

Whole system approaches to obesity prevention: Review of cost-effectiveness evidence

Guidance to tackle obesity at a local level using whole system approaches was initiated by NICE in 2009. The work was put on hold in November 2010 and reviewed as part of the Government's obesity strategy work programme. The revised scope has a stronger focus on local, community-wide best practice. It addresses both process and outcomes.

Before the development of this guidance was put on hold, the Programme Development Group (PDG) for this work met on four occasions and a series of evidence reviews was completed.

This is one of four evidence reviews that were considered by the PDG. The review has been edited to produce a shorter more accessible report for stakeholders.

The PDG is of the view that this review on the cost effectiveness of *whole system* approaches to obesity prevention will have resonance in considerations about *community-wide* approaches to obesity prevention. This review includes studies that took a community wide approach to obesity prevention. However, we would also like to hear stakeholder's views on the work that the PDG has considered to date.

We are particularly interested to hear stakeholder's views on:

- 1. The implications of the review findings for current and emerging practice at the community-wide level.**
- 2. Whether any evidence has been overlooked, particularly in light of revisions to the scope.**
- 3. The implications of the review findings on any future economic modeling for this guidance.**

Please also see the associated call for evidence.

Whole system approaches to obesity prevention

Review of cost-effectiveness evidence

This is an edited version of a systematic review undertaken by the Peninsula Technology Assessment Group (PenTAG) for NICE (final version submitted January 2011). The original report authors were: Rob Anderson, Senior Lecturer, PenTAG; Anne Fry-Smith, Information Scientist, WMHTAC; Sue Bayliss, Information Scientist, WMHTAC

It was edited by analysts at NICE in order to produce a shorter more accessible report for stakeholders. The original unedited version of the report is available on the NICE website.

List of abbreviations

Abbreviation	Meaning
APPLE	A Pilot Program for Lifestyle and Exercise (New Zealand)
BAEW	Be Active Eat Well (child obesity prevention programme, Australia)
BMI	Body Mass Index
BMI-z	A standardised measure of Body Mass Index often used in children, (standardised according to the normal distribution of BMI in a given population).
DALY	Disability-Adjusted Life-Year
Incr.	Incremental
LY	Life-Years
NZ\$	New Zealand dollars
PDG	Programme Development Group (a NICE public health guidance development committee)
QALY	Quality-Adjusted Life-Year
QWB	Quality of Well-Being (quality of life scale)
ABM	Agent-Based Modelling

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1. Summary

1.1. Introduction

Since April 2010, three systematic reviews have been produced to inform the development of public health guidance on whole system approaches to obesity prevention¹. This fourth report describes a systematic review which serves the dual purpose of:

- Searching for, summarising and critically appraising evidence from economic evaluations of the cost-effectiveness of “whole system” approaches to either community-wide obesity prevention or community-wide smoking prevention.
- Reviewing the range of different approaches to modelling the outcomes of obesity and overweight, or obesity prevention programmes.

Cost-effectiveness evidence

Partly because of the relatively new concept of whole systems approaches in public health, but also because of the multi-dimensional definition of a whole system approach, we did not expect a significant body of cost-effectiveness studies of obesity prevention programmes which could unequivocally be judged as having adopted a whole system approach. Rather, as with our review of effectiveness studies (Hunt et al. 2010), we hoped to find evaluations of community-wide, multi-agency prevention programmes which exhibited the various features of a whole system approach to different degrees.

¹ These three reviews were on the following topics:

- Review 1: Defining the concept and practise of a whole systems approach in the context of tackling public health problems
 - Review 2: Assessing the effectiveness of whole systems approaches for community-wide obesity prevention or smoking prevention
 - Review 3: Assessing the barriers to and facilitators of the successful development and implementation of whole system approach to preventing obesity (or other complex public health problems)
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Modelling and obesity

Since the health and economic impacts of obesity and overweight unfold over peoples' lifetimes, any adequate assessment of either the economic burden of obesity at a national level, or of the cost-effectiveness of a specific obesity intervention or programme, requires some extrapolation from current data and estimation of the myriad disease and other long-term consequences of obesity. It is this mathematical modelling of relationships to estimate outcomes of interest, and how they might be related to programme resource inputs, rather than conceptual modelling which is the focus in the second part of this report.

1.2. Aims of this review

The aims of this review were to answer the following two questions:

Q1. How does the cost-effectiveness of whole system or whole community approaches to preventing obesity vary in relation to:

The combination of local actions and local strategies undertaken in concert by different community groupings to try and bring about change?

The characteristics of the population and/or places targeted (including level of social disadvantage)?

The local and national policy context?

Other factors which influence the effectiveness, implementation and/or cost of the relevant actions and strategies?

Q2. What modelling methods have been used, or are suggested for use, in modelling the cost-effectiveness of whole system approaches to obesity prevention initiatives?

1.3. Methods

The main elements of the search strategy for this review were (in chronological order):

- Screening references of reports or papers flagged as potential ‘economic studies’ at the title/abstract screening stage of Review 1 and Review 2.
- E-mail contact with main authors of reports or papers
- Searching within the titles and abstracts of references in the obesity-related RefMan databases from Review 1 and Review 2
- Selected new searches in economic bibliographic databases (NHSEED & EconLit) (for Q1 only)

Each of the four cost-effectiveness studies that ended up being selected for inclusion were summarised narratively.

1.4. Findings on Aim 1: Cost-effectiveness

Evidence statement 1: Quantity and quality of published cost-effectiveness and obesity modelling evidence

Only **four** published economic evaluations were found which related to community-wide multi-faceted obesity prevention or smoking prevention programmes.

Two of the economic evaluations (a conference poster relating to the *Be Active Eat Well* programme in Australia, and a 3-page section of a larger evaluation report on the *Breathing Space* smoking prevention intervention in Edinburgh) were not presented in sufficient detail to warrant a full summary or critical appraisal (Moodie et al.; Platt et al.). The other two cost-effectiveness analyses were not comparable because they were of (i) a small pilot-trial based cost-effectiveness analysis of a school-based community-wide child obesity prevention programme (in New Zealand, results in \$NZ per kg of weight gain prevented after 2 years) (McAuley et al. 131-36), and (ii) a modelling-based study of the cost-effectiveness of two US-based community-wide campaigns to promote physical activity (the Stanford Five Cities Project and Wheeling Walks programme for older people; results presented in cost per life-year and cost per

quality-adjusted life-year) (Roux et al. 578-88).

Three of these four economic evaluations (and both of the under-reported ones) were based on effectiveness evaluations of programmes that were included in our related effectiveness review for NICE (NB. Roux et al. 2008 was not).

