Systematic Review of Economic Evaluation Model for Childhood Obesity

Lim Chin Choon[1*], Asrul Akmal Shafie[2]

[1]Faculty of Medicine, Widad University College, Kuantan, Pahang, Malaysia

[2]School of Pharmaceutical Sciences, Universiti Sains Malaysia, Pulau Pinang, Malaysia

***Corresponding author*: lcchoon@widad.edu.my**

Abstract

Objectives: To review and compare economic evaluation models used for cost-effectiveness study of childhood obesity. Methods: This review explores current methods utilized to evaluate non-medical intervention for childhood obesity. The search was limited to studies published in English language, covering literature until January 2013. First stage screening was done at title-keyword-abstract level. In second stage screening, full text was obtained and screened for true full economic evaluation. Results: The literature search identified ten studies and three variations of models. The present models are decision tree models, Markov Cohort model and Markov Microsimulation models. Conclusions: It is imperative to synergize risk factors, cardiovascular diseases states and intervention effects on childhood obesity and combine these findings into a simplified health outcomes dynamic macro–Markov Cohort model for childhood obesity that can be utilized for proper economic evaluation of childhood obesity.

Keywords: Economic Evaluation Childhood Obesity Model

1.0 Introduction

Childhood obesity is believed to leads to obesity in adulthood and non-communicable diseases (NCDs) (Dehghan et al., 2005). NCDs will be a burden to individuals and public health care systems (Trasande and Chatterjee, 2012). In children, a BMI greater than the 85th percentile for age (6-19 years old) and sex is diagnosed as overweight while a BMI more than the 95th percentile is diagnosed as obese (Kuczmarski et al., 2002). Non-medical intervention for childhood obesity is seen as a key strategy to reduce the burden. Non-medical intervention for childhood obesity involved health promotion activities. Health promotion is defined by the World Health Organization (WHO) in the “Ottawa Charter” as a “process that enabled people to increase control over the determinants of health and thereby improved their health.”

Health promotion can be achieved by building healthy public policy, creating supportive environments for health, strengthening community action, encouraging development of personal skills and re-orienting health services. Healthy public policy for childhood obesity would encourage participations in activities that increased healthy lifestyle like parks for people to exercise, reducing sugar consumptions and reduction in smoking area. A good environment will encourage more physical activities and improved health. Communities’ programs will encourage participations in physical activities, improve cordial relationships and reduce psychological problems. Furthermore, better personal skill will increase knowledge on obesity, quality of life, family relationships and encourage more healthy lifestyles. A better health services would encourage early prevention, treatment and increase health educations on childhood obesity. Disease prevention measures prevent the occurrence of diseases by risk factor reduction, arresting the progression of risk factors or reducing the consequences of risk factors once developed (Nutbeam, 1998). Risk factors reduction for childhood obesity includes primary prevention for childhood obesity.

Primary preventions for childhood obesity include reduce consumptions of high calorie diet, exercise, consumptions of food and vegetables, increase fibre intake and reduce sedentary activities like watching televisions and driving within a short distance.

The effectiveness of non-medical intervention to manage childhood obesity among children varied with only one third of the intervention shown to be effective in reducing BMI or obesity prevalence (Safron et al., 2011) and others shows limited evidence (Khambalia et al., 2012). However, these programs differed tremendously in term of their content, delivery method and conduct, and often evaluated only after a short period of time with intermediate process/health outcome. As the program is expected to manage the consequences of obesity, the economic evaluation should be long enough to capture both morbidity and mortality outcomes. Nevertheless, long term economic evaluation study for childhood obesity is difficult to be conducted, costly and time consuming. Therefore, it is imperative to model them for their effectiveness and costs to optimize resources for childhood obesity intervention programs.

Currently, modelling methods have been utilized to improve our current knowledge on health conditions and inform right decision making. There are several modelling work on adult obesity (Hollingworth et al., 2012, Levy et al., 2011) but very few study was conducted for childhood obesity. Decision Model for childhood obesity is essentially a simplified representation of the intervention effects of childhood obesity in adulthood (Popkin et al., 2006). Impact of childhood obesity on NCDs is extensive. Therefore, it is necessary to study widely various economic evaluation models currently used to conduct economic evaluation for childhood obesity to prevent NCDs. Economic evaluation, decision or simulation model is a logical mathematical framework, which integrate facts and values with outcomes of interest to help decision makers with choices as in Table 1. In healthcare, the choices involve clinical practices and health-care resource allocations (Weinstein et al., 2003). Economic evaluations involve the process of comparisons of costs (inputs) and effectiveness (outcomes) of two or more alternative (Drummond and Jefferson, 1996).

