# A Systematic Review of Economic Evaluations Involving Childhood Obesity

A mini dissertation submitted in partial fulfilment of the requirements for the degree:

Master of Public Health in Health Economics

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# Plagiarism Declaration

I, *Killoran Ann Kettles,* hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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Date: 03/02/2025

# Dedication

I dedicate this piece of writing to my family, who have supported me through this research process and inspire me to try and bring about positive change.

## Abstract

TITLE: A Systematic Review of Economic Evaluations Involving Childhood Obesity

BACKGROUND: Owing to the limited resources in developing countries, effective use of funds is necessary in the health care sector. Understanding the economic burden of prevalent health problems and ensuring cost-effective treatment thereof is, therefore, an important part of policy development. In developing countries, childhood obesity is becoming increasingly prevalent and is associated with significant morbidity and mortality. This study, therefore, examines the economics around childhood obesity and its interventions.

METHODS: A search was conducted on PubMed. Economic evaluations reporting quantitative data were included in the review. Data was extracted and grouped according to common themes. Findings were then described and reported, highlighting similar findings and needs for further research.

RESULTS: 105 eligible articles were included in the systematic review. Of these articles, 39 assessed the economic consequences of childhood obesity, with 27 focusing on healthcare costs thereof. The other 66 studies were largely cost-effectiveness analyses of various interventions. The studies examining economic consequences demonstrated that children who were classified as overweight or obese had higher healthcare expenditures than their healthy weight counterparts. Key findings regarding interventions illustrated that the following are cost-effective in addressing childhood obesity: early childhood interventions, school-based interventions targeting physical activity, sleep interventions and policy changes. The lack of studies conducted in low and middle-income countries highlighted the need for further research.

CONCLUSION: It is evident that childhood obesity is a pressing health concern with substantial economic consequences within the healthcare sector. Various interventions have been studied, with regards to their effectiveness at managing this illness. Early childhood interventions and school-based programs seemed to have the most supporting evidence regarding their economic benefits, however, further research

is needed to determine their comparative effectiveness and their effectiveness in resource limited settings.

# Acknowledgements

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To my family – I want to thank them for their kindness and support throughout the process, and for offering help in any way possible to make the completion of this thesis easier. I would also like to thank my friends for their encouragement and understanding during the more stressful time of this process.

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# PART A: PROTOCOL

## Section 1: Introduction

Over the past few decades, childhood obesity has become increasingly prevalent. The World Health Organisation recently highlighted the growing rates of childhood and adolescent obesity, indicating that it is a rising public health concern globally (World Health Organisation, 2021).

Childhood obesity is associated with many negative health outcomes, majority of which affect the child into adulthood and are associated with increased risk of mortality (World Health Organisation, 2021). Childhood obesity and the effects later in life also place substantial economic burden on individuals and families, owing to both loss of income and cost of treatment. Effective interventions are, therefore, needed to address this concern.

Furthermore, childhood obesity is becoming more prominent in developing countries (World Health Organisation, 2021). Developing countries have limited financial resources and thus need to be very careful when allocating funds to new interventions. Economic evaluations are, therefore, becoming more instrumental to policy makers and health care providers in assessing cost-effectiveness and the efficiency of evaluations as well as making informed decisions (Drummond et al., 2015).

A systematic review of economic evaluations on childhood obesity is essential for both assessing the quality of available evidence and consolidating the findings of previous studies. In doing so, it will provide a better understanding of the economic implications of childhood obesity and both the prevention and treatment thereof. It will also highlight methodological considerations and gaps in established knowledge, to guide future research.

## 1.1 Background Information

In developing countries there are limited resources available in health care, resulting in an increased need to ensure that the available funds are being allocated in an efficient manner. This involves ensuring that cost-effective interventions are being implemented, and that interventions are aimed at targeting at-risk groups and prevalent health problems. The use of economic evaluations is, therefore, becoming increasingly prominent in health policy making (Drummond et al., 2015).