Evidence statement 2: Cost-effectiveness findings

There is evidence from only one community-wide obesity prevention programme which estimated incremental cost-effectiveness ratios, and can be judged as having used appropriate methods (of the APPLE pilot project in four small towns in New Zealand; McAuley et al. 2009). However, while having some community-based activities, the APPLE project was judged to only weakly exhibit only two of the ten defined features of a whole system approach (as defined by and refined from Review 1). Only four published economic evaluations were identified that were potentially relevant to the scope of this guidance (Moodie et al. 2010; Platt et al 2003; McAuley et al. 2009; Roux et al. 2008). Two of these studies (by Moodie et al., and Platt et al.) were so underreported that their findings cannot be relied upon. The other included cost-effectiveness study was of two community-wide physical activity promotion campaigns in the USA (Roux et al. 2008).

Cost-effectiveness of community-wide obesity prevention programmes: 1 paper

The cost-effectiveness of the small-scale APPLE pilot project to prevent obesity in children (aged 5-12 years) in small towns in New Zealand was reported in a full journal article (McAuley et al. 131-36). From their sample of 279 children, evaluated using a non-randomised controlled trial design from the beginning to the end of the 2-year intervention, they estimated an average weight gain *prevented* of 0.75kg (in 7-year old children) and 1.93kg (in 13-year old children). Combined with a programme cost per child of NZ\$1,281, this implies a cost per kg of weight gain prevented of NZ\$1,708 and NZ\$664 respectively (in 2006 NZ\$). It is very difficult to interpret what this cost-effectiveness ratio might mean in terms of the balance between the cost of

the programme and the longer term impacts of such reductions in weight gain (if they were to be sustained).

Cost-effectiveness of community-wide programmes to promote physical activity: 1 paper

A model-based cost-effectiveness study by Roux et al. (2008) presented both a cost-effectiveness analysis and cost-utility analysis of seven programmes for promoting physical activity in communities, two of which were community-wide programmes. Their estimated incremental cost-effectiveness ratios of the two programmes were the highest (Stanford Five City project: \$22,600 per Life-Year; \$14,300 per QALY) and the lowest (Wheeling Walks: \$110,000 per Life-Year; \$68,000 per QALY) of the seven physical activity programmes evaluated using the simulation model (in 2003 US\$). While such incremental ratios (<\$100,000 per QALY) are often viewed as representing good value for money in the US health care context, there is considerable uncertainty surrounding these estimates, and the extent to which these two programmes have used a whole system approach is unclear.

Cost-effectiveness of the other two (under-reported) community-wide prevention programmes

While the Be Active Eat Well programmes has adopted many features of a whole system approach to obesity prevention, the conference poster presenting the cost-effectiveness of the programme is insufficiently reported to draw any reliable conclusions. There are also unresolved inconsistencies between the stated incremental cost per Disability-Adjusted Life-Year and the stated underlying cost and effectiveness results. Finally, the 'economic evaluation' of the *Breathing Space* smoking cessation programme (Edinburgh) was restricted to cost analysis, because there were no measured differences in effectiveness between the intervention and control communities.

Applicability of evidence

Whether in terms of the lack of UK evidence, the lack of fully reported studies, or the lack of economic studies of programmes which could be judged unambiguously as having adopted a whole system approach, the limited evidence base has very weak

applicability to the UK or the scope of NICE's obesity guidance.
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1.5. Findings on Aim 2: Approaches to modelling of obesity and for obesity prevention

A very recent (September 2010) and authoritative systematic review of simulation modelling in obesity (Levy et al, 2010) was the main source of this overview. This was supplemented by two other key papers (on System Dynamics modelling and Agent-Based Modelling respectively)

Areas of application of modelling and obesity

The Levy et al. 2010 review identified five areas of application of simulation modelling:

- Estimating the health and economic consequences of obesity
- Assessing trends in BMI as a function of past trends
- Predicting change in body weight from specific changes in diet and/or physical activity (i.e. 'below the skin', physiological models)
- Estimating and explaining how changes in the environments in which people live, work or go to school can enable or constrain healthy behaviours and change obesity prevalence.
- Policy and programme evaluation

While all five of these are potentially relevant, previous modelling in the first and the last two of these areas is likely to be most informative for modelling the cost-effectiveness of alternative policies for promoting a whole system approach to obesity prevention.

Different aspects of simulation models

As in other areas which use simulation models, models of obesity or obesity prevention may be: static or dynamic; involve macro- (population groups) or micro-simulation (modelling individuals); follow cohorts or cover a whole population for a limited period of time; use discrete or continuous time; be deterministic (only using central or 'best' estimates of each input) or stochastic (i.e. probabilistic, with model inputs sampled from distributions); and may allow or exclude the possibility of interaction between individuals or other simulated 'agents' (e.g. where a disease is thought to spread by some contagion effect).

Modelling approaches consistent with evaluating complex systems

Two types of simulation modelling are increasingly advocated for their particular applicability to the evaluation of complex adaptive systems, and therefore to public health problems such as obesity:

- System Dynamics modelling
- Agent-Based Modelling

Compared with other mathematical simulation models **system dynamics models** are based on the dynamic accumulation of different factors or resources or information, combined with specified balancing or reinforcing feedback mechanisms. Such models will tend to have 'broader boundaries', admitting more variables on the basis of logic or expert opinion (and therefore perhaps rely more on mediating variables that are more conceptual than empirical). This, Homer and Hirsch (2006) argue, means that systems dynamic models can include "a variety of realistic causal factors, policy levers, and feedback loops" (p.453) and are therefore better at finding effective solutions to "persistent, dynamically complex [public health] problems".

Agent-based modelling (ABM) is a dynamic form of micro-simulation in which every individual person (or 'agent') is explicitly simulated, and has their own characteristics, initial state and position, and also defined rules of interaction with other agents in the system. Given a set of these starting conditions and interaction rules for a whole simulated population, the whole population's 'macro-level' outcomes can evolve over time. According to Hammond (2010, pp.11-12) the particular advantages of ABM for

modelling complex systems like obesity are that the approach: “allows for substantial diversity amongst agents”; “allows for more flexible cognitive assumptions about individual decision-making”; “can incorporate feedback dynamics and explicit spatial contexts” (and at both the individual level, and other aggregate levels); and, through the focus on mechanisms, “the ability to study non-equilibrium dynamics” so that emergent and adaptive social phenomena can be explicitly included. For these reasons Hammond argues that ABM is also well-suited to evaluating the complex impacts of programmes and policies.

In conclusion, simulation modelling of obesity or obesity policies is still at a relatively early stage of development. However, in some cases methods for modelling outcomes in the area of obesity and obesity prevention policies or programmes has already become so complex and advanced that the usefulness (or even feasibility) of attempting to develop credible new models without significant modelling capacity, access to national data, and significant modeller time and other resources is questionable. Instead, with limited resources, any realistic modelling of alternative local community-wide obesity prevention policies should aim to make best use of one of the well-established and tested existing population-level obesity models (such as the National Heart Forum’s micro-simulation model, or the ACE Obesity model framework).

