population-based obesity-prevention interventions. Database and internet searches were conducted for both published and unpublished evidence about studies addressing obesity prevention (i.e. those aimed at preventing weight gain rather than treating obesity) in the general population (not specifically those who were overweight or obese) of any age. Reference lists of relevant studies were also checked for additional evidence. Among the relevant material, the database and internet searches identified 18 systematic reviews which assessed programmes aimed at preventing obesity.

It should be noted that the scoping literature search aimed to identify programmes specifically targeted at preventing obesity. However, programmes targeted at other issues (e.g. improving overall health and fitness, preventing diabetes, preventing cardiovascular disease) could also

impact on obesity. We searched the reference lists in the already identified systematic reviews on preventing obesity to identify such additional studies. An additional database search was also undertaken to identify these types of studies published since the systematic reviews.

Emphasis was placed on identifying New Zealand-based interventions as priority would be given to assessing the cost-effectiveness of interventions already implemented or under development in New Zealand, and those that address the particular needs of New Zealand's priority populations. Interventions conducted outside of New Zealand or Australia were only included if they were one year or more in duration (allowing sufficient time for assessment of effectiveness); provided an outcome measure relevant to obesity prevention, including BMI, weight, percentage body fat, skin fold and incidence of obesity or overweight (necessary for the planned economic modelling); and had been evaluated. More inclusive criteria were allowed for interventions assessed in New Zealand and Australia, including some of shorter duration or which had not yet been evaluated.

Depending on the focus of the intervention, each study located was classified into one of four categories: activity (e.g. exercise programmes); nutrition (e.g. changes to availability of foods at a school canteen); education (sub-classified by activity or nutrition, depending on whether the education focused on increasing physical activity or improving diet); and advertising or social marketing. Many studies had a combination of different types of intervention. Activity, nutrition and education interventions or combinations were common, but few addressed advertising. Only one intervention study relating to breastfeeding and obesity was identified. Interventions also took place in a variety of settings: pre-school, primary school and/or high school; college or university; general practice; the community; workplaces. The majority of obesity prevention interventions were targeted at children, and consequently many were implemented in a school environment.

Studies were also classified by their level of evidence according to Australian National Health and Medical Research Council guidelines as follows:
- **Level I:** A systematic review of level II studies.
- **Level II:** A randomised controlled trial.
- **Level III-1:** A pseudo-randomised controlled trial (i.e. alternate allocation or some other method).
- **Level III-2:** A comparative study with concurrent controls: (i) non-randomised, experimental trial; (ii) cohort study; (iii) case-control study; or (iv) interrupted time series with a control group.
- **Level III-3:** A comparative study without concurrent controls: (i) historical control study; (ii) two or more single arm studies; (iii) interrupted time series without a parallel control group.
- **Level IV:** Case series with either post-test or pre-test/post-test outcomes.

The result of the scoping search was the identification of a total of 95 relevant primary prevention interventions: 22 in New Zealand, 16 in Australia, 31 in the United States (USA) or Canada, and 26 from the United Kingdom (UK), Europe or elsewhere in the world. The majority of primary prevention obesity intervention programmes identified in New Zealand were found through a grey literature search. Unfortunately, many of these interventions did not appear to

have been evaluated or had been evaluated for outcomes not related to weight. This included the Fruit in Schools initiative. Of the 22 New Zealand interventions identified, only four had been formally evaluated for relevant outcomes, and these were also the only studies including an identified proportion of Māori and Pacific Island participants. These interventions included a cluster randomised controlled trial assessing Green Prescriptions, a non-randomised controlled trial assessing APPLE (A Pilot Programme for Lifestyle and Exercise), and a non-randomised workplace intervention for men. The remaining evaluated intervention (Let's beat Diabetes – Community Nutrition Project) showed a significant benefit in terms of BMI but was only of 6 months duration.

Most of the Australian studies were of school-based interventions, and many appeared to lack evidence of evaluation. In contrast, all but one of the 31 intervention programmes in the USA and Canada had been evaluated and in 14, the evaluation period was greater than a year, an objective measure of weight was used, and the intervention was considered effective. Similarly, 14 of the 26 UK/European/Other interventions had been evaluated over a period greater than 1 year using an objective measure of weight and were considered to be effective.

The research team and stakeholder reference group considered the findings of the scoping search and selected 16 interventions for full systematic review. In order to be considered for systematic review, interventions generally had to have been found to be effective using a weight-based outcome. A balanced selection of interventions was also sought, covering both nutrition and physical activity interventions in a variety of age groups and settings (pre-school, school, tertiary education, community, primary care and workplace). Because few studies had been found in the workplace setting which appeared relevant to New Zealand, an additional search was conducted specifically for interventions in this setting. This found an extra 11 studies that met the criteria for inclusion, from which two were selected for systematic review. The final list of interventions chosen for systematic review following the scoping search is set out in **Table 1**. Full details of this phase of the research are contained in the scoping protocol in appendix 1 of the systematic review[20].

Table 1: Interventions selected for systematic review following initial scoping search

Number	Setting	Intervention	Description of Intervention	Location
1	Pre-school	Hip Hop to Health Junior[21]	**Nutrition/Activity** Culturally proficient dietary and physical activity programme.	USA
2	Community children aged 4-12 years	Be Active Eat Well[22-26]	**Nutrition/Activity/Behaviour modification** Decrease high sugar drinks and promote water and milk, decrease energy dense snacks and increase fruit and vegetables, increase active play and decrease TV viewing, increase the proportion who walk/cycle to school.	Australia

3	Primary school/community	KOPS (Kiel Obesity Prevention Study)[27-28]	**Education (nutrition)** Nutrition education and health promotion for students, parents, and teachers. Repeated information sessions for 3 months.	Germany
4	Primary school/community	APPLE (A Pilot Programme for Lifestyle and Exercise)[29]	**Activity/Education** Intervention components included nutrition education that targeted reductions in sweetened drinks and increased fruit and vegetable intake and activity coordinators who managed an activity programme that focused on non-curricular lifestyle-based activities (e.g. community walks).	New Zealand
5	Primary school	Changing drinking behaviours[30-32]	**i. Education (nutrition)** Various education and games associated with reducing carbonated beverage consumption. **ii. Nutrition** Water fountains were installed and 4 sessions presented by teachers.	UK and Germany
6	Community children	Shape up Somerville[33]	**Education/Activity/Nutrition** Programme designed to increase PA options and availability of health foods.	Germany
7	Primary school	CATCH (Child and Adolescent Trial for Cardiovascular Health)[34-37]	**Activity/Education/Nutrition** Diet and PA lessons, PA intervention, family involvement, school food service intervention.	USA
8	Primary school	Switch-Play[38]	**Activity/Behaviour modification** Four groups: behavioural modification group, fundamental movement skills group, a combined BM/FMS group and control.	Australia
9	Primary school	SNPI (School Nutrition Policy Initiative)[39]	**Education (nutrition)/Nutrition** School self-assessment, nutrition education, nutrition policy (e.g. reduced priced health food), social marketing and parent outreach.	USA
10	High school	Health Education Intervention Programme[40]	**Education** 10 sessions and practical instruction on health issues in the classroom.	Crete
11	University/college	Small-group interactive seminars[41]	**Education (nutrition/activity)** Educational/behavioural intervention designed to help maintain a healthy lifestyle.	USA

12	Workplace	Health promotion, education and intervention[42-43]	**Education** Gomel et al conducted a work-site cardiovascular risk reduction study among ambulance employees in Sydney that assessed the effectiveness of four different work-site health promotion programmes primarily concerned with behavioural counselling and education. Gemson et al assessed the impact of a multi-faceted intervention, primarily focusing on encouraging physical activity, on hypertensive Merrill Lynch employees in the US.	Australia and USA
13	Community (women)	Women's Health Initiative Dietary Modification Trial[44]	**Education** Group and individual sessions to promote reduced fat intake and increased fruit and vegetables. Control group received diet-related educational material.	USA
14	Community (women)	Women's Healthy Lifestyle project[45-46]	**Activity/Nutrition** Participants were randomly assigned to either a lifestyle intervention group receiving a 5-year behavioural dietary and physical activity programme or assessment only control group.	USA
15	General Practice	Green Prescription[47-48]	**Activity** A health professional's written advice to a patient to be physically active, as part of patient health management.	New Zealand
16	General Practice	General Health Screening[49]	**Education** Health screening or health screening plus 2 follow-up consultations versus no health screening.	Denmark

2.2 Stage 2: Systematic Review and Selection of Interventions for Economic Modelling

The second phase of the research was a full systematic review of each of the 16 interventions selected in the first stage. The aim of this review was to formally assess the evidence on the effectiveness of each intervention. The review methodology was broadly based upon guidelines published by the Australian National Health and Medical Research Council (NHMRC) [50-52] using the following steps:
1. Develop research questions appropriate for the review using the following criteria: Patient, Intervention, Comparator, Outcomes.
2. Systematically search the literature to identify studies relevant to research questions using a priori inclusion and exclusion criteria.
3. Obtain and assess the available evidence for relevance, quality, strength and effect size using standardised data extraction forms.
4. If appropriate, quantitatively synthesise the relevant evidence, or summarise in tables.