This review explores the current economic evaluation models utilized to conduct economic evaluation for childhood obesity; specifically on the structure of the models. (Brennan et al., 2006). Firstly, economic evaluation or Simulation models can be classified as static or dynamic. Static SMs consider results at two points in time or two different conditions at a single point in time. While, Dynamic SMs are based on path of changes of outcome variable over time (Levy et al., 2011). Secondly, SMs are further divided into macro or micro models. Macro models distinguish and tracks proportions of individuals in each category, such as socio-demographic status (e.g. by age, gender or income), and weight class for obesity (e.g. normal, overweight or obese). Whilst, micro models track individual characteristics (e.g. body mass index [BMI] by age and gender from a multivariate distribution) (Levy et al., 2011). Thirdly, discrete, or continuous transitions are used for time and events for specific categories (such as age or weight). Discrete time models follow state transitions at fixed time intervals (e.g., yearly), whereas continuous time models allow transitions at random. Discrete transitions are usually specified as Markov model (Sonnenberg and Beck, 1993), whereby future events in period t+1 depend only on the current state, period t (Sonnenberg and Beck, 1993). Decision tree is the most common structure for decision models in economic evaluation which represent prognoses based on intervention by a series of pathways or alternative branches (Drummond et al., 2005).

Markov cohort model are based on a series of "states" that a patient can occupy at a given point in time (Drummond et al., 2005). Microsimulation or "individual sampling" tract the process of individual patients through particular states and allows them to accumulate costs and benefit over time (Drummond et al., 2005). Relevance and credibility of a economic evaluation model must be evaluated before making a decision whether the model is suitable to be applied in the required settings (Caro et al., 2014). Relevance will addresses the applicability of results from the economic evaluation model to the setting of interest of the decision maker (Caro et al., 2014). The credibility of an economic evaluation model refers to the trustworthiness of a model and can be assessed by the validation, design, data, analyses, reporting, interpretation, and conflicts of interest of the model (Caro et al., 2014).

2.0 Objectives

To review and compare cost effectiveness models used for non-medical intervention for childhood obesity.

3.0 Methods

3.1 Literature search

The search was limited to studies published in English language, covering literature until January 2013 using the following keywords: ('childhood obesity' or 'adolescent obesity') and ('cost model' or 'cost-effectiveness model" or 'economic model' or 'Markov chain model' or 'Monte Carlo model' or 'statistical model' or 'decision model' or 'natural history adjusted model' or 'disease adjusted model' or 'economic evaluation model'). The key words chosen for this systematic review was based on the objective of the study with words synonym to the keywords in the objective included. The search was performed using PubMed databases. The literature search was undertaken in January 2013 and included all published literature available between 1 January 1982 and 31 December 2012. Furthermore, hand search from reference lists of articles were carried out until a saturation point was reached whereby the duplicates of the same studies gradually became more frequent from one reference list to the last.

All identified abstracts were reviewed by the author for their relevancy. First stage screening was done at title-keyword-abstract level. Studies on both cost and outcome were included if they evaluate the effect of health promotion program for childhood obesity to adulthood. Studies were excluded if they duplicate, no full article published, just abstract available, include childhood obesity intervention or management of childhood obesity only, include other diseases in addition to childhood obesity, irrelevant to the topic (not at least cost or childhood obesity health promotion programs related), did not show both the costs and the outcomes of childhood obesity research or if they were a review, editorial or methodological article. In second stage screening, full text of included studies were obtained and subsequently screened for study selection by reviewing the methods and results section of the studies for true full economic evaluation (cost effectiveness (CE), cost benefit (CB), or cost utility (CU) analysis) (Drummond et al., 2005).

Studies with two or more types of economic evaluation were also included even if only one of them is true. Data abstracted from all remaining articles were reviewed using their full-text formats and classified according to (i) modelling method, (ii) focus population covered, (iii) study design, (iv) main data source, (v) health and economic outcomes, (vi) study descriptions, (vii) results, (viii) relevance and (ix) credibility as in Table 2. Item (i) to (vii) were taken from Levy (Levy et al., 2011), whilst, item (viii) and (ix) were taken from Caro (Caro et al., 2014). Modelling methods, study design and study description referred to modelling techniques used to model the long term effects of childhood obesity, formulation of intervention for childhood obesity and details descriptions of study conducted respectively (Levy et al., 2011).