2. Introduction

This report describes a systematic review which serves the dual purpose of:

- Searching for, summarising and critically appraising evidence (published economic evaluations) of the cost-effectiveness of whole system approaches to either community-wide obesity prevention or community-wide smoking prevention.
- Reviewing the range of different approaches to modelling the outcomes of obesity and overweight, or obesity prevention programmes.

Specifically the aims of this review are to answer the following questions:

Q1. How does the cost-effectiveness of whole system or whole community approaches to preventing obesity vary in relation to:

The combination of local actions and local strategies undertaken in concert by different community groupings to try and bring about change?

The characteristics of the population and/or places targeted (including level of social disadvantage)?

The local and national policy context?

Other factors which influence the effectiveness, implementation and/or cost of the relevant actions and strategies?

Q2. What modelling methods have been used, or are suggested for use, in modelling the cost-effectiveness of whole system approaches to obesity prevention initiatives?

2.1. Context to this review

Previous evidence reviews on which this review builds

Since April 2010, three systematic reviews have been produced to inform the development of public health guidance on whole system approaches to obesity prevention. These reviews were on the following topics:

- Review 1: Defining the concept and practise of a whole systems approach in the context of tackling public health problems
- Review 2: Assessing the effectiveness of whole systems approaches for community-wide obesity prevention or smoking prevention (or, at least, assessing whether adopting *more of the features* or *particular features* of systems working appears to make for more effective or sustainable programmes)
- Review 3: Assessing the barriers to and facilitators of the successful development and implementation of whole system approach to preventing obesity (or other complex public health problems)

These reviews produced a list of the eight 'core features' of a whole system approach to public health problems. The development of this list was conducted using an evidence-based approach, and the list was revised and expanded as the reviews progressed.. This, in the light of PDG discussions and the later reviews, has since expanded to become ten features of a whole system approach. These ten features (see Box 1 below) were used in the present assessment of local policy documents and are listed in the protocol of this research, but they have also evolved further since the beginning of this case study (mainly in terms of how individual features are described).

Box 1. Ten defined features of a Whole System Approach

1. **Explicit recognition of the public health problem(s) as a system:** recognition of interacting and evolving elements; self-regulation; synergy and emergent properties associated with complex adaptive systems.
2. **Capacity building:** capacity building within communities and organisations stated as an explicit goal. This could take the form of increasing understanding about obesity as a problem in the community and in potential partners organisations, training for those in posts addressing obesity, more dedicated staff addressing obesity etc.

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3. **Local creativity:** local creativity and/or innovation was encouraged to address obesity prevention. This might be evidenced by mechanisms for local people to design locally relevant activities and solutions, while rigid requirement for activities imposed from outside the area would suggest that this was not present.
 4. **Relationships:** clear methods were used to develop and maintain working relationships, within and between organisations.
 5. **Engagement:** clear methods used for engaging community members in programme development and delivery. This engagement should be with diverse people, organisations and sectors.
 6. **Communication:** clear methods were used for enhancing communication between actors and organisations within the system. This would not mean communication of health promoting messages to the people living in a community as part of a specific intervention.
 7. Focus on the **embeddedness of action and policies** for obesity prevention in organisations and systems. Examples of this might include the visibility of obesity as an explicit policy goal or concern for non-health organisations, ongoing strategic commitment to obesity as a local concern etc.
 8. Focus on the **robustness and sustainability** of the system to tackle obesity. Ongoing strategies for resourcing existing and new projects and staff might be an indicator of this feature.
 9. **Facilitative leadership.** This is leadership which is not necessarily located at any particular level or organisation and is likely to encourage bottom up solutions and activities whilst providing strong strategic support where needed as well as appropriate resourcing.
 10. Well articulated methods for ongoing **monitoring and evaluation** of activities, the results of which feedback into the system and drive change to enhance appropriateness and effectiveness. This relates to notions of the adaptability and learning capabilities of the systems/networks/partnerships established.

The second review, of the effectiveness of community-wide multi-agency, programmes to prevent obesity or to prevent smoking, found disappointingly few studies which met the inclusion criteria – there were only eight community-wide obesity prevention programmes (and only two smoking prevention programmes) which had been evaluated using comparative quantitative study designs. They were also highly variable in the extent to which they demonstrated features of a whole system approach, with only five of the eight evaluated programmes being judged to exhibit four or more features of systems working (and none having explicitly been developed from a systems-based understanding of the causes of obesity). While the direction of the obesity prevention programme effects (mostly changes or differences

in BMI or BMI-z scores) was generally favourable, few of the results were statistically significant. Also, only one of the studies in the review of effectiveness studies - of a smoking prevention programme in Scotland – was from the UK. All of the obesity prevention programmes mainly targetted children under the age of 14 years, and most were predominantly school-based although for inclusion they had to have some wider community-based programme activities. Given this paucity of evaluative evidence, and considerable diversity in the nature, intensity, components, and duration of the programmes, it was impossible to draw any firm conclusions about the potential additional effectiveness of adopting a whole systems approach (or even particular combinations of features of such an approach).

The third review sought to identify barriers to and facilitators of effective whole system approaches by summarising and synthesising qualitative research. The factors were identified from six qualitative studies alongside obesity prevention programmes, two studies alongside smoking prevention programmes and nine studies conducted about whole community approaches in the UK to health improvement or health inequalities (e.g. Health Action Zones, Health Improvement Programmes). The review identified one or more factors which hinder or help the effective operation of each of eight features of systems working. The appropriate management of meetings – in a way which recognises the system – was also central to the implementation of a whole system approach. However, there were no identified factors specifically associated with ‘local creativity’ as an aspect of systems working.

While, collectively, these reviews have provided a well-refined and workable definition of a whole system approach, they do not provide clear evidence on whether using whole system approaches at a local level increases programme success, the sustainability of changes, and whether they more effectively prevent obesity and overweight in whole communities. Also, with the exception of the review of qualitative studies, much of the published evidence relating to particular programmes is from outside the UK. Given that the social, economic, organisational and cultural factors which create and sustain obesity will often be country-specific it is therefore important to search for other evidence more specific to the obesity problem and its potential solutions in England.

Expectations about relevant cost-effectiveness evidence

Partly because of the relatively new concept of whole systems approaches in public health, but also because of the multi-dimensional definition of a whole system approach we and the PDG have developed, we did not expect a significant body of cost-effectiveness studies of obesity prevention programmes which could unequivocally be judged as having adopted a whole system approach. Rather, as with our review of effectiveness studies (Hunt et al. 2010), we hoped to find evaluations of community-wide, multi-agency prevention programmes which exhibited the various features of a whole system approach to different degrees.