5.   Provide a list of all potentially relevant scenarios based on the evidence.

The published peer-reviewed medical literature was searched using the Cochrane, Medline, EMBASE and CINAHL databases. Other databases and websites which were searched included the Healthy Eating Healthy Action Knowledge Library (http://www.heha.org.nz/), NICE (http://www.nice.org.uk/), AHRQ/USPSTF (http://www.ahrq.gov/) and INAHTA (http://www.inahta.org/Search2/?pub=1). Finally, the National Guideline Clearing House Database (http://www.guideline.gov/) was searched in order to identify any recent clinical practice guidelines that had been underpinned by full systematic reviews that had not been captured elsewhere. Hand searching of specific journals or conferences was not undertaken, although the reference lists of key papers were searched to identify any peer-reviewed evidence that may have been missed in the literature searches.

In a systematic review, the eligibility of identified citations should be determined using criteria based on the elements of the clinical question being answered. In the case of this review, the following exclusion criteria were defined:
1.   Not a relevant study: Excludes non-systematic reviews, case reports, animal studies, short notes, letters, editorials, conference abstracts, in-vitro studies.
2.   Wrong intervention: does not assess one of the selected public health obesity-prevention interventions.
3.   Wrong outcomes: does not measure one of the defined outcomes (e.g. change in BMI).
4.   Not in English: due to resource constraints non-English publications were not included.

The evidence was assessed according to the dimensions outlined in **Table 2**. Information regarding these dimensions as well as the results data was extracted into a specifically designed data extraction sheet.

Table 2: Dimensions of evidence

Dimension	Definition
Strength of evidence	
Level	The study design used, as an indicator of the degree to which bias has been eliminated by design.
Quality	The methods used by the investigators to minimise bias within a study design.
Statistical precision	The P-value or alternatively, the precision of the estimate of the effect (as indicated by the confidence interval). It reflects the degree of certainty about the existence of a true effect.
Size of effect	The distance of the study estimate from the 'null' value and the inclusion of only clinically important effects in the confidence interval.
Relevance of evidence	The usefulness of the evidence in clinical practice, particularly the appropriateness of the outcome measures used.

Source: NHMRC [50].

Further details of the systematic review phase are found in the full report[20]. **Table 3** below summarises the findings of the systematic review for each of the selected scenarios.

Table 3: Summary of evidence from systematic reviews of selected interventions

Intervention	Number of relevant citations identified	Strength of Evidence			Size of Effect	Relevance of Evidence
		Level	Quality	Statistical Precision		
Hip Hop to Health Junior [Pre-school children, USA]	4	The primary studies were Level II cluster-randomised controlled trials.	The studies were high quality controlled trials with standardised assessment.	Weight measures were adjusted for baseline demographic and study characteristics. In the Fitzgibbon *et al* (2005) study the p-value for adjusted mean difference in BMI was p=0.022. In Fitzgibbon *et al* (2006), for the same outcome, the p value was p=0.49.	There was a significant difference in adjusted mean BMI and adjusted BMI z score in the study of African American children at 1 and 2 years follow-up. There was no significant difference in these measures between the control and intervention group at any follow-up time point in the study of predominantly Latino children.	The study presents adjusted mean BMI and BMI z score, which are both clinically relevant outcomes. The studies were conducted in African-American and Latino populations; whether or not these are applicable to NZ is uncertain.
Be Active Eat Well [Community children aged 4-12, Australia]	7	The primary study was a Level III-2 non-randomised, controlled trial.	The study was a good quality, quasi-experimental study. There was a difference in duration of follow-up between the intervention and control group which may have influenced results, although this was adjusted for in statistical analysis. Group allocation was not blinded. Response rates were moderate (~50%).	The confidence intervals around the mean difference between the intervention and control group for weight related outcomes were narrow.	Children in the intervention group gained less weight (–0.92 kg), showed significantly lower increases in waist circumference (–3.14 cm), BMI-z score (–0.11) and waist/height ratio (–0.02), compared with the control group. However, the prevalence of overweight and obesity increased in both groups, and the incidence of overweight/obesity was not significantly different between the intervention and control group (incidence rate ratio: 0.91 (95% CI: 0.65–1.28)). Nor was the difference in BMI	The study presents relevant weight-based outcomes. It was conducted in Victoria, Australia, and therefore demographic characteristics of the population are likely to be similar to NZ. The study results are likely to be generalisable to NZ.

				(–0.28kg/m^2) significant.		
KOPS (Kiel Obesity Prevention Study) [Primary school/ community, Germany]	5	The primary study was a Level III-II cluster-sampled, quasi-randomised controlled trial.	The study was a controlled trial with standardised assessment of weight-related outcomes. Investigators were blinded to the allocation of children. However, there was significant loss to follow-up. Prevalence of overweight and children of low SES families were higher in dropout rate compared with participants. The higher prevalence of overweight mothers in the control group may have caused selection bias.	The confidence intervals around the adjusted OR for four-year cumulative incidence of obesity and remission of obesity were (OR: 0.58 (95% CI 0.24 to 1.45) p=0.244) and (OR: 1.71 (0.42 to 6.91) p =0.449), respectively. The confidence intervals around the adjusted OR of prevalence for overweight and obesity were moderate (OR: 0.83 (95% CI: 0.40 to 1.74) p=0.628).	At four-year follow-up, there was no significant difference in overall prevalence of overweight and obesity. There was significantly lower prevalence and cumulative incidence in intervention children from high SES (OR 0.26; p=0.03). A significant difference in remission of overweight was also seen in children of normal-weight mothers (OR: 5.43; p=0.022).	The study uses measures of TSF, waist circumference and BMI to determine the prevalence, cumulative incidence and remission of overweight and obesity. These are all relevant outcomes. The study was conducted in Germany, therefore the generalisability in terms of participant demographics is uncertain.
APPLE (A Pilot Programme for Lifestyle and Exercise) [Primary school/ community, New Zealand]	4	The primary studies were Level III-1cluster non-randomised controlled trials.	The studies were high quality controlled trials with standardised assessment	The confidence intervals around the estimates of risk difference for weight related outcomes were narrow.	There was a significant difference in change in BMI z score in the intervention group. The risk difference for one, two and three-year follow-up was RD -0.09 (-0.18, -0.01), RD -0.26 (-0.32, -0.21) and RD -0.17 (-0.25, -0.08).	The study presents BMI z score rather than BMI; however BMI z score is still clinically relevant. The studies were conducted in NZ and therefore are applicable in terms of population characteristics and implementation.
Changing Drinking Behaviours (2 studies) [Primary school, UK & Germany]	6	Both studies were Level II cluster randomised controlled trials.	The studies were high quality controlled trials with standardised assessment measures of obesity. Blinding was not possible given the nature of the interventions. There was some (~33%) loss to follow-up three years after baseline in the CHOPPS study.	In the CHOPPS study, for the prevalence of overweight, the confidence intervals around the odds ratio and risk difference were moderate at one year follow-up 0.58 (0.37 to 0.89) and wide at three year follow-up 0.79 (0.52 to 1.21). In the Muckelbauer *et al* (2009a) study, the confidence intervals around the odds ratio estimates for weight related outcomes	In the CHOPPS study, there was a significant difference in the mean percentage of overweight and obese children at 12 months follow-up (mean difference 7.7%, 95% CI 2.2% to 13.1%), but not at three years follow-up (risk difference 4.6%, -4.3% to 13.5%). In the Muckelbauer *et al* (2009[a]) study, the risk of overweight at the follow-up assessment was	The primary weight-based outcome in the CHOPPS study was the number of overweight and obese children. The prevalence of overweight and BMI SD scores were both assessed in the Muckelbauer *et al* (2009a) study. The CHOPPS study was conducted in the UK and the Muckelbauer study in Germany. Whether or not these populations are