Health economic assessments are becoming increasingly relevant to children, owing to them being a vulnerable group and the effectiveness of interventions (both to prevent and treat diseases) in this population (Ungar, 2007; Ungar and Santos, 2004). The Paediatric Economic Database Evaluation (PEDE) Project brought specific attention to the need for research in this area, and there has been a rising trend in the presence of paediatric health economic evaluations since 1980 (Ungar and Santos, 2004). Increasing the availability of economic evaluations would allow for their increased use in health policy decision making (Ungar and Santos, 2004).

Health policy decision making also rests largely on targeting leading health concerns. The rising rates of childhood obesity have become a cause for concern globally (World Health Organisation, 2021). Furthermore, the morbidity and mortality associated with being overweight at a young age suggests that intervention is needed to address this health issue.

This study aims to systematically review economic evaluations around childhood obesity. In exploring childhood obesity, consideration will be given both to the pecuniary burden of disease, the morbidity and mortality rates and the cost of interventions at various levels.

### *Childhood Obesity*

#### Definitions

The classification of children and adolescents is important when assessing obesity, owing to the differing body compositions of those below 19 years of age. According to the Bill of Rights and Children's Act, a child is an individual below 18 years of age (Steyn et al., 2022; Mahery and Proudlock, 2011). The World Health Organisation further goes on to define adolescents as those children between 10 and 19 years old (World Health Organisation, 2020; United Nations, 2019).

The World Health Organisation uses these age categories to provide very clear definitions for what being overweight and obese entails in both children and adolescents. For children under 5 years of age, WHO Child Growth standards are used. A child will be categorised as overweight if their weight-for-height is greater than 2 standard deviations above the mean and obese if their weight-for-height is greater than 3 standard deviations above the mean (World Health Organisation, 2021). For children between 5 and 19 years of age, BMI is used against the WHO Growth Reference Median. Overweight is where a child's BMI-for-age is greater than 1 standard deviation above the median and obese is where it is greater than 2 standard deviations above the median (World Health Organisation, 2021).

#### Incidence and Prevalence

Recent data indicates that childhood obesity is a growing problem in the world. WHO reported that in 2019 approximately 38.2 million children under the age of 5-years-old were defined as either overweight or obese, and that in 2016 over 340 million children and adolescents between the ages of 5-19 fell into the overweight or obese categories (World Health Organisation, 2021). Statistics further indicate that the issue of child and adolescent obesity is growing, with a 14% rise in the prevalence of overweight and obesity being reported in 5 to 19-year-olds between 1975 and 2016 (World Health Organisation, 2021).

Although initially considered a first-world problem, childhood obesity is now becoming an increasing problem in developing countries, with a 24% rise in the number of overweight under-5 year-olds being reported in Africa between 2000 and 2019 (World Health Organisation, 2021). In South Africa, it has been reported that one-in-eight children are classified as obese (Mukwevo, 2021). The childhood obesity rate in South Africa is, therefore, considered to be more than double the global average (Reddy and Fricker, 2022). The problem is particularly prevalent amongst adolescent females, of which 31,3% were reported to be either overweight or obese (Reddy and Fricker, 2022).

## Risk Factors

One of the most well-described risk factors associated with childhood obesity is diet (Willett and Stampfer, 2013; Wrottesley et al., 2019; Kupka et al., 2020; Steyn et al., 2022). A study conducted in South Africa demonstrated that adolescents are ingesting more processed foods, which are generally higher in both sugar and fat, and this increases their risks of becoming overweight or obese (Wrottesley et al., 2019; Steyn et al., 2022).

Lack of physical activity is also associated with an increased risk of developing childhood obesity. Studies have estimated that increasing physical activity by as little as 10% can significantly reduce the likelihood of becoming overweight (Lee et al., 2021; Steyn et al., 2022).

Environmental and socioeconomic factors contribute to a child's diet and level of physical activity, and therefore also influence a child's weight. This is owing to the availability and cost of healthy foods, education around diet and lifestyle and the prioritisation of physical activity in the home and at school (Steyn et al., 2022; Wrottesley et al., 2019).

### *Morbidity and Mortality*

Childhood obesity is associated with a variety of adverse health outcomes and has a significant impact on both morbidity and mortality.