Modelling and obesity

Models are simplified representations of reality, typically created in order to understand a real-world problem or system (Brailsford et al. 130-40). Simulation models are models that usually consist of a collection of mathematical equations that quantitatively relate a number of inputs and one or more outputs of interest (Levy et al.). For evaluating the cost-effectiveness of policies or programmes modelling invariably means simulation or decision modelling combining empirical evidence with realistic assumptions about alternative courses of action. (This type of modelling should be distinguished from the formalised expression of economic theory in mathematical equations which is the main form of modelling used by some economists.)

Since the health and economic impacts of obesity and overweight unfold over people's lifetimes, any adequate assessment of either the economic burden of obesity at a national level, or of the cost-effectiveness of a specific obesity intervention or programme, will require some extrapolation from current data and estimation of the myriad disease and other consequences of obesity. It is this mathematical modelling of relationships to estimate outcomes of interest, and how they might be related to programme resource inputs, rather than conceptual modelling which is our focus in this report.

3. Methods

3.1. Identification of evidence

3.1.1. Search strategy

Tagged references from previous searches

The reviewers who screened the search hits for the previous three systematic reviews marked any titles and abstracts which looked like potentially relevant economic evaluations, or economic studies relating to obesity more generally. These ‘tagged’ titles and abstracts were screening against the review criteria in the usual way, and full text articles were requested of any potentially includable studies found.

Searches in databases of economic literature

3.1.2. Identifying the literature: Overview

The search strategies for Q1 and Q2 were different, with the Q1 search strategy more explicitly building on the search results from Review 1 (defining whole system approaches) and Review 2 (effectiveness review).

The search strategy for Q1 used search terms and flagged results from title and abstract screening of Review 1 and Review 2. Importantly, economic studies of relevant named obesity programmes identified through searches already conducted in Reviews 1 and 2 were directly sought from study authors. It also involved new searches of relevant ‘economic’ bibliographic databases (NHSEED & EconLit). This was supplemented by communication with experts and/or organisations involved in the relevant research or policy areas and citation searching. A separate and more detailed Search Protocol and Search Strategy was agreed separately between this project’s information specialists (at WMHTAC) and the relevant CPHE analysts and information specialists.

The search strategy for Q2 used similar strategies to those used above, but was not an explicit focus of the new searches in NHSEED and EconLit. Given

the iterative nature of this review, the Search Strategies are being agreed separately from the Search Protocol (which provided the overall framework of what types of searches may be conducted amongst which databases and sources, and using which key search terms).

In summary, the main elements of the search strategy for this review were (in chronological order):

- Screening references of reports or papers flagged as potential 'economic studies' at the title/abstract screening stage of Review 1 and Review 2.
- E-mail contact with main authors of reports or papers included in Review 2 (effectiveness studies)
- Searching within the titles and abstracts of references in the obesity-related RefMan databases generated for Review 1 and Review 2
- Selected new searches in economic bibliographic databases (NHSEED & EconLit) (for Q1 only)

3.1.3. Search processes and methods

- Searches covered bibliographic databases and grey literature sources particularly websites. A broad strategy was devised comprising a combination of textwords and index terms to express the intervention (systems approaches/working or community-wide/-based) and the populations (obesity prevention).
- Databases to be searched and search terms are detailed separately in the search protocol and strategy (although likely to only be NHSEED and EconLit)
- Two information specialists (SB & AF-S) conducted the new bibliographic database searches, with the lead reviewer/health economist (RA) undertaking the other searches for this review.
- All searches were fully documented (databases and websites used, strategies and dates of searches. References were stored on a Reference Manager database.

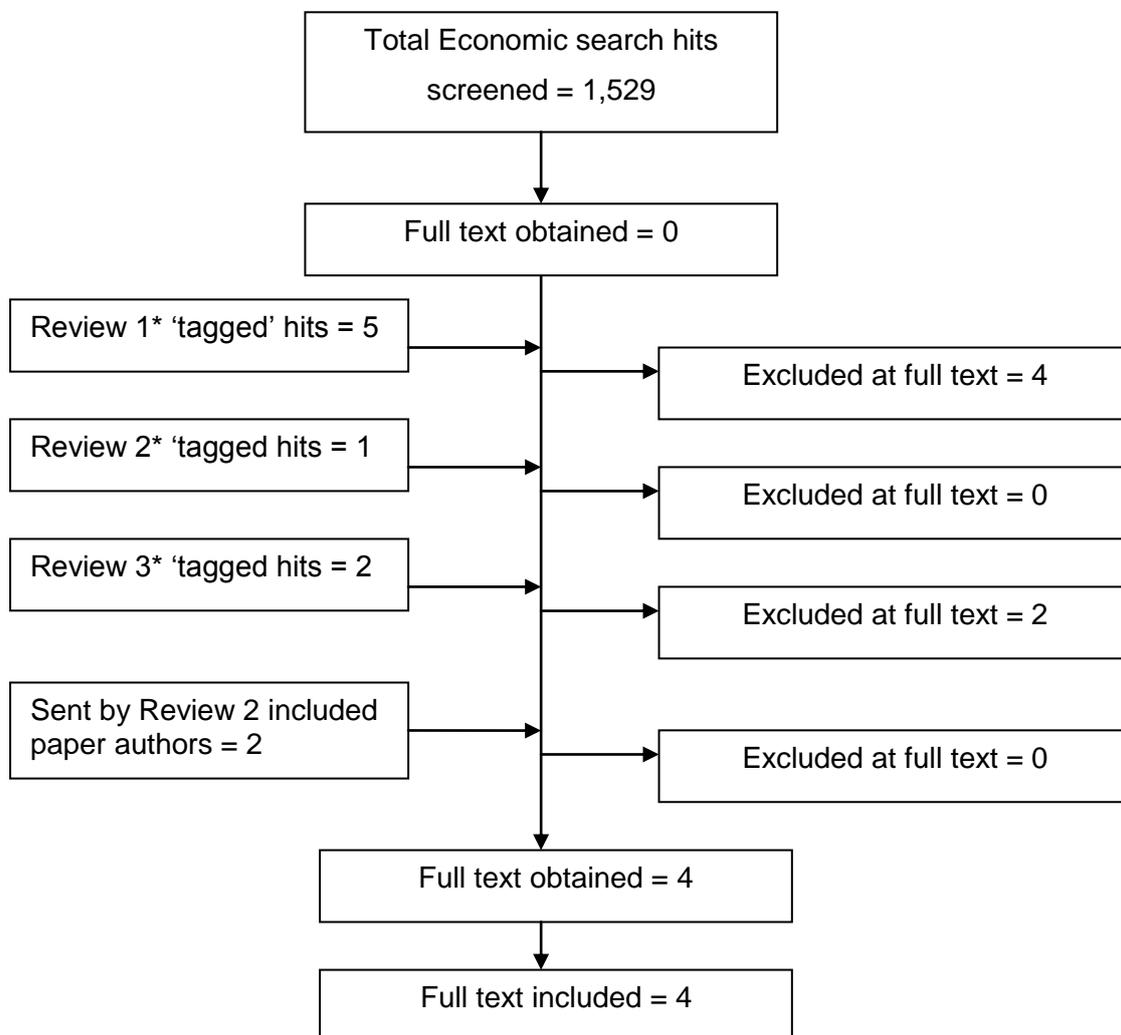
3.1.4. Study selection at search stage

- Studies published from 1990
- Studies published in the English language
- Studies conducted in OECD countries