				were narrow. The p-value for the adjusted risk odds ratio was p=0.04. Baseline variables were generally comparable between the control and intervention groups in both studies, and were adjusted for in both analyses.	significantly reduced in the intervention group, compared with the control group, as indicated by an odds ratio of 0.69 (95% CI: 0.48-0.98).	generalisable to NZ is uncertain.
Shape up Somerville [Community children, Germany]	2	The primary study was a Level III-2 non-randomized controlled trial with one intervention city (Massachusetts) matched to two socio-demographically similar control cities (not reported).	The study was a high quality controlled trial with standardised assessment measures	The confidence interval was narrow and p-values small and significant for the change in BMI z-score (for intervention vs. pooled controls, 95% CI: –0.1151 to –0.0859; p=0.001).	There was a small but significant difference in change in BMI z score between the intervention and control group 1 (–0.1307), control group 2 (–0.1048) and the pooled control groups (–0.1005).	The study presents BMI z score rather than BMI, however BMI z score is still clinically relevant. The intervention was conducted in a culturally diverse population in the US. Whether or not the results can be generalised to the NZ population is uncertain.
CATCH (Child and Adolescent Trial for Cardiovascular Health) [Primary school, USA]	11	The primary study was a Level III-I pseudo-randomised, cluster controlled trial.	The study was a controlled trial with controls matched to intervention schools. There did not appear to be selection bias. There was some loss to follow-up (~17%). There was limited information regarding confidence intervals and p-values.	Confidence intervals around the differences in risk of overweight ($\geq$ 85th percentile of BMI) and overweight ($\geq$ 95th percentile of BMI) were not reported. P-values were not reported.	There was a significantly lower increase in risk of overweight and overweight in boys (difference ~8%) and girls (difference ~11%) in the CATCH schools compared to controls from third to fifth grade.	The study assessed the risk of overweight and overweight. The study was conducted in a low-income, Hispanic population. Generalisability to NZ is uncertain.
Switch-Play [Primary school, Australia]	3	The study was a Level II cluster randomised controlled trial.	The study used objective measurement and children's FMS were evaluated by specialist staff blinded to the intervention group. With the intervention groups being randomised by class, there was potential for contamination between intervention and control groups.	The confidence intervals around the odds ratio estimates of overweight/obesity and around the mean BMI estimates were moderate.	Children in the BM/FMS group recorded significantly lower adjusted BMI compared to children in the control group 12 months after follow-up (β-coefficients, 95% CI;1.53 (-2.82 to -0.24))	The study presents BMI and prevalence of overweight/obesity, both of which are clinically relevant outcomes. The study was conducted in Australia and therefore the study population is likely to be applicable to NZ.
SNPI (School	1	The study was a	The study was high	The 95% confidence	Significantly fewer children	The primary outcome was

Nutrition Policy Initiative) [Primary school, USA]		Level III-1 pseudo-randomised, cluster controlled trial.	quality with standardised assessment measures of obesity. Blinding was not possible given the nature of the intervention. There was a significant difference in ethnicity between the intervention and control schools at baseline; however this was adjusted for in statistical analyses.	interval around the odds ratio estimate for the primary outcome (incidence of overweight, obesity) was 0.74 to 0.99. The p-value was P<0.05.	in the intervention schools than in the control schools became overweight after two years (OR: 0.67; 95% CI: 0.47-0.96). There were no differences between intervention and controls schools in the incidence of obesity. For the two categories combined, the incidence was ~15% lower for the intervention group (OR: 0.85; 95% CI: 0.74 to 0.99; P <0.05).	incidence of overweight and obesity. This is a clinically relevant outcome. Prevalence and remission of overweight and obesity, change in mean BMI, and change in mean BMI z score were also measured. The study was conducted in the US in a low SES population, the generalisation to the NZ population is therefore uncertain.
Health Education Intervention Programme [High School, Crete]	1	The study was a Level III-2, non-randomised, cluster, controlled trial.	The study was not randomised; however two geographically separate, but demographically similar regions were compared. There was a significant difference in BMI and triceps skinfolds for those participants lost to follow-up compared with those with follow-up. Whether this would have introduced bias is uncertain.	There were no confidence intervals reported. The p-value for the difference in adjusted change in mean BMI between groups was p<0.05.	There was a significant difference in change in mean BMI between the intervention and control group ($\sim$0.5 kg/m^2). There were no other significant differences in weight-based outcomes between the groups.	The study presents BMI and triceps skinfolds, both clinically relevant outcomes. The study was conducted in Greece, in Cretan adolescents. Whether or not NZ adolescents are sufficiently similar for generalisability is unclear.
College small-group interactive seminars [USA]	5	The study was a Level II randomised controlled trial.	The study was a high quality controlled trial with standardised assessment	The variation around the estimates of weight related outcomes were small. The study was sufficiently powered to detect a significant difference between the control and intervention group.	There was a significant difference in change in BMI over 24 months between the control and intervention group (mean difference: 0.5kg/m^2, p= 0.01). The control group, on average, gained weight, whereas the intervention group, on average, lost weight over the two year follow-up period.	The study presents weight change and BMI, both clinically relevant outcomes when examining obesity prevention programmes. Whether or not these results, found in a population of health science university students, are generalisable to other college/university settings, is uncertain.
Workplace health promotion,	2	The Gomel et al study was a Level II cluster randomised	The study was a high quality randomised trial but with no control	The p value for difference in BMI increase between the average of the health	BMI increased significantly in all four groups at one year follow-up. However,	This study was conducted in Australia amongst ambulance service

education and intervention [Australia]		trial	group. There was 12 months follow-up and minimal loss to follow-up. Recruitment may have introduced some selection bias.	risk assessment and risk factor education groups compared to behavioural counseling plus incentive groups was small (p=0.04)	the increase in BMI from baseline to the 12-month follow-up for the average of the health risk assessment and the risk factor education groups was 4% higher than the average increase in the behavioral counseling and behavioral counselling plus incentives groups.	workers. Standard measures of obesity assessment were used. Results could be applied however minimal change was observed.
Workplace health promotion, education and intervention [USA]		The Gemson et al study was a Level III-2 non-randomised controlled trial	There was no randomisation and substantial attrition over the course of the study. There was no reporting of differences between those who were followed-up and those who weren't. Selection bias may have also been an issue.	The p value for the difference in change in BMI between the intervention and control group at one-year follow-up was <0.01.	The mean difference in BMI between the intervention and control group was 1.2 kg/m^2 at one year follow-up.	The study was conducted in the US amongst Merrill Lynch employees who were hypertensive. Therefore, whether or not these results for such a specific population are applicable to NZ is uncertain.
Women's Health Initiative Dietary Modification Trial [Community, USA]	4	The primary study was a Level II randomised controlled trial	The study was a high quality controlled trial with standardised assessment of weight outcomes. Clinical staff responsible for anthropometric assessments were blinded to treatment assignments to the extent practical.	P-values were small for estimates of difference in weight change between the intervention and control group at one year (P<0.001) and at 7.5 years (P=0.01) follow-up.	Women in the intervention group lost weight in the first year (mean of 2.2 kg) and maintained lower weight than control women during an average 7.5 years of follow-up (difference, 1.9 kg, at 1 year and 0.4 kg at 7.5 years). For mean BMI, there was a difference at follow-up between the intervention and control group of 0.3 kg/m^2 (p<0.001).	The study presents change in weight in kg and BMI, both clinically relevant outcomes. The study was a large RCT conducted in the US. It is likely the results are generalisable to the NZ population.
Women's Healthy Lifestyle project [Community, USA]	4	The primary study was a Level II randomised controlled trial	The study was a high quality controlled trial with standardised assessment measures of weight, and blinding of outcome assessors to minimise the chance of bias. Participants were	The p-values for the comparison of mean change from baseline in BMI between the intervention and control group were small (p<0.001) at 30, 42 and 54 months.	There was a significant difference in change in mean BMI in the intervention group compared to the control group (~0.9 kg/m^2) at 54 months follow-up. However, on average, at 54	The study presents weight-related outcomes including BMI for a population of premenopausal women in the US. It is likely that results are generalisable to women in NZ.

			volunteers; how this may have affected motivation and response is uncertain.		months, the intervention group had an increase in BMI of 0.05 kg/m^2.	
Green Prescription [General Practice, New Zealand]	10	The studies were Level II evidence, randomised controlled trials	The studies were high quality with randomisation and 1 and 2 year follow-up	The p-values were non-significant for weight-based outcomes, but significant for physical activity outcomes.	There was no significant difference between the intervention and control group for weight-based outcomes. The difference in mean change in BMI was 0.06kg/m^2 in favour of the intervention group in the Elley *et al* (2003) study. There were significant differences between the intervention and control group, in favour of the intervention group, for physical activity outcomes.	The weight-based outcomes were mean change in BMI, mean weight and mean waist circumference, which are all clinically relevant outcomes. The green prescription intervention has been implemented in NZ and is therefore applicable.
General Health Screening (2 studies) [General Practice, Denmark]	6	The Engberg et al study was Level II evidence, a randomised controlled trial.	The study was good quality RCT with 5 years follow-up. Stratified randomisation based on the GP with whom they registered their sex, age, cohabitation status, and BMI. There was some (~30%) loss-to-follow up which may have biased results.	There was a significantly difference between groups in mean BMI (p<0.05) in favour of the intervention. The difference in mean change of BMI from baseline was 0.6 kg/m^2.	There was a small but significant difference between the intervention and control group for BMI.	The outcomes were mean BMI, mean BMI change from baseline, both relevant weight outcomes.

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When the systematic review was completed, the research team and stakeholder reference group met again to consider the evidence and select 10 obesity-prevention scenarios to undergo cost-effectiveness analysis in the final phase of the research. A scenario is a particular obesity prevention intervention in a specific population or sub-population. For example, modelling the APPLE programme for children in the general population, Māori children and children with a high baseline BMI would represent three scenarios.