Childhood obesity is associated with an increased risk of having a raised BMI in adulthood (Singh et al., 2008; Juonala et al., 2011; Sun Guo et al., 2002). Having a raised BMI is associated with many disease outcomes, the most prominent being cardiovascular disease (Singh et al., 2013; Juonala et al., 2011). Studies have demonstrated that being overweight as a child and carrying this into adulthood further increases the risk of developing metabolic disorders such as diabetes, hypertension, and dyslipidaemia (Juonala et al., 2011). The risk of death from stroke, coronary heart disease or a sudden unknown cause is markedly increased in this group (Juonala et al., 2011; Franks et al., 2010).

These studies also demonstrate that those who were overweight or obese in childhood, but had healthy BMIs as adults, have the same risk of cardiovascular disease as those who were never obese (Juonala et al., 2011). This suggests that treatment interventions may effectively reduce the risk of disease progression (Sun Guo et al., 2002).

### *Global Response*

The increasing rates of childhood obesity, and the associated morbidity and mortality rates, has drawn the attention of international policy makers and highlighted the need for interventions globally.

The third sustainable development goal is to "ensure healthy lives and promote wellbeing for all at all ages" (United Nations, 2023). One of the targets below this highlights the importance of addressing obesity, as it is an identifiable risk factor for non-communicable diseases. SDG target 3.4 is the commitment to reduce premature mortality from NCDs through both prevention and treatment by 2030 (World Health Organisation, 2021).

In 2016, WHO published the Commission for Ending Childhood Obesity in order to try and assist in achieving sustainable development goals (World Health Organisation, 2016). This report's recommendations for reducing childhood obesity involved promoting healthy food intake and physical activity, weight management, appropriate antenatal care and interventions targeted at school-age children (World Health Organisation, 2016).

## 1.2 Economic Evaluations

This study will focus on health economic evaluations. Drummond et al (2015) define economic evaluations as “the comparison of alternative options in terms of costs and consequences”.

Economic evaluations can be divided into full economic evaluations and partial economic evaluations (Drummond et al., 2015). Partial economic evaluations are not, however, recommended for inclusion in systematic reviews (Van Mastrigt et al., 2016). Full economic evaluations can further be divided by different parameters to illustrate comparisons between cost and outcome (Drummond et al., 2015). Three basic types have been defined: cost-effectiveness analyses, cost-utility analyses and cost-benefit analyses (National Information Center on Health Services Research and Health Care Technology , 2016). Cost-effectiveness analyses are the most common type of economic evaluation used, especially in paediatrics (Ungar and Santos, 2004; Briggs et al., 2006). These analyses compare the cost of certain interventions with the effectiveness thereof. The term “effectiveness”, in these studies, is defined by a single measure (National Information Center on Health Services Research and Health Care Technology , 2016). Cost-utility analyses, on the other hand, use multidimensional measures of effectiveness (Briggs et al., 2006). In a health-care settings, Quality-Adjusted-Life Years are the most commonly used outcome measure in a CUA (Briggs et al., 2006). Quality Adjusted Life Years are calculated by combining the effect that an intervention has on an individual’s lifespan and the quality of life that one will have with regards to health during this time (Briggs et al., 2006). Cost-benefit analyses are another form of economic evaluation that will be included, although they are used less frequently in a health care setting (National Information Center on Health Services Research and Health Care Technology , 2016).

## Section 2: Aims and Objectives

The proposed study is a systematic review on economic evaluations involving childhood obesity and interventions targeting the prevention and treatment thereof. The study will consider all aspects of childhood obesity and the economic implications thereof, including: risk factors, economic burden of disease, prevention measures, intervention strategies, and health education.

### 2.1 Research Question

The main research question is:

> What economic evaluations involving childhood obesity are available, and what do the findings thereof suggest?

The sub-research questions are:

- How were these economic evaluations conducted?
- When and where were these economic evaluations done?
- What settings do these economic evaluations apply to?
- Have these economic evaluations guided policy changes?
- Were these economic evaluations of adequate quality?
- What further research needs to be done in this area?

### 2.2 Aim

To conduct a systematic review of economic evaluations involving childhood obesity.

### 2.3 Objectives

The proposed study seeks to:

- Assess the availability and quality of existing economic evaluations involving childhood obesity.
- Identify and assess the methodologies used for the different economic evaluations.