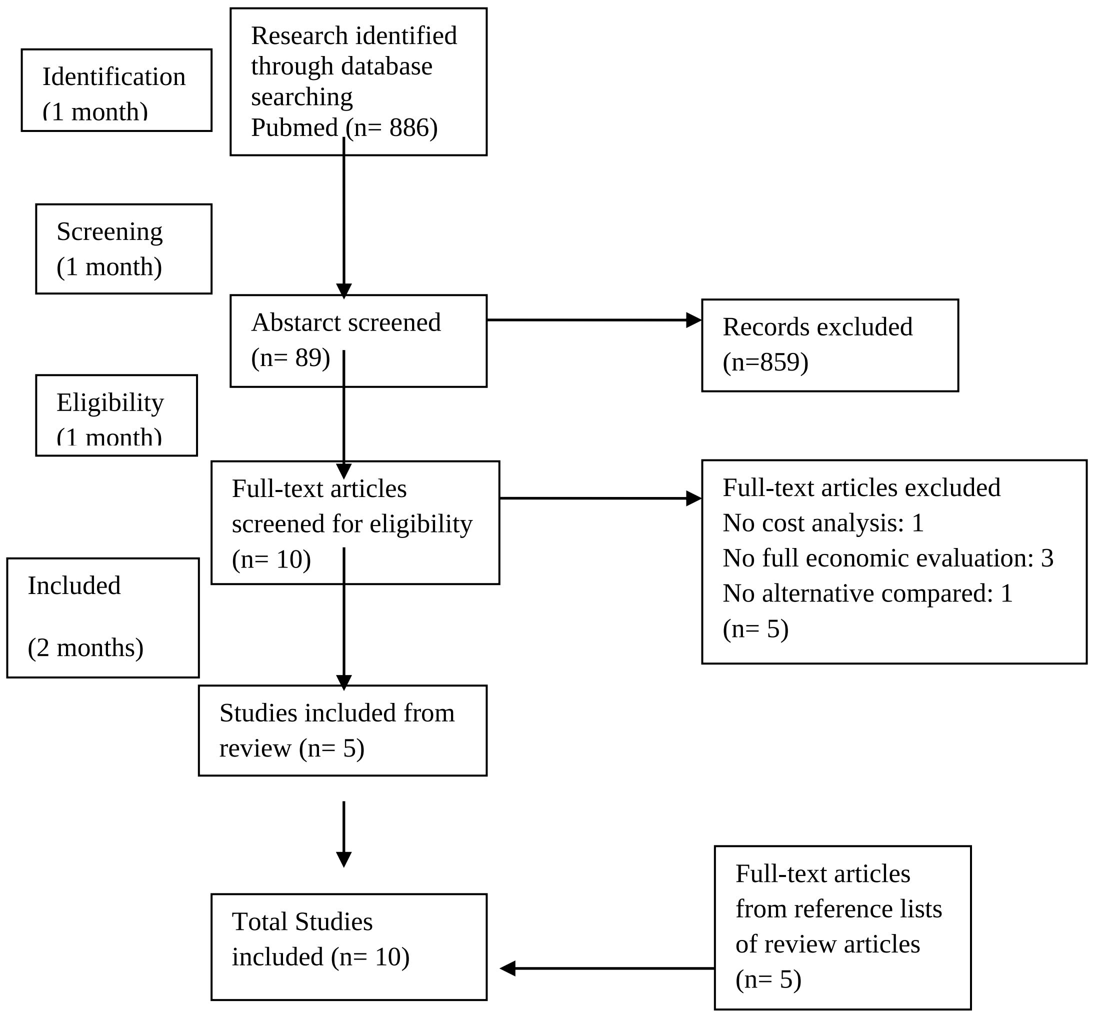

Figure 1. Flow diagram of studies identified by literature review

Table 1 Summary of the characteristics of the identified literature/studies modelling cardiovascular disease due to childhood obesity

No. / Ref	Author/s	Year	Country	Time Horizon	Study design	Intervention	Health State	Model used	Evaluation framework
1	Wang 2003	2003	USA	Lifetime	CUA. CBA	Planet Health Promotion Program for secondary school children	• 3 health states for 14-, 21-29- and 40-65-years old females respectively.	De novo	Decision tree model, cohort
2	Haby 2006	2006	Australia	Lifetime	CUA	ACE obesity Health Promotion Program for children and adolescents	• 12 health states based on gender (male/female), age (5-9, 10-14, 15-19 years old) and grouping (base case or intervention)	De novo	Markov model, cohort
3	Brown 2007	2007	USA	Lifetime	CUA, CBA	CATCH Health Promotion Program for secondary school children	• 3 health states for 11-, 25-29- and 40-64-years old subjects respectively.	Wang 2003 model	Decision tree model, cohort
4	Moodie 2008	2008	Australia	Lifetime	CUA	LEAP Health Promotion Program for ACE obesity research	• Intervention group (5-9 years old) and base case (no intervention)	Haby 2006 model	Markov model, cohort
5	Magnus 2009	2009	Australia	Lifetime	CUA	Removing television advertising in ACE obesity research program	• Intervention group (5-14 years old) and base case (no intervention)	Haby 2006 model	Markov model, cohort
6	Moodie 2009	2009	Australia	Lifetime	CUA	Walking school bus programs in primary school children in ACE obesity research	• Intervention group (5-7 years old) and current practice (no intervention)	Haby 2006 model	Markov model, cohort

7	Wang 2010	2010	USA	Lifetime	CUA	Economic impacts of preventing or reducing of 1% of overweight and obesity in adolescents.	• Body weight status (non-overweight, overweight and obese) at age 16-17 and body weight status at age 40	De novo	Mathematical model, cohort
8	Moodie 2011	2011	Australia	Lifetime	CUA	Travel SMART Health Promotion Program in ACE obesity research program	• Intervention group (10-11 years old) and current practice (no intervention)	Haby 2006 model	Markov model, cohort
9	Ma 2011	2011	USA	Lifetime	CUA	Economic impact (breakeven cost) for childhood obesity with a 1% reduction in obesity rate in adult	• 3 health states for 0-6, 7-12- and 13-18-years old subjects respectively.	Wang 2010 model	Mathematical model, cohort
10	Moodie 2012	2012	Australia	Lifetime	CUA	AASC Health Promotion Program in ACE obesity research program	• Pre-intervention and Post-intervention BMI for school children	Haby 2006 model	Markov model, cohort
11	Trasande 2010	2010	USA	Lifetime	CUA	Economic impacts of preventing or reducing 1% prevalence of obesity (16.3% to 15.3%) in 12 years old	• Health state for 12 years old subjects from various studies	Wang 2010	Mathematical model, cohort
12	Carter 2009	2009	Australia	Lifetime	CUA	Accesing cost effectiveness to reduce unhealthy weight gain in children and adolescents in Australia for ACE obesity project.	• children and adolescents (aged 5-19 years) in 2001 from 13 ACE obesity project	Haby 2006 model	Markov model, cohort
13	Hollingworth 2012	2012	UK	Lifetime	CUA	Estimate lifetime cost effectiveness of lifestyle interventions to treat overweight	• Children were subdivided based on sex, age and BMI	De novo	Microsimulation model, Monte Carlo