The following criteria were used to determine the selection of scenarios:
- relevance to the New Zealand population (including Māori and Pacific peoples)
- relevance to the New Zealand policy setting
- feasibility for implementation in New Zealand
- effectiveness of the intervention at preventing obesity
- ability to produce population benefits
- a balance of intervention types, settings and ages.

In addition, the research team and stakeholder reference group considered which interventions should be modelled for the general population, Māori and/or Pacific populations. A decision was also taken that the modelling should where possible enable comparisons across population groups, and that key interventions should therefore be modelled for the general population, Māori and Pacific populations. However, as the funding for the project would support modelling only 10 scenarios in total, we had to carefully prioritise the interventions modelled where a scenario involved an intervention for a specific population group.

The final list of interventions selected for cost-effectiveness modelling is set out in **Table 4**. While other interventions that were systematically reviewed have merit, they were excluded due to their lesser relevance to the New Zealand setting; perceived difficulties in implementing them here; or conversely, a sense that the approach is already well-established here (such as drinking water in schools) and an additional programme would not add value; and their lack of evidence of effectiveness.

Table 4: Interventions selected for cost-effectiveness modelling following systematic review

Scenario Number	Study	Country in which Evidence was Collected	Setting	Intervention Type	Proposed Population for Modelling
1	APPLE (children)	New Zealand	Community	Activity/Education	General population
2, 3, 4	Be Active Eat Well (children)	Australia	Community	Nutrition/Activity/ Behaviour modification	General population, Māori, Pacific
5, 6, 7	General Health Screening (adults)	Denmark	General Practice	Education	General population, Māori, Pacific
8	Green Prescriptions (adults)	New Zealand	General Practice	Activity	General population
9	SNPI (School	USA	Primary	Education (nutrition)/	General population

	Nutrition Policy Initiative) (children)		school	Nutrition	
10	Switch-Play (children)	Australia	Primary school	Activity/Behaviour modification	General population

2.3 Stage 3: Cost-Effectiveness Analysis

The objective of this component of the overall project was to estimate the cost-effectiveness of various public health interventions aimed at preventing obesity in New Zealand. The results of the ten scenarios agreed upon by the research team and the stakeholder reference group are presented here.

3. Economic Modelling

3.1 Overview

The purpose of this research was to provide information to assist decision making and cost-effective investment in population-based public health interventions designed to prevent obesity and obesity-related health problems in New Zealand. This section outlines the approach and results of the health-economic modelling component of the project, with the ultimate aim being to rank ten selected intervention scenarios in terms of their cost-effectiveness in the New Zealand setting. The methods, data sources, key assumptions and areas of uncertainty are outlined in conjunction with the results.

As noted in the preceding section, a total of six interventions were considered, all of which were aimed at particular age groups. For simplicity the segment of the New Zealand population in a particular age group was referred to as the 'general population', and the modelling represents all ethnic groups. Cost-effectiveness in the Māori and the Pacific populations was also considered separately in two of the six interventions. A total of ten scenarios, therefore, were considered in total, as set out in **Table 4** above.

The cost-effectiveness for each of the scenarios was assessed using a lifetime model to calculate the incremental cost per quality adjusted life year (QALY). That is, a cost-utility model was used. In structuring the economic evaluation in this way, additional survival time resulting from the prevention of obesity was considered as was the improved quality of life arising from the avoidance of chronic health problems associated with overweight/obesity. This approach also ensured that, in addition to the health benefits offered, potential decreases in expenditure arising from a reduction in the incidence of chronic illness were included. Importantly, however, the possibility of increases in expenditure due to increased life expectancy was also considered.

By conducting a cost-utility analysis, comparisons with other economic evaluations adopting a similar approach could be drawn. That is, by adopting a standard outcome of cost per QALY, this would aid decision makers in determining which scenarios are considered to be cost-effective and how their cost-effectiveness compares with results of other cost-effectiveness analyses across a wide range of health interventions in a range of therapeutic areas.

The survival and quality of life of individuals was accounted for by considering the body mass index (BMI) of two cohorts of individuals: those subject to the intervention and those not (i.e. the control group). From BMI, the model calculated the likelihood of individuals contracting any of fourteen chronic illnesses related to BMI. Those not contracting any of these illnesses are herein referred to as being in 'good health'. Mortality was also considered, both in terms of that due to the fourteen chronic illnesses and other 'background' mortality. The cost, survival and quality of life implications of each of these outcomes were considered in the analyses.

Where an intervention originated in a country other than New Zealand, the costs of each intervention were converted to New Zealand dollars. All costs were also inflation-adjusted to 2010 dollars. A more comprehensive discussion of the model structure, which was based on a cost model by van Baal *et al*[53], is presented in **Section 3.5**.

3.2 Population

As discussed above, the majority of scenarios included for assessment were aimed at the general population, albeit at different age groups. Additional to these, however, specific analyses are presented relating to the Māori population and the Pacific population of New Zealand for two of the interventions (i.e. Be Active Eat Well and General Health Screening). Additionally, it should be noted that the stakeholder reference group explicitly sought to investigate the cost-effectiveness of interventions aimed at both children and the general population. Of the scenarios of interest, six were interventions aimed at children. The remaining were interventions aimed at the general population, which would likely translate to use in adults.

In the base case of each of the scenarios, a particular age was selected for analysis. In the case of childhood interventions, the base case age was selected on the basis of the reported evidence. Where a range of ages were available from the literature, the median of the range was used for the base case analysis. In the case of the interventions applied to the general population, on the basis that these interventions would be expected to be applied to middle-aged adults, a base case age of 45 was used in the analyses. The impact of these assumptions was tested in the sensitivity analyses presented in **Section 3.7.3.**

The ages considered in each of the scenarios are presented below in **Table 5**.

Table 5: Ages considered in each of the scenarios modeled

Intervention	General population	Māori population	Pacific population
A Pilot Programme for Lifestyle and Exercise (APPLE)	9 years		
Be Active Eat Well	8 years	8 years	8 years
General Health Screening	45 years	45 years	45 years
Green Prescription	45 years		
School Nutrition Policy Initiative (SNPI)	11 years		
Switch-Play	10 years		

In each of the scenarios considered, the BMI and associated risk of illness and mortality that was applied to the model was dependent on the age and ethnic composition of the population considered. The gender mix appropriate to each scenario was also considered. Sub-populations with increased or decreased risk were not explicitly considered. Similarly, the cost-effectiveness of populations with BMI profiles different from the average of each of the scenarios considered was not modelled, except in the case of those analyses assessing the cost-effectiveness in Māori and Pacific populations explicitly, in which case ethnic-specific BMI data were used.

3.3 Perspective

A total health care budget perspective was adopted for the cost-effectiveness analyses. That is, all government-incurred health care costs were accounted for. Any out-of-pocket expenses incurred by individuals due to the intervention or downstream health care arising from illness were not considered. Similarly, societal costs, such as the impact of illness on productivity, were not valued. Given that any public health initiative aimed at preventing obesity will be government funded, this perspective is appropriate as it focuses on the impact from the government's perspective.

By taking a perspective such as this, the analysis ensures compatibility with other health economic evaluations of health care resource allocation decisions. In particular, the approach is consistent with that taken by PHARMAC in its decisions regarding pharmaceuticals. In this regard, the perspective should assist decision makers in their deliberations. This approach will, however, result in a conservative estimate of the economic implications of preventing obesity in New Zealand.

3.4 Time Frame

A lifetime model was considered for each of the scenarios. That is, in each instance, the economic model tracked a cohort of individuals from the beginning of the intervention (at the age specified in **Table 5**) until death or a maximum of 100 years of age. Age at death was modelled according to New Zealand population data. In those surviving to 100 years of age, the model did not continue to accrue either costs or health outcomes beyond this stage. By applying such a frame, the incremental lifetime impact of the interventions on survival and quality of life would be ascertained. Sensitivity analyses, however, were also conducted to look at the impact of shortening the time horizon to 60 years of age (see **Section 3.7.3**). In doing so, the sensitivity of the results to downstream health care costs versus intervention costs can be better understood. All costs and outcomes were discounted at a rate of 3.5% per annum in the base case, though this rate was tested in sensitivity analyses.

3.5 Model Structure

A simulation was conducted to estimate the BMI of 10,000 individuals in each ethnic group (i.e. the general population, Māori population and Pacific population) for each age between 2 and 75 years. The simulated BMI was estimated on the basis of estimates of mean BMI and their standard errors provided by the New Zealand Ministry of Health. On the basis of Penman *et al*[54], BMI was assumed to be distributed according to a lognormal distribution.

Each simulated individual was categorised as being overweight, obese or otherwise (herein referred to as being of 'healthy' weight for simplicity). The categorisation was achieved by applying the BMI thresholds for each weight category according to age.