3.2. Study selection process

Assessment for inclusion was undertaken initially at title and/or abstract level (to identify potential papers/reports for inclusion) by a single reviewer (RA), and then by examination of full papers. Where the research methods used or type of initiative evaluated were not clear from the abstract, assessment was based upon a reading of the full paper.

Figure 1 on the following page shows the paper selection process (including the very disappointing yield of the bibliographic searches that were conducted specifically for this review).

Figure 1. Review flowchart – ‘Economics’ searches

*NB. Review 1 was the review to define a Whole Systems Approaches to public health problems; Review 2 was the review of relevant effectiveness studies; and Review 3 was the review of qualitative research studies (to describe 'barriers and facilitators').

Both papers tagged from review 2 were on smoking cessation

Both papers sent by authors related to obesity prevention programmes which had effectiveness evaluations included in Review 2 (Be Active Eat Well, and the APPLE project)

4. Findings

4.1. Overview

There was only one published paper/report of an economic evaluation relevant to review Question 1, about the cost-effectiveness of whole systems approaches to obesity prevention. That is, we found only one full paper or report reporting an economic evaluation of a community-wide multi-agency approach to either obesity or smoking prevention. This was an economic evaluation of the APPLE pilot project which was a school- and community-based prevention programme in small towns (four schools) in New Zealand (McAuley et al. 131-36).

However, in addition to summarising the economic evaluation of APPLE, we summarise three of the more relevant studies found which may provide some useful insights for the PDG in considering the cost-effectiveness of these types of programme (section 4.2).

For review question 2, to identify different approaches to modelling (and especially the economic modelling of obesity), we found a number of potentially informative papers (section 4.3). In particular, a recent (published 2010) systematic review on approaches to the modelling of obesity and obesity prevention has been published which is authored by almost all the key researchers who are involved in the leading international examples of obesity modelling (Levy et al.). Given that this review directly addresses our second review question, and given the expert status of the authors and the transparency of methods of their systematic review, this source provides the main overview of potential modelling methods. This overview is supplemented by insights from other papers which specifically advocate using System Dynamics Modelling (Homer and Hirsch 452-58), or using Agent-Based Modelling for understanding complex public health problems such as obesity (Hammond 1-10; Hammond 767-77).

4.2. Cost-effectiveness evidence

Although no papers met the review's formal inclusion criteria, four documents were found which were of potential relevance to our review question. All three were related to one of the obesity prevention or smoking prevention programmes reviewed in our recent review of effectiveness studies (Hunt et al.). They were:

1. An incremental cost-effectiveness study of the *APPLE pilot project* community-wide child obesity prevention programme in small towns (4 schools) in New Zealand (full journal paper)
2. An incremental cost-effectiveness study of the *Be Active Eat Well* community-wide child obesity prevention programme in Victoria, Australia (reported in very brief form, as a conference poster) (Moodie et al.).
3. A 3-page report section on economic evaluation as part of the evaluation of the *Breathing Space* community-based smoking prevention programme, in Edinburgh (Platt et al.).
4. A paper reporting an analysis of the cost-effectiveness of seven different community-based interventions for promoting physical activity (Roux et al. 578-88).

We also briefly summarise another paper reporting the relationship between the costs and participation rates in the *COMMIT* smoking cessation trial in the USA (and Canada) (Shipley et al. 286-92). However, while this is a comparison of the costs and effectiveness of one of the smoking cessation programmes included in our effectiveness review (Hunt et al.), it only focuses on one programme element (the stop smoking contests) rather than the community-wide *COMMIT* intervention as a whole.

Since the cost-effectiveness findings of these studies are mostly inconclusive, and too diverse to be comparable, they are summarised below. Apart from the studies by McAuley et al (2009) on *APPLE* project, and Roux et al (2008) on two US community-wide physical activity programmes, they were too briefly reported for a standardised assessment of their quality as economic evaluations to be worthwhile.

4.2.1. **Cost-effectiveness of the APPLE pilot project, New Zealand**

A journal article by McAuley, Taylor and colleagues (2009) reports an incremental cost-effectiveness evaluation of the child obesity prevention programme in four New Zealand schools and their surrounding small communities (APPLE: A Pilot Project for Lifestyle and Exercise). (NB. Three published evaluations of the APPLE project were included in the review of effectiveness studies (Hunt et al.)). Their economic analysis was conducted from a societal perspective, and reports their results in terms of New Zealand \$s per kilogram of weight gain. Although they had measured health-related quality-of-life from parental completion of the HUI (health utilities index) quality of life instrument, there were no significant differences for this outcome and therefore there was no estimation of the incremental cost per quality-adjusted life-year (QALY).

While dominantly school-based and child-focussed, the community Activity Coordinators in the APPLE project fostered a number of out-of-school activities some of which targetted parents or other adults. However, it was judged (in our effectiveness review) to exhibit only 2 of the 10 defined features of a whole system approach, and even these (community engagement and local creativity) were not fully evidenced. The effectiveness programme was evaluated using a non-randomised controlled trial study design, with anthropometric outcome data (BMI-z scores and the prevalence of overweight and obese children) measured at two years and only in the school children (279 children aged 5 to 12 years). The programme costing appears comprehensive, covering administrative/travel costs, the project coordinator and four Activity Coordinators (half-time for two years) plus various equipment and other costs related to monitoring height and weight and other school-based health promotion activities.

The average cost per child was estimated as NZ\$1,281 (in 2006 NZ\$). Combined with the study's estimates of the average weight gain *prevented*, of 0.75kg (in 7-year old children) and 1.93kg (in 13-year old children), this implies a cost per kg of weight gain prevented of NZ\$1,708 and NZ\$664 respectively. One-way sensitivity analysis indicated that these weight differences could have

been between 0.5 and 1.0kg in the young children and between 1.4 and 2.4kg in the older children, giving a range of possible cost-effectiveness estimates between NZ\$2,562 and NZ\$534 (NB. *from reviewer's calculations based on information within the paper*).