						and obese children compared with no or minimal intervention			

*CUA=Cost Utility Analysis, CBA=Cost Benefit Analys

Table 2 Summary of the characteristics of the identified literature/studies for simulation model for childhood obesity

Decision Tree Models									
References	Modeling method	Focus population covered	Study Design	Main data source (calibration/ validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Wang 2003 (1)	Dynamic discrete decision tree model	USA: Secondary school students from Planet Health Program	Cost Utility Analysis	Planet Health, school based intervention designed to reduce obesity in secondary school students in Boston by promoting curriculum that improve academic, physical education and health education.	Reduction in percentage of overweight adults. Increased in QALYs, medical costs saved and gained in productivity. Cost effectiveness and Net Monetary Benefit to society was included.	Considers the effect of health promotion programs to BMI status and health outcomes using a dynamic decision tree model	ICER of USD 4305 per QALYs saved and NMB of USD 7317 to society.	Settings is based on US Intervention was based on Planet Health study. Health outcomes based on QALYs and economic endpoint based on ICER and NMB. Time horizon is lifetime. Third party payer perspectives used.	Validation was not conducted. Effect of Planet Health study was used to model this study, with intervention and non-intervention school used for comparison. Prevalence, cost and effect were based on reliable data source. ICER and NMB calculated. One-way sensitivity analysis was conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Brown 2007 (2)	Dynamic discrete decision tree model	USA: Secondary school students from CATCH Health Promotion Program in Texas.	Cost Utility Analysis	CATCH , school based intervention designed to reduce obesity in primary school students (11 years old) in Texas by emulating Planet Health interventions.	Reduction in percentage of overweight adults. QALYs gained, reduced medical costs and gained in productivity. Cost effectiveness and Net Monetary Benefit to society was included	Considers the effect of health promotion programs to BMI status and health outcomes using a dynamic decision tree model	ICER of US 900 per QALYs saved and NMB of US 68125 to society.	Settings is based on US. Intervention was based on CATCH study. Health outcomes based on QALYs and economic endpoint based on ICER and NMB. Time horizon is lifetime. Third party payer perspectives used.	Validation was not conducted. Effect of CATCH study was used to model this study, with intervention and non-intervention school used for comparison. Prevalence, cost and effect were based on reliable data source. ICER and NMB calculated. One-way sensitivity analysis was conducted. No conflict of Interest in this study.

Markov Microsimulation Model									
References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Hollingworth 2012 (3)	Dynamic discrete Markov Micro-simulation model	UK: General model, 4-5 years old and 10-11 years old cohort from National Child Measurement Programme	Cost Utility Analysis	Hypothetical obese or overweight cohort of children from National Child Measurements Programme	Increased life expectancy and saving in future treatment cost	Adaptation of National Heart Forum Economic Model to predict lifetime health services costs and outcomes of lifestyles intervention	For obese children aged 10-11 years, median intervention at a moderate cost of £400 resulted in increased life expectancy by 0.19 years and net saving of £110 per child with discounted cost per life year of £13859	Setting is based on UK. Intervention was based on changes in BMI SDS score with 10 RCTs conducted. Health outcomes based on increased life expectancy and economic endpoint based on net saving per child. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted for RCT based on peer review. 10 RCT for childhood obesity was used to model this study. Prevalence, cost and effect were based on reliable data source. Discounted cost per life year calculated. Sensitivity analysis was not conducted. Conflict of Interest was based on grant received.