- Identify the settings of the studies available and assess their applicability to a South African setting.
- Describe the findings of the studies and identify and analyse any differences which may exist across the different studies.
- Analyse the findings of the studies, and any policy implications thereof.
- Identify any gaps in knowledge, to advise on further research that may be needed.

## 2.4 Justification

Studies have demonstrated that childhood obesity is a rising public health concern and is associated with a large number of adverse health outcomes, most prominently non-communicable diseases (World Health Organisation, 2021). Targeted interventions are, therefore, needed to address childhood obesity.

Childhood obesity is becoming increasingly prevalent in low and middle income countries where resources are scarce. Economic evaluation assesses the most cost-effective intervention strategies and is, therefore, useful in guiding health policy makers and health care professionals.

Conducting a systematic review involves the synthesis of information already available, assessment of the quality of this research and identifying the gaps where further research needs to be done. It is therefore a useful tool for policy makers as it compares and contrasts multiple studies, ensuring that policy-makers are basing their decisions on best practise. Although previous systematic reviews pertaining to childhood obesity have been conducted, many of these focus specifically on clinical interventions or morbidity and mortality. Few have focussed specifically on the economic consequences. This would assist policymakers with evidence-based decision-making when allocating resources and introducing new interventions.

## Section 3: Methods

A five-step approach has been described in conducting a systematic review of economic evaluations (Van Mastrigt et al., 2016). These five steps ensure that the systematic review is conducted and reported in a manner that allows this information to inform healthcare decisions (Van Mastrigt et al., 2016).

The first step described is the initiation of the systematic review and focuses largely on the development of the protocol (Van Mastrigt et al., 2016). Although not part of the study methodology, this step is important in ensuring careful design and planning prior to the conduction of the study (Van Mastrigt et al., 2016; Moher et al., 2015).

Steps 2 to 4 describe how to conduct the review and analyse the findings and are discussed in more detail under the study design section (Van Mastrigt et al., 2016).
Step 5 involves discussing and interpreting the results and must include the following: summary of results and conclusions, heterogeneity, strengths and limitations, sources of funding, and potential conflicts of interest (Van Mastrigt et al., 2016; Brouwers et al., 2010; Moher et al., 2015; Husereau et al., 2013).

### 3.1 Study Design

The second step involves identifying the evaluations and articles to be included in the study (Van Mastrigt et al., 2016). Relevant data sources need to be selected, a search strategy developed, and the actual searches can then be conducted (Van Mastrigt et al., 2016). The inclusion and exclusion criteria will be defined prior to conducting any searches (Van Mastrigt et al., 2016; Higgins et al., 2022).

Once the search has been performed, studies need to be selected to be included in the evaluation (Sassi et al., 2002; Higgins et al., 2019). During this process, articles need to be downloaded to allow for analysis thereof. These articles will then be assessed, and relevant studies will be selected to be included in the final review.

The third step has two parts – extracting data and assessing for risk of bias and transferability (Van Mastrigt et al., 2016). A data extraction table can be used to present the data from the included studies (Van Mastrigt et al., 2016; Mlika-Cabanne et al., 2011).

Step 4 involves analysing and synthesizing the findings of the studies and reporting the results in an appropriate manner as well as identifying any potential gaps in the data (Van Mastrigt et al., 2016). From this, a report can be written up and policy implications identified.

## 3.2 Eligibility Criteria

Cochrane suggests that eligibility criteria for studies should be based on the population, intervention, comparators, and outcomes of interest (Higgins et al., 2019). Other elements can also be used to further allow for relevant articles to be selected for inclusion.

### *Study Population*

The study will focus on the paediatric population, targeting ages 0-12 years old. Both sexes will be included. Although WHO defines children as being between the ages of 0-18 years old, the South African Road-to-Health book only includes ages 0-12 years old and this range is therefore more relevant to childhood interventions in a South African context.

### *Intervention*

The interventions to be considered are those pertaining to childhood obesity. In order to ensure that all relevant interventions are included, medical subject headings will be used to find different terms used to describe the condition of interest. Free-text terms will also be used (Higgins et al., 2022). This implies that synonyms, spelling variations and truncations will be included in the search.