Given currently accepted standards of economic evaluation, for example ideally using long time horizons and using quality-adjusted life-years as a standard outcome within a decision model (Sculpher et al. 677-87), it is very difficult to say whether any of these incremental costs per kilogram of weight gain prevented in the short-term would represent good value for money over children's lifetimes. The authors rightly acknowledge the limitation that their programme was evaluated using small sample sizes and relatively short follow-up (2 years). However, this also means that with economies of scale the programme cost per child might reduce significantly if a similar programme were to be implemented in a larger number of schools and in larger communities, and therefore the cost-effectiveness would also improve.

4.2.2. Cost-effectiveness of Be Active Eat Well, Victoria

A conference poster by Moodie and colleagues (2010) reports an incremental cost-effectiveness evaluation of the child obesity prevention programme in Colac, Victoria, from a societal perspective, and reports their results in terms of Australian \$s per Disability-Adjusted Life-Year (Moodie et al.). While dominantly school-based and child-focussed, the Be Active Eat Well (BAEW) was judged (in our effectiveness review) to exhibit 9 of the 10 defined features of a whole system approach. According to the conference poster, the BAEW programme "aimed to build the capacity of the community to create its own solutions to promote healthy eating, physical activity and healthy weight in children ... and their families".

The method of this cost-effectiveness analysis is shown in Table 1 below.

Table 1. Moodie et al 2010 cost-effectiveness study characteristics

Feature	Approach used
Overall design	Modelling-based study: annual costs of programme, combined with estimated lifetime obesity outcomes and related savings (consistent with the <i>ACE-Obesity</i> methods ^a)
Perspective	Societal, and assuming 10% of Australian primary schools participate
Effectiveness study data	For BAEW: n=1,001 from 6 primary schools and 4 pre-schools For comparator: n=1,183 from 12 primary schools and 4 pre-schools
Programme costs	Retrospective costing based on detailed process evaluation reports, stakeholder interviews, school newsletters and reports (not described in more detail).
Cost savings	Savings due to estimated reductions in obesity-related diseases (method not described)

^aThe "ACE-obesity method" is a specific approach to evaluating the cost-effectiveness of preventing a variety of major chronic diseases in Australia, to assess their cost-effectiveness relative to each other and relative to treatment interventions (Vos et al.).

The results of the mean incremental cost-effectiveness analysis of BAEW was estimated as Aus\$ 31,700 per Disability-Adjusted Life-Year (although with a 95% confidence interval for this estimate ranging from the intervention being dominated -\$266,000 to \$352,270; see below).

Table 2. Cost-effectiveness of BAEW as estimated by Moodie et al 2010

Outcome	Point estimate from model	Lower 95% CI	Upper 95% CI
Change in BMI per child:			
Boys aged 5-9 years	0.045	-0.641	0.732
Boys aged 10-12 years	-1.155	-2.012	-0.298
Girls aged 5-9 years	-0.535	-0.535	0.141
Girls aged 10-12 years	-1.276	-3.453	0.902
Total reduction in BMI over the population	70,800	27,110	167,390
Total estimated DALYs saved	1,285	240	2,950
Gross intervention costs ^a	\$48.2m	\$46.9m	\$50.3m
Total cost offsets ^a	\$3.27m	-\$1.12m	\$7.97m
Net (incremental cost) per DALY gained ^a	\$31,685	-\$266,000 ^b	\$352,270

Results are exactly as presented in the conference poster. There are some clear inconsistencies in the reported confidence intervals. In particular the lower 95% Net cost per DALY gained should not be negative given positive DALYs saved and positive incremental Net costs.

^aAll costs and incremental ratios are in 2006 Australian \$.

^bNegative cost offsets means both higher costs and lower effectiveness, leading to a negative cost-effectiveness ratio. Therefore it looks like the programme is dominated by 'no programme', although the calculations are hard to check.

They estimate that in a year the programme would reach 185,030 children (10% of Australian children of that age) and cost \$48.6m to deliver. Unfortunately, there is no detail on critical modelling assumptions, such how the annual changes in children's BMI are assumed to persist into later years and adult life, or how the lifetime changes in DALYs are calculated from these BMI changes.

It is therefore extremely difficult to judge the validity and reliability of these estimates, or their applicability to the UK setting. In addition, the confidence intervals for the cost-effectiveness ratio suggest that the programme might in reality range from highly cost-effective to highly cost-ineffective, depending on the true value of programme effectiveness. The presentation of cost-effectiveness acceptability curves may have allowed a better interpretation. Furthermore, even if the mean incremental cost-effectiveness ratio were taken at face value, there is no way of discerning what proportion of the programme's costs and benefits are due to using a whole system approach (which the BAEW programme, in many respects, appeared to do; see effectiveness review).

4.2.3. 'Economic evaluation' of Breathing Space, Edinburgh

The final report of the evaluation of the Breathing Space community-based anti-smoking programme in Edinburgh, included several pages supposedly describing an economic evaluation (Platt et al. 2003). However, while they present a time series analysis of the monthly (mainly prescribing cost) spend per smoker in the intervention area and the three comparator areas, they ultimately do not compare the extra costs and the estimated benefits of the programme. This is simply because "there were no observable differences"

(p.40) between the intervention and control areas in the main effectiveness evaluation.

However, they present detailed costs of the Breathing Space programme broken down by the stage or type of programme activity (their Table 6.12, p.40), and also by the *specificity of purpose* of the different activities – distinguishing ‘narrow activities’ (related to specific projects) from ‘broad activities’ (i.e. those activities tackling the wider determinants of smoking, activities “aiming to create health promoting environments” and other activities to plan or sustain those activities, such as participation in multi-agency meetings with a broader policy agenda than Breathing Space).

This separation of the programme’s ‘broad costs’, plus the separate coding and presentation of costs associated with things such as engagement, evaluation and sustainability, allow an overall assessment to be made of the potential additional costs of adopting a whole system approach (with this programme in this community context). We have done this in Table 3 below, making different assumptions about how the categories of costs actually reported might reflect the costs of adopting a whole system approach. In this simple exercise, for a specific community-wide smoking prevention programme in Scotland, the estimated cost of using features of a whole system approach could potentially be between a fifth and two-fifths of the total programme cost.

Table 3. Crude estimation of the cost of Whole Systems working within Breathing Space

Assumption regarding costs of adopting a ‘whole system approach’ (WSA)	Cost of WSA	% of total programme cost
Half of costs of ‘engagement’, half of ‘evaluation’ costs, and half of ‘sustainability’ costs	£20,965	20.5%
As above plus all costs for ‘broad activity’ ^a	£25,833	25.2%
As above but assuming 90% of the costs for engagement, evaluation and dissemination can be attributed to adopting a ‘whole system approach’	£42,605	41.6%

Source data = Table 6.12, p.41, in Platt et al. 2003.