Markov Cohort Model									
References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Haby 2006 (4)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	11 ACE-obesity projects in Australia that target reduction in obese childhood cohorts.	DALYs (aggregated over diseases)	Type of modeling depends on health policy. Starts with single cohort, discrete time, macro models, moves to multiple cohort /dynamic population or micro model dependent on health policy and research question. C-E analysis includes the link from Physical activities to reduction in BMI status and future disease prevalence.	Model has been used to evaluate 13 interventions targeting youth in ACE obesity project to determine most cost-effective policy of interventions. Ultimately help decision-makers to move resources towards more efficient proven C-E packages of interventions or efficient preventive action.	Setting is based on Australia. Intervention was based on policy for ACE Obesity project. Health outcomes based on DALYs and economic endpoint based on effectiveness in DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of ACE obesity project intervention was used to model this study. Prevalence and effects of BMI were based on reliable data source. DALYs was included. Sensitivity analysis was not conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Moodie 2008 (5)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	Live Eat and Play health (LEAP) promotion programs in Australia that compared GP mediated intervention for childhood obesity to control group	DALYs (aggregated over diseases), $/DALY saved	Same as Haby 2006	LEAP Health Promotion Program for ACE obesity research with 2300 units of BMIs saved, 511 DALYs saved and net cost per DALYs of AUD $4670	Setting is based on Australia. Intervention was based on policy for LEAP promotion programs . Health outcomes based on DALYs and economic endpoint based on ICER with $/DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of LEAP health promotion programs was used to model this study. Prevalence, effects of BMI, and cost were based on reliable data source. ICER based on AUS$/DALYs calculated. Sensitivity analysis was conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Magnus 2009 (6)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	Study the effect of removing television advertising of high calorie diet to school students in Australia as part of ACE obesity research	DALYs (aggregated over diseases), $/DALY saved	Same as Haby 2006	Removing television advertising in ACE obesity research program with DALYs saved of 37000 and net cost per DALYs of AUD $3.7	Setting is based on Australia. Intervention was based on policy for ACE Obesity projects. Health outcomes based on DALYs and economic endpoint based on ICER with $/DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of ACE obesity project intervention was used to model this study. Prevalence, effects of BMI, cost and effectiveness were based on reliable data source. ICER based on AUS$/DALYs calculated. Sensitivity analysis was conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Moodie 2009 (7)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	Programs that initiate walking within a distance from school bus compared to other transportation to schools in Australia	DALYs (aggregated over diseases), $/DALY saved	Same as Haby 2006	Walking school bus programs for primary school children in ACE obesity research with 30 DALYs saved and net cost per DALYs of AUD$ 0.76m	Setting is based on Australia. Intervention was based on policy for ACE Obesity project . Health outcomes based on DALYs and economic endpoint based on ICER with $/DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of ACE obesity project intervention was used to model this study. Prevalence, effects of BMI, cost and effectiveness were based on reliable data source. ICER based on AUS$/DALYs calculated. Sensitivity analysis was conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Carter 2009 (8)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	11 ACE-obesity projects in Australia that target reduction in cohort of obese children with cost effectiveness study conducted.	DALYs (aggregated over diseases), $/DALY saved	Same as Haby 2006	Model has been used to evaluate 13 interventions targeting obese children in ACE obesity project to determine most cost-effective policy of interventions. Ultimately –help decision-makers to move resources towards more efficient proven C-E packages of interventions or efficient preventive action.	Setting is based on Australia. Intervention was based on policy for ACE Obesity project. Health outcomes based on DALYs and economic endpoint based on ICER with $/DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of ACE obesity project intervention was used to model this study. Prevalence, effects of BMI, cost and effectiveness were based on reliable data source. ICER based on AUS$/DALYs calculated. Sensitivity analysis was conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Moodie 2011 (9)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	Travel SMART health promotion programs is an extension of walking school bus programs in Australia that encourage participations in more physical activities rather than sedentary activities when travelling to and from schools.	DALYs (aggregated over diseases), $/DALY saved	Same as Haby 2006	Travel SMART Health Promotion Program in ACE obesity research program with 890 units of BMIs saved, 95 DALYs saved and net cost per DALYs of AUD $117000	Setting is based on Australia. Intervention was based on policy for ACE Obesity project. Health outcomes based on DALYs and economic endpoint based on ICER with $/DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of ACE obesity project intervention was used to model this study. Prevalence, effects of BMI, cost and effectiveness were based on reliable data source. ICER based on AUS$/DALYs calculated. Sensitivity analysis was conducted. No conflict of Interest in this study.

References	Modeling method	Focus population covered	Study Design	Main data source (calibration/validation)	Health and economic outcomes	Study descriptions	Results	Relevance	Credibility
Moodie 2012 (10)	Dynamic Macro Markov cohort model	Australia: various ages	Cost Utility Analysis	Australia After School Communities studies the effects of activities conducted in communities after school hours for obese children compared to control in Australia	DALYs (aggregated over diseases), $/DALY saved	Same as Haby 2006	Australia After School Communities (AASC) Health Promotion Program in ACE obesity research program resulting in 450 DALYs saved and net cost per DALYs of AUD $82000	Setting is based on Australia. Intervention was based on policy for ACE Obesity project. Health outcomes based on DALYs saved and economic endpoint based on ICER with $/DALYs. Time horizon is lifetime. Third party payer perspectives used.	Validation was conducted based on best available evidence. Effect of ACE obesity project intervention was used to model this study. Prevalence, effects of BMI, cost and effectiveness were based on reliable data source. ICER based on AUS$/DALYs calculated. Sensitivity analysis was conducted. No conflict of Interest in this study.

4.0 Results

The literature search identified ten studies used to model health promotion program for childhood obesity (Figure 1). All models were based on projection of childhood obesity to adult obesity. Modelling techniques applies shows that , two were based on decision tree models (Wang et al., 2003, Brown et al., 2007), one based on markov microsimulation model (Hollingworth et al., 2012) and seven based on Markov cohort models (Haby et al., 2006, Moodie et al., 2008, Magnus et al., 2009, Carter et al., 2009, Moodie et al., 2010, Moodie et al., 2009, Moodie M. et al., 2011) as in Table 2.