### *Comparators*

The comparators to be considered would be no action (including assessment of risk factors, development of disease and the complications thereof) or intervention (including prevention strategies and treatment of disease).

### *Outcomes*

The outcome measures for this study would be defined by the outcome variables of the economic evaluations available. They would include, but not be limited to, cost-effectiveness ratios and cost-utility ratios.

### *Other*

#### Setting

To increase applicability, economic evaluations from high, middle and low-middle income countries will be included in the review.

Studies conducted in clinical and community settings will be included, to broaden the spectrum of interventions studied. Clinical setting will include primary, secondary and tertiary levels of care. Community setting will include community centers and schools.

#### Study Types

The study will include the following economic evaluation study types: cost analysis, cost-effectiveness analysis, cost-utility analysis and cost-benefit analysis.

#### Language

Only studies reported in English will be included in the literature review.

#### Timeline

In order to ensure that the included studies are relevant to our current setting, only articles published after 2000 will be considered.

## 3.3 Search and Selection

### *Sources*

Multiple electronic databases will be used to identify potential studies for inclusion in the review. The databases have been selected owing to the availability of health-related studies on them.

The Cochrane handbook suggests that the minimum databases to be searched are CENTRAL, MEDLINE and Embase (Higgins et al., 2022). MEDLINE has been highlighted as one of the most useful sources for reviews of economic evaluations (Sassi et al., 2002). Further databases on which searches will be conducted are: Google Scholar, PubMED, Web of Science, Cochrane library.

### *Search Strategy*

The search terms used on each of the databases will encompass the population, intervention, comparator, and outcomes. To ensure that the search identifies as many relevant studies as possible, controlled vocabulary will be used (Higgins et al., 2022). This involves using medical subject headings to find different terms used to describe the condition of interest. Free-text terms will also be used (Higgins et al., 2022). This implies that synonyms, spelling variations and truncations will be included in the search. Boolean operators will be used to allow for the search to include multiple search terms under each domain, as it allows for appropriate translation within the search engine.

### Population

The following terms will be used to describe the population domain: [“paediatric” OR “pediatric” OR “child” OR “children” OR “childhood” OR “infant” OR “infants” OR “infantile” OR “neonates” OR “neonate” OR “neonatal” OR “newborn”]

### Intervention

The following terms will be used to include the various interventions around childhood obesity: [“obesity” OR “obese” OR “overweight” OR “over-weight” OR “over weight” OR “metabolic” OR “metabolic syndrome” OR “BMI” OR “body mass index”]

### Outcome

The following terms will be used to ensure that the studies generated by the search pertain to economic evaluations: [“economic evaluation” OR “economic” OR “costs” OR “cost analyses” OR “cost-effectiveness” OR “cost-effectiveness analysis” OR “cost-effectiveness analyses” OR “cost-utility” OR “cost-utility analysis” OR “cost-utility analyses” OR “economic burden of disease” OR “financial” OR “health technology assessment”]

## Documentation

To ensure that the study is reproducible, each search will be recorded in an Excel spreadsheet detailing the source, time and date and specific search term.

The references will be managed using EndNote 21, allowing for an extensive list of the results of the searches to be kept and shared with interested parties. Each study will be exported to the reference manager.

### *Selection of Studies*

After conducting the search, studies to be included will be selected using the predefined eligibility criteria. An initial screening will be done based on titles and abstracts of the articles generated in the search (Van Mastrigt et al., 2016; Higgins et al., 2019). After the initial screening, each study will undergo a full review to determine eligibility for inclusion. In order to increase transparency, a list of excluded studies will be kept and included in the appendices (Van Mastrigt et al., 2016).

## 3.4 Data Collection

According to the Cochrane Handbook, the following information needs to be collected for each eligible study: identification features; study methods; participants; intervention; comparator; outcomes; results (Higgins et al., 2022). Systematic reviews on economic evaluations also need to include information on the characteristics of the evaluation itself.