^aSee definition of 'broad activity' within the paragraph preceding the table.

4.2.4. Cost-effectiveness analysis of community-based interventions for promoting physical activity

Two of the seven evaluated programmes that were classed by the authors of this study as 'Community-wide' campaigns were the Stanford Five City project and a media campaign to promote walking amongst sedentary older adults (Wheeling Walks). Both of these programmes were judged as involving many community sectors in highly visible, broad-based, multiple intervention approaches; communication techniques directed at large populations; tackling sedentary behaviour; multiple formats for media messages (e.g. radio, newspaper, mailings); and the interventions also included some combination of social support, risk-factor screening, counselling, and education in a variety of settings.

Methods

The cost-effectiveness estimates were produced by a simulation model of a cohort of the US adult population (aged 25-64 years in 2004), assuming that all cohort members were well at the beginning of the model simulation (the 'CDC-MOVE' model). The model itself was a 10-state Markov process model which comprised four "risk states", to describe the degree of physical activity of a person (inactive, irregularly active, active enough to meet national guidelines, and highly active), plus five "disease states" (for which good evidence exists showing a reduction in disease risk is associated with regular physical exercise: coronary heart disease, ischaemic stroke, type 2 diabetes, breast cancer and colorectal cancer). The tenth Markov state was death. The median relative risk of each disease amongst people in the "physically inactive" state, relative to those in the "highly active" state, was estimated from a review of 120 studies.

For mortality (i.e. in modelling terms, the transition probabilities from any of the six disease states to death) a common method was used to estimate the annual probability of death, specific to each disease and the age and gender of a simulated person with the disease. This method drew on national disease-specific vital statistics data wherever available. Quality-of-life scores (between 0 and 1) were derived from a national survey dataset which had used the Quality of Well-Being (QWB) scale/questionnaire. Although not designed to do so, these QWB scores were used as the basis of preference weights for the estimation of life-time Quality-Adjusted Life-Years (QALYs). The costs of each intervention were estimated “through direct communication with the authors of original investigations in combination with a review of manuscript protocols” (p.581) (Roux et al. 578-88).

Finally, the effect of the interventions or programmes was implemented in the model through associating each level of physical activity/inactivity with a certain number of ‘MET-minutes’ per week (see footnote for definition²). The probability of moving to a higher physical activity level after intervention was estimated by adding intervention-specific MET-minutes to current population ‘background’ levels of MET-minutes, and therefore the proportion of the population who moved from one level of physical activity to another.

Results

Table 4 below shows the incremental cost-effectiveness of the two community-wide physical activity programmes compared with having no programme. Interestingly, their incremental cost-effectiveness ratios were the highest (Stanford Five City project) and the lowest (Wheeling Walks) of the seven physical activity programmes evaluated using the simulation model.

² Where 1 MET is the metabolic rate equivalent to consuming 3.5 millilitres of oxygen per kilogram of bodyweight per minute, and is equivalent to a resting metabolic rate.

Table 4. Cost-effectiveness of community-wide campaigns to promote physical activity (deterministic results)

Programme	Incr. cost	Incr. LYs	Incr. QALYs	Cost/LY	Cost/QALY
Stanford Five City project	\$960	0.009	0.014	\$111,322	\$68,557
Wheeling Walks	\$700	0.031	0.049	\$22,654	\$14,286

Source: Table 4. p.583 of Roux et al. 2008. All columns show results per person in the target populations. Costs and incremental cost-effectiveness ratios are in 2003 \$US (not inflated).

Abbreviations: Incr. = Incremental; LYs = Life-Years; QALYs = Life-Years

If, somewhat conservatively, a ratio of \$50,000 per QALY gained is assumed to represent good ‘value for money’ (in the US health care context) then it might be concluded that the Stanford programme is not cost-effective, whereas the Wheeling Walks programme is. However, some regard \$100,000 or \$200,000 per QALY as a more realistic cost-effectiveness threshold given currently funded programmes. Also, this table shows the results of the deterministic analysis – that is, the model outcomes if the best or central estimate is used for the different model inputs. If a probabilistic simulation analysis is conducted, which reflects the underlying uncertainty in input parameters, the results show that there is a 55% likelihood that the Stanford Five City project achieved physical activity improvements at less than \$50,000 per QALY.

Therefore, overall, the conclusion of the analysis is that such community-wide programmes would be “an acceptable use of societal resources” (p.584). It is also impossible to know from these analyses whether additional programme elements which targetted improvements in diet would increase or decrease the cost-effectiveness of the programmes.

4.2.5. Resources and participation in smoking cessation as part of COMMIT study

Lastly, a large-scale evaluation of a comprehensive community-wide smoking cessation programme in 11 north-American towns and cities (10 in USA, 1 in

Canada; see effectiveness review, Hunt et al. 2010) produced one paper which examined the relationship between the amount of resources per smoker invested in 26 different 'Stop Smoking Contests' and their success in terms of participation rates (Shiple et al. 1995). However, while the comprehensive activities of the COMMIT community-wide smoking prevention intervention exhibited most of the defined features of a whole system approach - and it is interesting that this study discovered quite a strong and positive correlation between the participation percentage of a contest and the mean expenditure per smoker of each contest (excluding prize expenditure) - this relates to just one intervention type within each community, the stop smoking contests. Therefore, it is hard to see how this finding sheds any useful light on the potential costs and benefits of the wider adoption of a whole system approach.

4.3. Approaches to modelling in obesity

Our second review question - related to identifying possible modelling methods for assessing the cost-effectiveness of whole system approaches to obesity prevention initiatives - could have been addressed by reviewing the vast literature on simulation modelling of complex public health problems, simulation modelling of obesity, and simulation modelling of obesity prevention programmes. Despite conducting dedicated but ultimately fruitless searches, we identified (through a key contact) a very recent (September 2010) and authoritative systematic review on simulation modelling in obesity (Levy et al, 2010). This review formed the basis of our overview, supplemented by three other key papers (on System Dynamics modelling and Agent-Based Modelling respectively) identified separately from the searches or from the references of the Levy et al paper.

In contrast to the review methods for question one, it should be noted that while the processes for searching for potentially relevant papers or other reports was rigorous and pre-specified, the decision rules for deciding what should be read and summarised in greater depth has been less rule-based and was instead based on the reviewer's judgement. The four main sources that informed the content of the following sections were:

DT Levy, PL Mabry, YC Wang, S Gortmaker, TT-K Huang, T Marsh, M Moodie, and B Swinburn. Simulation models of obesity: a review of the literature and implications for research and policy. *Obesity Reviews*, 2010.