4.1Decision Tree model

Decision Tree model by Wang et al.(Wang et al., 2003) and Brown et al. (Brown et al., 2007) used mathematical model that link effects of health promotion programs such as diet or physical activity to body weight at individual or population level. Wang et al. (Wang et al., 2003) developed a dynamic decision tree model which study the effects of Planet Health intervention for childhood obesity on reduction in childhood BMI status, reduction in number of obese adults, increased QALYs and reduce lifetime medical cost. Both incremental cost effectiveness ratio (ICER) and net monetary benefit (NMB) were included in the study. Study by Brown et al (Brown et al., 2007) was similar to Wang et al, but obese children in CATCH health promotion program was used to populate their model (Brown et al., 2007). Both Planet Health and CATCH studies were based on intervention in US. Time Horizon of both studies was based on lifetime and funding was based on third party payer perspective. Prevalence, cost and effect were based on reliable data sources. No conflict of interest was present in both studies. Furthermore, one-way sensitivity analysis was conducted for both studies. However, no validation was conducted.

4.2 Markov microsimulation model

Hollingworth et al. (Hollingworth et al., 2012), developed a dynamic Markov Microsimulation model which used obese and non-obese children in 10 RCTs in UK (based on National Heart Forum Economic model) to estimate the increased life expectancy and net saving per child based on discounted cost per life year with intervention. Study by Hollingworth et al., is based on demographic in UK. This study was based on lifetime horizon and a third-party payer perspective was conducted. Prevalence, cost, and effect were based on reliable data sources. No conflict of interest was present in this study. Validation for this study was based on peer review. However, no sensitivity analysis was conducted.

4.3 Markov cohort model

"The Assessing Cost-Effectiveness in Obesity (ACE) project" is an example of Markov cohort model based on policy interventions in Australia (Haby et al., 2006). Policy-intervention consider policies that influence the environment (e.g. price and advertising) or education (with direct influence on individuals, diet and exercise) (Levy et al., 2011). Studies in ACE Obesity project modelled the average effect of a policy or intervention on total energy expenditure (TEE) or total energy intake (TEI), which then affects average BMI and health/cost outcomes (primarily disability adjusted life years (DALYs)) (Haby et al., 2006). Studies conducted by Haby et al. (Haby et al., 2006)., Moodie et al. (Moodie et al., 2008, Moodie et al., 2009, Moodie et al., 2010, Moodie M. et al., 2011), Magnus et al.(Magnus et al., 2009), and Carter et al.(Carter et al., 2009), were based on Policy developed by ACE Obesity project.

These studies were groups as dynamic macro-Markov cohort model. These studies were based on the effects of policy interventions on behavioural change, caloric intake/expenditure, BMI and finally health/cost outcomes (DALYs) over the lifetime of the cohort (Haby et al., 2006). Haby's (Haby et al., 2006)and Carter's (Carter et al., 2009) study was based on intervention Policy for 13 ACE Obesity projects, Moodie's study in 2008 (Moodie et al., 2008) was based on policy for Live, Eat and Play (LEAP) health promotion programs, Magnus's study in 2008 was based on policy to remove television advertising, Moodie's study in 2009 (Moodie et al., 2009) was based on policy of walking school bus programs, Moodie's study in 2011 (Moodie M. et al., 2011) was based on policy for Travel Smart Health Promotion Programs, while, Moodie's study in 2012 (Moodie et al., 2010) was based on policy for Australia After School Communities (AASC) Health Promotion Program as in Table 2. All these studies were based on setting in Australia. Time Horizon of these studies is lifetime and third-party payer perspectives were conducted for these studies.

Prevalence, cost, and effect were based on reliable data sourceand validation was based on best available data. One-way Sensitivity analysis was conducted by Magnus et al., 2009 (Magnus et al., 2009), Whilst, Probabilistic Sensitivity Analysis (PSA) was conducted by Moodie et al., (Moodie et al., 2008, Moodie et al., 2009, Moodie et al., 2010, Moodie M. et al., 2011). No conflict of interest is noted in these studies.

5.0 Discussion

Childhood obesity is associated with high morbidity and mortality due to cardiovascular diseases (Galani et al., 2007). The morbidity and mortality due to obesity is usually estimated in terms of years of life lost (YLL), QALYs or DALYs (Galani et al., 2007) (Haby et al., 2006). Higher morbidity and mortality associated with obesity become compounded at later ages, but health effects starts at childhood (Freedman et al., 2007), making it necessary to conduct interventions for obesity during childhood. Currently, there are only three variations of models used for economic evaluation of health promotion programs for childhood obesity (Hollingworth et al., 2012, Wang et al., 2003, Haby et al., 2006). The current models available for childhood obesity were based on decision tree model, Markov Cohort model and Markov Microsimulation model. Generally, current available models employ a Markov assumption, whereby health outcomes depend only on current BMI status. However, health outcomes over individual lifespan of obese individuals may depend on how BMI evolved over time and the relative health risks associated with different levels of BMI at each age (Levy et al., 2011). Furthermore, data on diseases that is linked to obesity are often prevalence-based (Levy et al., 2011) and data on incidence and duration of disease are not easily available (Levy et al., 2011).