The simulation was applied to the control arm of the economic model in which no intervention was administered, with the 2006/07 BMI data provided used to represent the current status quo. The simulation was performed once only for each individual age. As the model unfolded over time, individuals were assumed to change BMI according to the simulation (i.e. a 12 year old cohort will take on the characteristics of a 13 year old cohort after one year). This implicitly assumes that no other environmental factors change in future years.

In order to estimate the proportion of overweight, obese or 'healthy' weight individuals following the intervention, the impact of the intervention on mean BMI was subtracted for each simulated individual to generate a new post-intervention cohort of 10,000 individuals. The proportion of individuals in each of the three weight categories was thus altered to reflect the expected distribution following the intervention. A simplified illustration of the approach is provided in **Figure 1**. In the absence of evidence to the contrary, the model assumes that the average long-term effect of the interventions is applicable, on average, to all participants irrespective of their baseline BMI. Note that the model does not consider underweight, nor does it attach any ill health to individuals who may be considered underweight.

Figure 1: BMI simulation applied to the economic model
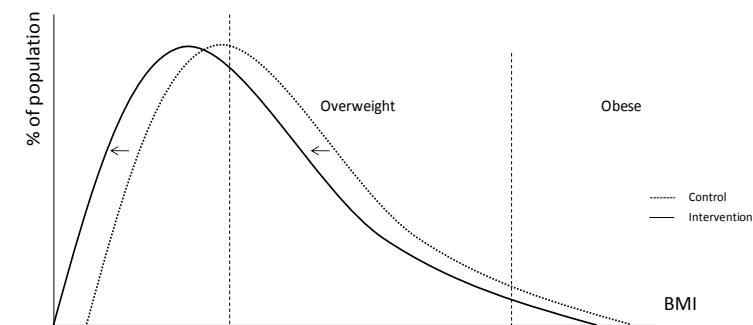

Abbreviations: BMI, Body Mass Index

The model estimated the likelihood of either staying in 'good health' or of contracting one of fourteen obesity-related chronic illnesses, according to age, in each yearly cycle for the duration of the simulation. General population incidence rates of these conditions, from a survey of the Dutch population[53], were applied to the 'healthy' weight population for individuals aged 20 years and over. This is consistent with the available data. These were also applied in conjunction with relative risk estimates for the overweight and the obese populations that were derived from the literature to estimate the incidence of the fourteen obesity-related chronic illnesses in these groups, again for individuals aged 20 years and over. Again, Dutch data were used in the absence of appropriate New Zealand data. Due to the differing distribution of simulated individuals across the three weight categories between the two arms of the model, different incidence rates were observed, with the intervention arm associated with a higher likelihood of remaining in 'good health' and a lower likelihood of contracting a chronic illness. Note that an individual

could transition from 'good health' to any of the fourteen chronic illnesses in any cycle of the model. Once in any of these fourteen health states, however, individuals could not transition to any other health state except death.

On the basis of the health states predicted by the model, mortality was estimated in each yearly cycle of the model. This was achieved using New Zealand life tables (by gender, for general, Māori and Pacific populations) and excess mortality rates for each of the fourteen chronic illnesses considered in the model for individuals aged 20 years and over. As was described in relation to the estimated incidence rates above, the model calculated an increased risk of mortality in the control arm due to the increased likelihood of individuals being either overweight or obese and, in turn, contracting a chronic illness.

A simplified schematic of the model structure is presented in **Figure 2**.

Figure 2: Simplified schematic of the economic model
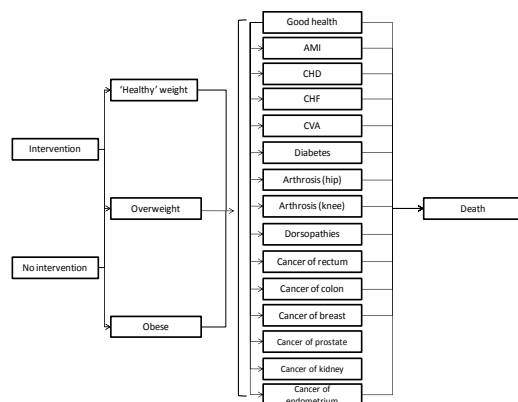
Abbreviations: AMI, acute myocardial infarction; CHD, coronary heart disease; CHF, congestive heart failure; CVA, cerebrovascular accident

The economic model attributed costs and outcomes (life years and, in the base case, utility weights) to each of the health states in figure 2 to calculate incremental cost-effectiveness ratios (ICERs) as a measure of cost-effectiveness.

Where an intervention originated in a country other than New Zealand, the costs were converted to New Zealand dollars using the relevant exchange rate. All costs were inflation-adjusted to 2010 dollars using the CPI. All costs and outcomes were discounted at a rate of 3.5% per annum in the base case, though this was tested in sensitivity analyses.

3.6 Variables

The economic model required a multitude of variables: population variables, clinical variables, utility variables, cost variables and variables relating to the effectiveness of the intervention.

Population variables included BMI distributions and mortality rates by age, gender and, where appropriate, ethnicity. Clinical variables considered the incidence and excess mortality of the 14 chronic health states of interest. As New Zealand incidence data were not available for these

chronic conditions, published Dutch data were used. Though it is not possible to ascertain how closely these match the New Zealand context, it could be reasonably assumed that the relationship between BMI and incidence, which is the key driver of the modelled results, would be of a similar size across both populations. Though there does exist some research on the role ethnicity plays in terms of incidence, relative risk and excess mortality (see for example Hill *et al*[55]), no evidence was sourced to provide an estimate of any of these independent of BMI. As such, it was not possible to adjust for ethnicity *per se* in the context of the approach taken in this economic evaluation (i.e. it was not possible to quantify the impact of ethnicity *per se* on the effectiveness of the interventions considered). It can be argued, therefore, that the model captured the increased incidence and mortality associated with the Māori or Pacific population via differences in their BMI profiles relative to the general population rather than via ethnicity *per se*.

In addition to estimating the distribution of the 14 health states, health related quality of life estimates were attributed to each of these in the form of quality adjusted life years (QALYs) sourced via a comprehensive search of the clinical and economic literature. The model structure did not distinguish between the various levels of disease severity, or stage, but rather identified the presence or otherwise of a chronic illness, the utility weights applied represent the *average* quality of life over the duration of the illness. As such, it would be inappropriate, for instance, to apply a disutility for end-of-life health states as disease severity worsens. However, in reality, disease severity could worsen over time. The model also assumed that all individuals in the 'good health' health state had perfect health. This has the potential to overestimate health-related quality of life, potentially biasing the results of the analysis in favour of the interventions relative to the control. Similarly, no disutility was applied with age, whereas some researchers have shown health-related quality of life to reduce with age. Again, this could be a source of bias in favour of the intervention arm of the model.

There were two groups of cost variables: intervention costs for each scenario (sourced from published studies and in one case, directly from an author), and costs related to ongoing health care both for the general New Zealand population and for those with chronic illness (using New Zealand and Dutch data).

Reduction in BMI was used as a proxy for the overall effectiveness of each intervention. The interventions used in this study provided a maximum of five years follow-up of BMI. Following discussions between the research team and the SRG, an effect was included for each intervention, for each of the first five years, interpolating and extrapolating from the available follow up data. As explained earlier, the economic model adopted a lifetime perspective, so it was necessary to extrapolate the intervention effects beyond a five-year timeframe. Though no literature could be found to justify a particular level of decay of intervention effect on BMI following the cessation of intervention programmes, it is reasonable to assume that the relative reduction in BMI is temporary in the event of an intervention not continuing. This may be particularly so in the case of childhood interventions, where the time spent undertaking an intervention relative to that outside of the intervention is negligible. It was assumed, therefore, that the reduction in BMI, relative to the control group, would decay by 1% per annum after the fifth year of the economic model. The influence of the rate of decay on the results of the economic model was tested in sensitivity analyses (see **Section 3.7.3**).

Another issue related to whether the effects of each intervention would be the same across all ethnic groups. On the basis of no ethnicity-specific data or analyses, any possible impact of ethnicity *per se* on effectiveness could not be quantified for any of the interventions considered. However, since it is known that availability and uptake of healthcare interventions, and in particular prevention interventions, can be affected by socio-economic circumstances[56-60], this was considered. For those scenarios considering the cost-effectiveness of interventions in the general population, the effect sizes were not altered as these are clearly inclusive of the full representative range of socio-economic distributions across New Zealand. For those scenarios in which particular focus was given to the cost-effectiveness in either Māori or Pacific populations, changes were made in a series of sensitivity analyses to reflect the increased likelihood of these individuals within these populations belonging to lower a socio-economic group (see **Section 3.7.3**).