RA Hammond. Complex systems modeling for obesity research. *Preventing Chronic Disease* 6 (3):1-10, 2009.

RA Hammond. A complex systems approach to understanding and combating the obesity epidemic. In: *Obesity Prevention: The Role of Brain and Society in Individual Behaviour*, edited by L Dube, A Bechara, A Dagher, A Drewnowski, J LeBel, P James, and R Yada, Amsterdam:Elsevier, 2010, p. 767-777.

JB Homer and JB Hirsch. System dynamics modeling for public health: Background and opportunities. *American Journal of Public Health* 96 (3):452-458, 2010.

4.3.1. **Modelling obesity-related outcomes in general**

The Levy et al. 2010 review identified five areas of application of simulation modelling:

- Estimating the health and economic consequences of obesity
- Assessing trends in BMI as a function of past trends
- Predicting change in body weight from specific changes in diet and/or physical activity (i.e. 'below the skin', physiological models)
- Estimating and explaining how changes in the environments in which people live, work or go to school can enable or constrain healthy behaviours and change obesity prevalence.
- Policy and programme evaluation

While all five of these are potentially relevant, previous modelling in the first and the last two of these areas is likely to be most informative for modelling the cost-effectiveness of alternative policies for promoting a whole system approach to obesity prevention.

As in other areas which use simulation models, models of obesity or obesity prevention may be: static or dynamic; involve macro- (population groups) or micro-simulation (modelling individuals); follow cohorts or cover a whole population limited period of time; use discrete or continuous time; be deterministic (only using central or 'best' estimates of each inputs) or stochastic (i.e. probabilistic, with model inputs sampled from distributions); and may allow or exclude the possibility of interaction between individuals or other simulated 'agents' (e.g. where a disease is thought to spread by some contagion effect).

Two types of simulation modelling are increasingly advocated for their particular applicability to the evaluation of complex adaptive systems, and therefore to public health problems such as obesity:

-
- System Dynamics modelling
 - Agent-Based Modelling

Compared with other mathematical simulation models system dynamics models are based on the dynamic accumulation of different factors or resources or information, combined with specified balancing or reinforcing feedback mechanisms. Such models will tend to have ‘broader boundaries’, admitting more variables on the basis of logic or expert opinion (and therefore perhaps rely more on mediating variables that are more conceptual than empirical). This, Homer and Hirsch (2006) argue, means that systems dynamic models can include “a variety of realistic causal factors, policy levers, and feedback loops” (p.453) and are therefore better at finding effective solutions to “persistent, dynamically complex [public health] problems”.

Agent-based modelling is a dynamic form of micro-simulation in which every individual person (or ‘agent’) is explicitly simulated, and has their own characteristics, initial state and position, and also defined rules of interaction with other agents in the system. Given a set of these starting conditions and interaction rules for a whole simulated population, the whole population’s ‘macro-level’ outcomes are evolve over time. According to Hammond (2010, pp.11-12) the particular advantages of ABM for modelling complex systems like obesity are that the approach: “allows for substantial diversity amongst agents”; “allows for more flexible cognitive assumptions about individual decision-making”; “can incorporate feedback dynamics and explicit spatial contexts” (and at both the individual level, and other aggregate levels); and, through the focus on mechanisms, “the ability to study non-equilibrium dynamics” so that emergent and adaptive social phenomena can be explicitly included. For these reasons, Hammond argues that ABM is also well-suited to evaluating the complex impacts of programmes and policies.

4.3.2. Modelling the outcomes of obesity prevention programmes

Although there is already a wide range of models which have evaluated particular obesity prevention programmes and policies, two particular models have come to prominence globally as being well-validated and highly evidence-based. These are: the (UK) National Heart Forum’s micro-simulation model of

obesity, first developed for modelling to support the Foresight Obesity project, and the ACE Obesity prevention model developed by Rob Carter and his team in Melbourne Australia (Haby et al. 1463-75; Vos et al.).

Although the **ACE-obesity model** has been used to evaluate thirteen different obesity prevention policies in Australia (Haby et al. 1463-75), including some school-based programmes, none have been conducted so far which are of truly community-wide multi-faceted programmes.

The **National Heart Forum's micro-simulation model**, in contrast, has already been used on a number of occasions to predict the evolution of overweight and obesity in whole communities (PCT areas), and under different intervention scenarios (Tim Marsh, personal communication, 15th October 2010). It has also been used to simulate obesity outcomes in the USA and is based on comprehensive health survey and other national datasets.

Simulation modelling of obesity or obesity policies is still at a relatively early stage of development. However, in some cases the complexity of modelling outcomes in the area of obesity and obesity prevention policies or programmes has already become so complex and advanced that the usefulness (or even feasibility) of attempting to develop credible new models without significant modelling capacity, access to national data, and significant modeller time and other resources is questionable. Instead, with limited resources, any realistic modelling of alternative local community-wide obesity prevention policies should aim to make best use of one of the well-established and tested existing models (such as the National Heart Forum's micro-simulation model, or the ACE Obesity model framework).

5. Discussion

5.1. Limitations of the review methods

The main limitation of this review is the very poor rate of hits of the bibliographic searches. However, this may in part relate to the actual paucity of relevant economic evaluations. We think that we can be confident that there are no or very few missed relevant studies because of (a) the amount of searches conducted for the previous 3 reviews, and the ‘economic papers’ tagged from them at the title/abstract screening stage (b) the efforts we have gone to in corresponding with authors of effectiveness evaluations and other experts in the field.

The review of the four cost-effectiveness studies ultimately did not include any formal (e.g. checklist-based) assessment of study quality. This was because (a) two of the four studies were so minimally reported that any overall quality assessment would only reflect the poor reporting rather than the potential quality of the analyses, and (b) because the two remaining economic evaluations that were fairly fully reported were of very different programmes, of limited generalisability to either the UK policy setting, and limited applicability to our main focus of interest (i.e. whole systems approaches to obesity prevention

5.2. Limitations of the identified studies

One of the key limitations of the few identified economic evaluations was the degree of underreporting of study details. While this is understandable and acceptable when the cost-effectiveness study is reported a conference poster, it is more disappointing when the report section entitled ‘economic evaluation’ in a larger evaluation report (a) does not report comprehensive detail of the methods used and (b) belies that a full (incremental) economic analysis was not actually conducted.

Given a larger number of relevant economic evaluations, it would also have been useful if the papers provided more information on *how* and *why* the particular combinations of resources were believed to generate the patterns and levels of

outcomes measured. This could then shed light on whether the adoption of a whole system approach could account for some of any measured cost-effectiveness.

5.3. Further research

Given the paucity of fully published economic evaluations relevant to our main review question, there is clearly an important gap in the research evidence base for community-wide multi-faceted obesity prevention or smoking prevention programmes.

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