In addition, the disease due to obesity varied and may depend on the level of BMI in a non-linear relationship (Levy et al., 2011), and vary by age, gender or socio-economic status making it difficult to be presented in a complex model. Therefore, the effects of obesity on health outcomes can be considered in a simplify Markov cohort model that encompassed only health states from cardiovascular diseases link to obesity (Galani et al., 2007) as it is the main NCDs due to obesity (Caro et al., 2007). Hence, a simplify Markov cohort model for childhood obesity could adopt health states (based on risk factors and diseases link to obesity) as utilized by Caro and Galani for cardiovascular diseases (Caro et al., 2007, Galani et al., 2007). Caro utilized Markov model with 5 health states (At Risk, Diabetes Mellitus, Cardiovascular disease, Secondary Cardiovascular disease events and Death) (Caro et al., 2007). While, Galani presented Markov model for adult obesity with 7 health state (obese adult, hypertension, diabetes mellitus, hypercholesterolemia, coronary heart disease, stroke and death (Galani et al., 2007).

Therefore, childhood obesity together with health states for diabetes mellitus, hypertension, hypercholesterolemia and cardiovascular diseases (encompass myocardial infarction and stroke) is suggested to be included in the suggested Markov model (Freedman et al., 1999). Suggested model should also include the effects of health promotion programs (that incorporate diet and physical activity) on health outcomes. The magnitude of effects of health promotion program may vary dependent on which health promotion activity and which age groups (Safron et al., 2011, Khambalia et al., 2012). Therefore, effects of health promotion programs on BMI of obese children were incorporated into the suggested model. Furthermore, health outcomes based on increased life expectancy and quality adjusted life years (QALYs) and economic endpoint based on Incremental Cost Effectiveness Ratio (ICER) was suggested in future model. QALYs was selected as it was able to capture reduce morbidity and mortality with intervention in a single measures (Drummond et al., 2005). In addition, lifetime horizon is suggested for future studies and third-party payer perspectives was envisaged.

Current studies reviewed can be improved with discounting of costs and outcomes, validation, and adequate sensitivity and uncertainty analysis.Validation is essential so that the parameters, structure and process of a developed model are accurate and valid when compare to other studies or real life practice (Weinstein et al., 2003). However, only peer review (Hollingworth et al., 2012) and evidence based validation from epidemiological data (Haby et al., 2006) was conducted in the studies under review. Validation that included both internal and external validation would be suggested for future studies (Caro et al., 2014). Internal validation can be conducted by comparing the results of the model developed with data sources from studies used to developed the model while external validation can be conducted by comparing the results of the model developed with external data sources (Weinstein et al., 2003). Furthermore, conducting a probabilistic sensitivity analysis (PSA) as in Moodie's studies (Moodie et al., 2008, Moodie et al., 2009, Moodie et al., 2010, Moodie M. et al., 2011) is suggested in the future to ensure that the parameter uncertainty is well addressed. In addition, future model should incorporate models that use data sources from local settings to increase the generalizability of the model to local settings (Caro et al., 2014).

6.0 Limitation of systematic review conducted

Limitation of this study included the followings: retrieval process done only by the main researcher, exclusion of non-English language papers, unavailability of some full-text articles, as well as affected by selection and analytical bias. Selection bias was overcome by extensive search and comprehensive studies. Analytical bias was overcome by detailed and strict adherence to definitions of economic evaluation terms.

7.0 Conclusions

This review summarized economic evaluation models available for childhood obesity. There are three general modelling approaches applied in the literatures. However, future models should encompass risk factors, diseases states and intervention to overcome the problem of a complex model for childhood obesity. It is imperative to synergize risk factors, diseases states and intervention effects with cardiovascular diseases due to obesity and combine these findings into a simplified dynamic health outcomes Markov macro model for childhood obesity that can then be utilized for proper economic evaluation of childhood obesity.

References

Brennan, A., Chick, S. E. & Davies, R. (2006). A taxonomy of model structures for economic evaluation of health technologies. *Health economics,* 15**,** 1295-1310.

Brown, H. S., Pérez, A., Li, Y. P., Hoelscher, D. M., Kelder, S. H. & Rivera, R. (2007). The cost-effectiveness of a school-based overweight program. *International Journal of Behavioral Nutrition and Physical Activity,* 4**,** 47-53.

Caro, J. J., Eddy, D. M., Kan, H., Kaltz, C., Patel, B., Eldessouki, R. & Briggs, A. H. (2014). Questionnaire to Assess Relevance and Credibility of Modeling Studies for Informing Health Care Decision Making: An ISPOR-AMCP-NPC Good Practice Task Force Report. *Value in Health,* 17**,** 174-182.

Caro, J. J., Stillman, I., Danel, A., Getsios, D. & Mcewan, P. (2007). Cost effectiveness of rimonabant use in patients at increased cardiometabolic risk: estimates from a Markov model. *Journal of Medical Economics,* 10**,** 239-254.

Carter, R., Moodie, M., Markwick, A., Magnus, A., Vos, T., Swinburn, B. & Haby, M. M. (2009). Assessing cost-effectiveness in obesity (ACE-obesity): an overview of the ACE approach, economic methods and cost results. *BMC Public Health,* 9**,** 419-425.