In terms of intervention effectiveness, note that two analyses were conducted for the Switch-Play intervention. While Salmon *et al*[38] reported a BMI difference of 1.53 units after adjusting for food frequency and moderate to vigorous physical activity, this observation was difficult to reconcile with reporting of a non-significant difference observed in males and a difference of 0.15 BMI points in females in the same publication. Therefore, at the suggestion of the stakeholder reference group, a second analysis was considered invoking the adjusted BMI difference observed in females only but applying to males and females. It was applied to both genders on the basis that it is unknown which result is correct and that the most likely scenario probably lies between the -1.53 in both genders and -0.15 in females only. While it is uncertain whether Analysis A (-1.53 BMI units applied to all) or Analysis B (-0.15 BMI units applied to all) would best represent reality, the presentation of the two analyses is aimed at enabling decision-makers to better understand the role of uncertainty in the cost-effectiveness estimate associated with the Switch-Play intervention.

In terms of the effectiveness of Green Prescriptions, it should be noted that primary intention of this intervention was to increase physical activity in sedentary patients rather than address weight management/obesity directly. However, a secondary outcome of this may be the prevention of further weight gain or promotion of weight loss.

In the absence of any empirical evidence of a variable effect, an intervention was assumed to have the same effect (difference in BMI) no matter what the value of baseline BMI was for an individual.

3.7 Results

This section presents the base case results of each of the scenarios modelled along with the results of sensitivity analyses that were performed.

3.7.1 Base case cost-effectiveness results

The estimated intervention costs are shown in **Table 6** below. It should be noted here that reporting of resource and cost information in the published studies was not ideal and assumptions

had to be made in order to obtain these estimates. These are detailed in the full economic report[61].

Table 6: Intervention costs applied to the economic model

Intervention	Annual cost per participant (NZD)	Number of years for which intervention cost is applied
APPLE	$704.73 [a]	2
Be Active Eat Well	$285.48 [b]	3
General Health Screening	$89.25	1
Green Prescription	$207.37	1
SNPI	$51.10 [a]	2
Switch-Play	$101.81	1

[a] Cost applied in each of the two years of the intervention
[b] Cost applied in each of the three years of the intervention
Abbreviations: APPLE, A Pilot Programme for Lifestyle and Exercise; SNPI, School Nutrition Policy Initiative

Table 7 summarises the cost-effectiveness of each of the scenarios considered, using incremental cost-effectiveness ratios, sorted in order from lowest to highest ICER. The incremental cost is an estimate of the *additional* cost of an intervention compared to no intervention. This includes the additional costs of downstream health care, as well as the intervention cost itself. The incremental cost is less than the intervention cost, because there are savings in downstream health care costs. These savings are small, in part due to all costs being discounted (by 3.5% per annum).

The incremental QALY is the *additional* quality adjusted life years from the intervention, compared to no intervention. The outcomes (QALYs) have also been discounted by 3.5%. The incremental cost effectiveness ratio (ICER) is the additional cost per additional QALY gained from the intervention.

Table 7: Summary of the base case cost-effectiveness results (2010 NZ dollars)

Analysis	Population	Incremental cost (fully discounted)	Incremental QALY (fully discounted)	ICER (fully discounted)
Switch-Play (general population, Analysis A)	Children	$128.38	0.027	$4824.18
General Health Screening (general population)	Adults	$89.10	0.014	$6179.51
General Health Screening (Pacific population)	Adults	$103.88	0.016	$6577.56
General Health Screening (Māori population)	Adults	$115.09	0.017	$6675.97
Switch-Play (general population, Analysis B)	Children	$104.62	0.003	$38,630.15
Be Active Eat Well (Māori population)	Children	$837.67	0.007	$123,536.19
Green Prescription (general population)	Adults	$206.59	0.002	$133,877.96
SNPI (general population)	Children	$101.31	0.001	$134,252.49
Be Active Eat Well (Pacific population)	Children	$834.41	0.005	$154,178.04
Be Active Eat Well (general population)	Children	$832.96	0.005	$168,391.38
APPLE (general population)	Children	$1392.65	0.007	$205,101.45

Note: Children refers to those aged less than 18 years; adults refers to all others

The Switch-Play (Analysis A) and the General Health Screening interventions would appear to be highly cost-effective given the approach taken and the assumptions utilised in the analyses. In the case of General Health Screening, this conclusion can be drawn regardless of the population. At less than $7000 per QALY gained, the value of these interventions is clear. The reader is advised, however, that the treatment effect size upon which Analysis A of the Switch-Play intervention relies is considerably larger than that observed with any other interventions and may benefit from validation within the New Zealand setting. Moreover, as discussed in the previous section, there are issues surrounding the reporting of the intervention effect by Salmon *et al*[38]. With this in mind, the reader is advised to consider the cost-effectiveness result of Analysis A of Switch-Play in conjunction with Analysis B. Though it is not possible to ascertain which of these, if any, is more correct, it may be encouraging to decision-makers to note that both results are within the realms of what may be considered cost-effective in New Zealand. Though a definition in terms of a specific threshold is elusive, it has been suggested that the ICER threshold in New Zealand (using PHARMAC as a proxy) lies somewhere between $15,000 and $50,000 per QALY[62].

The Be Active Eat Well intervention, applied to the Māori population, would appear to be the next intervention in terms of value for money, at approximately $123,500 per QALY gained. It would appear that the intervention is slightly less cost-effective in the Pacific population and least in the total population, though the differences are small in the context of the limitations inherent in the ethnicity-based analyses. Note that each of these results is beyond the range suggested as cost-effective in the literature[62].

At approximately $134,000 per QALY, the value offered by both the SNPI and the Green Prescription intervention is less clear and this could be beyond what decision makers would consider to represent good value for money. These interventions would most likely not be considered eligible for reimbursement in the absence of other reasons beyond cost-effectiveness arguments. The APPLE intervention similarly does not appear to offer good value for money if established in a manner similar to what was analysed in this research.

Unless substantial changes are made which lower the incremental cost and/or increase the incremental effect, it is unclear why these interventions would be selected over the alternatives considered here. It is acknowledged that there may be some scalability possible for the APPLE intervention in particular, should the programme be rolled out to a wider population. This could, at least hypothetically, result in a lower cost per participant, impacting substantially on the cost-effectiveness estimate provided here.

It should be noted here that the ranking is based on the cost effectiveness *ratio*, a 'value for money' metric, measuring the cost per QALY gain. Thus an intervention with a low incremental cost and a low incremental outcome could have the same ratio as one with high incremental cost and high incremental outcome. For health interventions, the incremental cost and the incremental outcome are each of interest. Table 7 shows that the top four interventions achieve more yet do not cost materially more than the other interventions i.e. they dominate.

3.7.2 Exploratory Analyses of Independent Disutility Effect Associated with Obesity

No difference in utility was applied in the base case to BMI categories *per se* (i.e. disutility of being obese independent of the presence of an obesity-related illness). This was a deliberate decision aimed at avoiding the possibility of double-counting and to be conservative in the face of somewhat variable evidence. It could, however, have led to the cost-effectiveness of all the scenarios being underestimated. Exploratory analyses are presented here to illustrate the potential effect of the base case assumption of no difference in utility.

Though the evidence base to support such a contention is variable at best, it has been reported that such an effect does exist (see for example, Dennett *et al*[63]). Moreover a consistent estimate cannot be sourced from any of the studies reporting such an effect. In light of this, analyses were conducted to each of the scenarios considered in the base case by assuming a disutility of 0.05 being applied to all obese individuals within the model. The absolute size of this disutility was not based on any particular estimate derived from the literature.

The analysis is exploratory only and should be interpreted as such. The results are not intended to provide decision makers with an alternative estimate of any of the scenarios considered, but rather to highlight the impact that this may have on the cost-effectiveness should such an impact be more convincingly supported in the future. The results of these exploratory analyses are reported alongside the base case results in **Table 8**.

Table 8: Exploratory analyses of the incremental cost-effectiveness of the scenarios when a disutility of obesity *per se* is incorporated

Analysis	Population	Base case ICER (fully discounted)	ICER inclusive of a disutility associated with obesity *per se* (fully discounted)
Switch-Play (general population, Analysis A)	Children	$4824.18	$3343.70
General Health Screening (general population)	Adults	$6179.51	$3800.78
General Health Screening (Pacific population)	Adults	$6577.56	$3230.87
General Health Screening (Māori population)	Adults	$6675.97	$3548.57
Switch-Play (general population, Analysis B)	Children	$38,630.15	$7219.34
Be Active Eat Well (Māori population)	Children	$123,536.19	$52,254.87
Green Prescription (general population)	Adults	$133,877.96	$11,540.04
SNPI (general population)	Children	$134,252.49	$8325.91
Be Active Eat Well (Pacific population)	Children	$154,178.04	$54,257.53
Be Active Eat Well (general population)	Children	$168,391.38	$51,212.22
APPLE (general population)	Children	$205,101.45	$75,260.14

Note: Children refers to those aged less than 18 years; adults refers to all others
Abbreviations: APPLE, A Pilot Program for Lifestyle and Exercise; SNPI, School Nutrition Policy Initiative

In all cases, the ICER falls markedly once a disutility of 0.05 is included in patients who are obese. The most pronounced impact was upon the SNPI intervention in children, with the ICER falling from approximately $134,000 per QALY to approximately $8000 per QALY. Once again, however, the reader is cautioned to treat these analyses as exploratory only and to avoid drawing conclusions on the cost-effectiveness of the scenarios on the basis of them.

3.7.3 Sensitivity Analyses

To determine key drivers of the base case results presented above, as well as the impact of the assumptions made, a number of sensitivity analyses were conducted. The key sensitivity analyses tested the effects of altering the following inputs independently in a series of one-way sensitivity analyses:

- The age at which the intervention is initiated (testing two ages either side of the median for childhood interventions, and from 35-55 years for adult interventions)
- The cost associated with the intervention
- The rate of decay of the intervention's impact on BMI following the first five years
- The degree of uptake of interventions inherent in the effectiveness estimates in populations more likely to comprise of lower socioeconomic groups
- Variation to the discount rate applied (0, 5%, 10%; and 8% on the basis that this is the rate recommended by New Zealand Treasury for cost-benefit analysis)
- Reducing the duration of the economic model to end at age 60.

Table 9: Results of sensitivity analyses

Input parameter	Incremental cost	Incremental QALY	ICER
Age (increased)	Increases for children Decreases for adults	Increases for children Decreases for adults	Decreases for children Increases for adults
Intervention cost (increased)	Increases	No change	Increases
Rate of decay of intervention effect (increased)	Decrease	Decreases	Increases
Uptake (decreased)	Decreases	Decreases	Increases
Discount rate (increased)	Decreases	Decreases	Increases
Model duration (decreased)	Decreases	Decreases	Increases

Sensitivity analyses of the age of intervention showed that in the interventions applied to childhood populations, both the incremental cost and QALY increase with the age of initiation. The *rate* of increase in the QALY gain, however, outstrips that of the increase in the incremental cost, translating to improvements in cost-effectiveness with the age of the intervention's initiation.

In the interventions applied to the adult populations, we see the opposite. Both the incremental cost and the incremental QALY fall with age. The rate of the decrease in the QALY gain, however, outstrips that of the decrease in the incremental cost, translating to a worsening in the estimated cost-effectiveness as the intervention's initiation age increases. The stronger impact on the incremental QALY gain is intuitive as it represents the poor effect that a delay in an intervention can have on a population subject to relative high incidence of disease can have on health outcomes. Costs, on the other hand, are not affected to such a degree, particularly since the bulk of the cost difference between the arms is due to the cost of the intervention which is incurred regardless of the age at which the intervention takes place.

Together, these results would imply that there is a point between childhood and middle-age at which interventions of this kind are most cost-effective. It is difficult to conclusively show this to be the case, however, as there is no evidence upon which such conclusions could be based.

None of the scenarios demonstrated particular sensitivity to the cost of the intervention. This is unsurprising given the relatively small incremental costs associated with each of the scenarios. Increasing or decreasing the cost of an intervention by 10% did not change the relative order of ICERs.

Those interventions applied to childhood populations were considerably more sensitive to the rate of decay in the intervention effect. Ethnicity did not appear to play a significant role in the sensitivity to the rate of decay after Year 5, with only minor differences in the rate of change in the ICER across different populations.

The base case results assumed that intervention uptake in lower socio-economic groups was no different to the average. Sensitivity analyses were conducted investigating the impact of lower uptake in the 9th and 10th deciles of the NZDep2006 index[64].

The socioeconomic sensitivity analyses considered reductions in the uptake rate of 5%, 10% and 25%. It is unknown what the reduction in the uptake rate of these interventions would be, nor whether it would vary from one intervention to another. In this light, it is important to note that the analyses are exploratory, aimed at determining how sensitive the base case results are to the assumption that there is no reduction in uptake among lower socioeconomic groups which may be unrealistic. It is also important to note that the analyses do not purport to link uptake with ethnicity; it is simply a case of these being the only scenarios considered in which a shift in the distribution of individuals to lower socio-economic groups is possible. Additionally, it should be noted that no adjustment was made to BMI profiles on the basis of socio-economic status. The sensitivity analyses for decreased uptake among lower socioeconomic groups found the impact on the ICER results was modest in all cases, indicating that more focused interventions are unlikely to lead to significant departures from the base case estimates, though there is of course the possibility that particularly well-focused interventions could have a more pronounced effect if they were able to generate substantial differences in effectiveness at a modest cost.

The base case economic model applied an annual discount rate of 3.5%. This ensures the approach is consistent with that recommended throughout New Zealand. In particular, it is consistent with guidelines for economic evaluation published by PHARMAC[65]. Consistent with the recommendations of PHARMAC, sensitivity analyses were also conducted testing the impact of varying the discount rate to 0%, 5% and 10% per annum. Additionally, a discount rate of 8% per annum was tested, in line with the recommendations of New Zealand Treasury for cost-benefit analysis (noting, however that they make no recommendations relating to cost-effectiveness analysis).

The base case results are predictably highly sensitive to the discount rate applied to costs and health outcomes. This is an expected result given that many costs occur downstream as individuals move into chronic health states that accrue, in some cases, substantial lifetime costs.

They are, therefore, heavily discounted. Similarly, since these chronic illnesses tend to occur in the latter part of the model, the benefit of avoiding such health problems is heavily discounted. This is true of the base case analysis of a discount rate of 3.5% per annum, but becomes more apparent when the discount rate is increased beyond this. Conversely, removing the discount rate altogether (i.e. applying a rate of 0% per annum) improves the cost-effectiveness estimates. It is notable that variation to the discount rate has a greater impact on the childhood interventions than the adult interventions. This is unsurprising, given that discounting of future health care costs and health outcomes is greater in these scenarios due to the greater time distance before chronic illnesses typically occur.

Finally, sensitivity analyses were conducted to determine whether the duration of the model assumed in the base case (i.e. a lifetime model) impacted markedly on the cost-effectiveness results generated. Assuming a lifetime model would appear appropriate to ensure that all downstream costs and outcomes are correctly accounted for, given that preventing obesity would ideally lead to long-term effects on both of these. Nonetheless, it is important to understand the role that such an assumption has on the conclusions that can be drawn from the analyses. By limiting the analysis to a maximum age of 60 years, some of the more downstream impacts were omitted from consideration. In doing so, the strong emphasis on downstream costs and benefits relative to intervention costs was shifted slightly. Additionally, since obesity is likely to cause health problems, and their associated costs, in older individuals, limiting the analyses in this way removes much of the potential benefit of obesity prevention and instead focuses more on short- to medium-term benefits. The results of this sensitivity analysis illustrated that the adult interventions were most sensitive to the shortening of the model duration. That the model is most sensitive in adult interventions can be explained largely by the discounting applied. Since the costs and outcomes associated with obesity-related chronic illnesses typically occur in the later stages of life, they are not subject to discounting to the same extent in the adult interventions as in the childhood interventions where they are very heavily discounted due to the elapse of time from the model commencement until the incidence of illness. By shortening the duration, the cost offsets and reduction in chronic illness, which is less heavily discounted, is markedly reduced in the case of the adult interventions when the model duration is shortened. It is worth reiterating, however, that the lifetime perspective taken in the base case analyses is appropriate as it captured the impact on both costs and outcomes of increased life expectancy.

Further details of all the sensitivity analyses and their results are set out in in the full report[61].

3.8 Limitations of the Economic Evaluation

The economic model presented above made use of the best available data in all circumstances. Where necessary, assumptions were made to fill data gaps and, where possible, these assumptions were conservative. Nonetheless, there are a number of limitations that must be considered when drawing conclusions from the analyses.

The main limitation relates to the absence of long-term follow-up data on the effectiveness of the interventions on BMI, and hence chronic illness. At best, five-year follow-up data were available (General Health Screening), while at worst one-year follow-up data were available (Switch-Play and Green Prescription). None of the data illuminate an understanding of how the reduction in BMI may impact on future BMI or health outcomes. Though the base case analysis assumed a

1% per annum reduction in the BMI benefit following the five-year modelled period, this was an assumption for which there is an absence of evidence. Although this was tested in the sensitivity analyses, it is worth noting this uncertainty remains a substantial limitation to the modeling particularly as any decay that may occur in true practice could vary from one intervention to another.

Related to this issue of uncertainty around the BMI reduction (and subsequent reduction in benefit over time), is the issue that there were no effectiveness data specific to the various ethnic groups considered. While the scenarios assessing cost-effectiveness in the general population were reasonably well matched with data from general populations, there were no data available to determine whether the changes in BMI due to the intervention would be different in Māori or Pacific populations. Though this was partially addressed through the sensitivity analyses examining the impact of lower uptake in lower socioeconomic groups, this could impact on the cost-effectiveness estimates substantially. Similarly, no data were available to support the possibility that BMI reductions were different among the three weight categories considered; instead, a mean reduction, equal in all groups, was assumed across the three categories. Should it be shown that the different categories respond differently to the interventions, there could be an impact on cost-effectiveness.