Dehghan, M., Akhtar-Danesh, N. & Merchant, A. T. (2005). Childhood obesity, prevalence and prevention. *Nutrition Journal,* 4**,** 24-33.

Drummond, M. F. & Jefferson, T. (1996). Guidelines for authors and peer reviewers of economic submissions to the BMJ. The BMJ Economic Evaluation Working Party. *BMJ: British Medical Journal,* 313**,** 275-290.

Drummond, M. F., Sculpher, M. J. & Torrance, G. W. (2005). *Methods for the economic evaluation of health care programs,* UK, Oxford University Press.

Freedman, D. S., Dietz, W. H., Srinivasan, S. R. & Berenson, G. S. (1999). The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics,* 103**,** 1175-1182.

Freedman, D. S., Mei, Z., Srinivasan, S. R., Berenson, G. S. & Dietz, W. H. (2007). Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. *The Journal of Pediatrics,* 150**,** 12-17.

Galani, C., Schneider, H. & Rutten, F. F. H. (2007). Modelling the lifetime costs and health effects of lifestyle intervention in the prevention and treatment of obesity in Switzerland. *International Journal of Public Health,* 52**,** 372-382.

Haby, M., Vos, T., Carter, R., Moodie, M., Markwick, A., Magnus, A., Tay-Teo, K. & Swinburn, B. (2006). A new approach to assessing the health benefit from obesity interventions in children and adolescents: the assessing cost-effectiveness in obesity project. *International Journal of Obesity,* 30**,** 1463-1475.

Hollingworth, W., Hawkins, J., Lawlor, D., Brown, M., Marsh, T. & Kipping, R. (2012). Economic evaluation of lifestyle interventions to treat overweight or obesity in children. *International Journal of Obesity,* 36**,** 559-566.

Khambalia, A., Dickinson, S., Hardy, L., Gill, T. & Baur, L. (2012). A synthesis of existing systematic reviews and meta-analyses of school-based behavioural interventions for controlling and preventing obesity. *Obesity reviews,* 13**,** 214-233.

Kuczmarski, R. J., Ogden, C. L., Guo, S. S., Grummer-Strawn, L. M., Flegal, K. M., Mei, Z., Wei, R., Curtin, L. R., Roche, A. F. & Johnson, C. L. (2002). 2000 CDC Growth Charts for the United States: methods and development. *Vital and Health Statistics,* 246**,** 1-190.

Levy, D., Mabry, P., Wang, Y., Gortmaker, S., Huang, T. K., Marsh, T., Moodie, M. & Swinburn, B. (2011). Simulation models of obesity: a review of the literature and implications for research and policy. *Obesity Reviews,* 12**,** 378-394.

Magnus, A., Haby, M. M., Carter, R. & Swinburn, B. (2009). The cost-effectiveness of removing television advertising of high fat and/or high sugar food and beverages to Australian children. *International Journal of Obesity,* 33**,** 1094-1102.

Moodie, M., Carter, R., Swinburn, B. & Haby, M. M. (2010). The Cost-effectiveness of Australia's Active After-school Communities Program. *Obesity,* 18**,** 1585-1592.

Moodie, M., Haby, M., Galvin, L., Swinburn, B. & Carter, R. (2009). Cost-effectiveness of active transport for primary school children - Walking School Bus program. *International Journal of Behavioral Nutrition and Physical Activity,* 6**,** 63-68.

Moodie, M., Haby, M., Wake, M., Gold, L. & Carter, R. (2008). Cost-effectiveness of a family-based GP-mediated intervention targeting overweight and moderately obese children. *Economics & Human Biology*, 6**,** 363-376.

Moodie M., Haby M., Swinburn B. & Carter R. (2011). Assessing Cost-Effectiveness in Obesity: Active Transport Program for Primary School Children — TravelSMART Schools Curriculum Program. *Journal of Physical Activity and Health,* 8**,** 503-511.

Nutbeam, D. (1998). Health promotion glossary 1. *Health Promotion International,* 13**,** 349-364.

Popkin, B., Kim, S., Rusev, E., Du, S. & Zizza, C. (2006). Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. *Obesity Reviews,* 7**,** 271-293.

Safron, M., Cislak, A., Gaspar, T. & Luszczynska, A. (2011). Effects of school-based interventions targeting obesity-related behaviors and body weight change: a systematic umbrella review. *Behavioral Medicine,* 37**,** 15-25.

Sonnenberg, F. A. & Beck, J. R. (1993). Markov models in medical decision making a practical guide. *Medical Decision Making,* 13**,** 322-338.

Trasande, L. & Chatterjee, S. (2012). The impact of obesity on health service utilization and costs in childhood. *Obesity,* 17**,** 1749-1754.

Wang, L. Y., Yang, Q., Lowry, R. & Wechsler, H. (2003). Economic analysis of a school-based obesity prevention program. *Obesity,* 11**,** 1313-1324.

Weinstein, M. C., O'brien, B. J. & Hornberger, J. (2003). Principles of good practice for decision-analytic modeling in health-care evaluation: report of the ISPOR Task Force on good research practices—modeling studies. *Value in health,* 32**,** 9-17.