A final point to consider in relation to the BMI data used within the model is that the economic model did not undertake comprehensive epidemiological modelling to predict future BMI of individuals. Instead, current BMI published for the New Zealand population were used. In using such data, there was an implicit assumption made that the BMI profile (by age, gender and ethnicity) would not alter over time. No environmental factors, for example, were accounted for. In reality, it may be that individuals aged 10 years now will have different BMI distribution at the age of 60 than current 60 year olds. To undertake such modelling is a substantial task and is beyond the scope of the current project. The omission of explicitly considering the impact of such possibilities is, therefore, a limitation of this research.

On the cost side, there was a scarcity of information on the intervention costs and the estimates used are subject to varying degrees of uncertainty. Though the analyses testing the impact of variation to these costs did not reveal alarming degrees of sensitivity to the costs used in the base case, it remains a substantial area of uncertainty since the incremental cost of the intervention in all cases is overwhelming comprised of the intervention cost rather than downstream health care costs (which are heavily discounted). Should the intervention costs be increased beyond the range tested, the conclusions drawn could be altered substantially.

With regard to health-related quality of life, the economic modelling assumed that all individuals in the 'good health' health state have perfect health. Similarly, no disutility was applied with age, whereas some researchers have shown health-related quality of life to reduce with age. Each of these has the potential to overestimate health-related quality of life, potentially biasing the results of the analysis in favour of the interventions relative to the control. The results of the exploratory analyses presenting the cost-effectiveness in the event of a disutility being applied to obesity *per se* are also worth reiterating at this point. These results, though not to be relied upon for drawing any conclusions, further demonstrate that other factors could lead to improvements in the estimated cost-effectiveness should they be supportable in the future as research into the quality

of life associated with obesity continues. Moreover, it could be expected that inclusion of benefits such as improved physical function, mobility, mental health and social interaction could similarly lead to improved cost-effectiveness should they be capable of being justifiably incorporated into future analyses.

The model was structured such that the health states are mutually exclusive. In reality, individuals may experience more than one chronic illness at any given time. The structure, therefore, has the potential to incorrectly estimate the costs and health-related quality of life in those individuals who may suffer from more than one chronic illness simultaneously. The effect of this on the final results, however, would be small. Since any substantial impact on either costs or outcomes due to chronic illness is likely to occur in the later stages of the model, the size of these impacts is heavily discounted, thereby reducing their influence on the estimated cost-effectiveness ratios. This means that the relative ranking of the cost-effectiveness of these scenarios is unlikely to change, nor are the ICERs, due to the presence of this structural assumption. As such, the conclusions drawn from this research are not expected to be influenced by the assumption that the health states of interest are mutually exclusive.

It should also be acknowledged that the approach taken with regard to costing the various chronic illnesses unavoidably double-counts health care costs by adding the incremental cost of each chronic illness to the general health care costs for individuals in New Zealand, which would already include the cost of treating illnesses including those accounted for in the economic model. This, however, is not expected to have impacted on the results markedly.

Finally, the analyses are potentially limited by the scarcity of New Zealand data. Where possible, New Zealand data were utilised but data gaps were filled with international data. International data, for example, were used to estimate disease incidence and excess mortality, health-related quality of life and used in the estimation of health care costs. This would not be expected to present major uncertainty or limit the analyses in a substantial way, but it should be considered nonetheless.

4. Discussion

The purpose of this research was to provide information on the relative cost-effectiveness of selected population-based initiatives aimed at preventing obesity and obesity-related chronic health problems in New Zealand. The reader should note that all results hinge on a modest effect on BMI due to the intervention. Additionally, it should be noted that the maintenance of the BMI effect, in all cases, contributes substantially to the estimation of each intervention's cost-effectiveness. Similarly, the cost per participant plays a key role. Given the inherent uncertainty in these estimates, the possibility of variation to the cost should be considered, particularly in the case of interventions in which scalability could reduce the costs and improve the cost-effectiveness. Finally, it was only possible to capture health related benefits and costs of diseases we know to be definitively related to obesity. It could be expected that inclusion of benefits such as improved physical function, mobility, mental health and social interaction could similarly lead to improved cost-effectiveness should they be capable of being justifiably incorporated into future analyses.

Ten scenarios were modelled, of which Switch-Play and General Health Screening appeared to be most cost-effective although the uncertainties about Switch-Play's reported treatment effect size should again be noted. Switch-Play was an Australian activity and behaviour modification programme for primary school children, while General Health Screening in Danish general practices involved a health check and advice. Both interventions could be feasible in the New Zealand setting, but their transferability would need further assessment. This would include consideration of affordability, the capacity of the health services to deliver, and acceptability to the New Zealand population. For example, General Health Screening was costed for an initial health check by a general practitioner and follow-up by a nurse. If implemented in New Zealand, more nurse-led delivery could be considered. This would lower the cost, but the effect on uptake and outcomes would also have to be assessed. In using the cost-effectiveness results of this research to guide the relative merits of public health investments in obesity prevention, it will also be important to consider how they should be implemented in New Zealand communities in culturally relevant ways.

The two New Zealand programmes modelled were Green Prescriptions and APPLE, neither of which appeared highly cost-effective. In the case of Green Prescriptions (a programme to promote physical activity through general practices), it is also important to remember that its published results showed no significant difference between the intervention and control groups for weight-based outcomes. With regard to APPLE (an activity and education programme for children in school and in the community), this was the least cost-effective scenario, although as noted earlier, some scalability could be possible if the programme were rolled out more widely and this might improve its cost-effectiveness.

The first step in this research was a broad scoping search for relevant interventions. It was notable that most of the New Zealand interventions that were identified had not been evaluated for outcome measures necessary for economic modelling (such as BMI or weight). There was also a dearth of information about any differential outcomes for different population groups such as Māori or Pacific peoples. It is important that future obesity-prevention programmes being

undertaken in New Zealand are evaluated for their effectiveness over sufficient time periods and in different population groups. Clear information about programme costs is also needed.

The available time and funding limited the economic modelling to ten scenarios. After careful consideration by the research team and the stakeholder reference group, we aimed for a selection of interventions which appeared most relevant to the New Zealand population and policy setting, and were able to include a variety of ages, settings and approaches (children in primary schools and the community; adults connected with general practice; nutrition, activity and education programmes). However, further work is needed to explore interventions for other age groups (pre-schoolers and adolescents), settings (such as workplaces, secondary schools and universities) and specific groups (such as women or Māori). The limitations noted in section 3.8 also highlight other areas where additional research is required, including evidence about the longer-term effectiveness of interventions and effectiveness for differing groups. The report also shows that assuming an independent disutility effect on health of obesity *per se* (about which we have no evidence), would also significantly improve the cost-effectiveness of all the interventions examined here and is an issue on which further work is needed.

Given New Zealand's high rates of overweight/obesity, and their contribution to morbidity, mortality and health care costs[3 66-68], it is essential that cost-effective public health efforts continue to focus on obesity prevention. This research provides information about the relative cost-effectiveness of different interventions to guide ongoing policy in this area. However, it is important to keep in mind that this research focused on modelling the cost-effectiveness of a selected set of interventions; other interventions could usefully be modelled as the evidence base improves.

The analysis has focussed on the incremental cost effectiveness *ratio*, that is the additional cost per additional QALY achieved by an intervention. This is a value for money metric, calculated by dividing the additional QALY gain per participant by the additional cost per participant. These two elements are themselves separately of interest, when contemplating investment in health services and need to be kept in mind alongside the ratio. In addition, the up-front cost of the intervention is of interest for budgeting purposes.

General health screening for the adult population and also for Māori and Pacific people dominated all other interventions (apart from Switch-Play Analysis A) i.e. they achieved better outcomes at much lower (or not materially higher) incremental cost. The up-front intervention cost was also the lowest. Switch Play may dominate all other interventions if the intervention effect assumed in analysis A can be verified; otherwise it seems likely to be similar to general health screening. The other interventions either have worse outcomes for the same cost (SNPI) or have worse outcomes for higher costs (Be Active Eat Well, Green Prescription, APPLE).

5. Conclusion
Based on the approach taken, the evidence available at the time of writing, and assumptions utilised in the economic modelling of this research, the most cost-effective interventions for obesity prevention would appear to be a school-based programme for children and general health screening and advice for adults in a primary care setting. Generalisability and feasibility need to be considered, and appropriate implementation in the New Zealand setting will also be crucial

for any programme adopted. As time and resources limited the number of scenarios that could be modelled, other interventions should also be considered, particularly if the evidence base supporting their effectiveness improves. Neither of the New Zealand programmes modelled appeared highly cost-effective, and it is notable that many New Zealand interventions have not been evaluated for outcome measures necessary for this type of modelling. Nonetheless, this does not detract from the need to address New Zealand's high rates of overweight/obesity, and their contribution to morbidity, mortality and health care costs, through public health programmes aimed at obesity prevention.

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