*Information*

| | |
|---|---|
| **STUDY DETAILS** | |
| **Identification Features** | Author |
| | Study title |
| | Journal name |
| | Year |
| | Sources of funding |
| | Database searched |
| **Study Methods** | Study design |
| | Economic perspective |
| | Timeline<br>- Length of enrolment<br>- Length of follow-up |
| | Units of analysis<br>- Currencies |
| | Data sources<br>- Costing<br>- Effectiveness |
| | Statistical analyses<br>- Costing<br>- Modelling<br>- Sensitivity analysis |
| | Reliability<br>- Methods reduce bias<br>- Methods to prevent and address missing data<br>- Potential conflicts of interest |
| | Ethical considerations |
| **Participants** | Age |
| | Weight (BMI; Obese, overweight, normal) |
| | Sex |
| | Socioeconomic status |
| | Country of residence |
| **Intervention** | Type of intervention |
| | Level of care |
| **Outcome** | Costs |
| | Cost-effectiveness/ cost-utility ratios |
| **ECONOMIC EVALUATIONS** | |
| **Characteristics** | Analytic framework and type of study |
| | Economic perspective of the study |
| | Timeline |
| | Main cost items |
| | Setting (including currency) |

(Higgins et al., 2022; Van Mastrigt et al., 2016)

*Extraction Tables*

Data extraction tables can be used to capture the information described above (Van Mastrigt et al., 2016; Mlika-Cabanne et al., 2011).

## 3.5 Risk of Bias and Quality Assessment

According to the Cochrane Handbook, risk of bias assessments should be conducted on all articles to be included in the review (Higgins et al., 2022). To conduct a risk of bias assessment for a systematic review for an economic evaluation, one must critically appraise the study design, methods, assumptions, models and possible biases for each included evaluation (Van Mastrigt et al., 2016; Evers et al., 2015). The CHEC-extended and BMJ checklist are both applicable to systematic reviews of health economic evaluations that are intended for CPG development (Van Mastrigt et al., 2016; Drummond and Jefferson, 1996; Evers et al., 2005). To further incorporate economic evidence into clinical practice guidelines, one should adopt the GRADE approach (Van Mastrigt et al., 2016; Guyatt et al., 2008). This approach allows for one to summarise findings and assess the quality of the evidence (Guyatt et al., 2008). If the economic evaluation being assessed is model-based, the NICE checklist will be used instead as it is better suited to assess this type of evaluation (National Institute for Health and Care Excellence, 2015). The Cochrane Risk of Bias Tool is another risk of bias assessment that has been developed, and is the tool that was selected for use in this review (Higgins et al., 2011). It was selected owing to it being easily applied to various studies and its recognition for being able to detect bias across specific domains.

Once a risk of bias assessment has been performed, the quality of the economic evaluations must also be assessed. The Consolidated Health Economic Evaluation Reporting Standards have been formulated into a checklist that allows for the assessment of the quality of economic evaluations and will be used to grade each included study (Husereau et al., 2022; Husereau et al., 2013).

## 3.6 Data Analysis and Synthesis

The collected data will be summarised using descriptive statistics.

The data will first be organised by the categories used for collection and described previously, namely: study methods; participants; intervention and economic evaluation characteristics (Higgins et al., 2022).

Summary statistics will be calculated for any numerical outcomes of eligible studies, such as costs and cost-effectiveness ratios. The statistics to be included are as follows, but not limited to: means, medians, ranges, proportions. This data will be presented in tables and charts, as described in the results section.

Summary statistics will also be calculated for the results of the risk of bias and quality assessments. The CHEC, BMJ and CHEERS checklist scores will be documented, and the following statistics will be presented: means, medians, ranges, min, max (Van Mastrigt et al., 2016). This data will also be presented in tables and charts, as seen in the results section.

## 3.7 Dissemination of Findings

The systematic review will be presented as an article formatted for a peer-reviewed journal. A policy brief will also be compiled, highlighting the key findings of the systematic review and providing suggestions for policy-makers as well as future research that may be required.

## 3.8 Possible Difficulties

One of the major difficulties in conducting this review will be the quantity of literature that the researchers will be required to read and analyse in order to identify appropriate studies. Once appropriate studies have been identified, a significant amount of time will also be required in order to adequately analyse each article and extract relevant data. In order to process the large quantity of work available, sufficient time will be allocated to

conducting the review. Furthermore, careful and organised recording of the process and findings will ensure that time is not wasted, and all data is correctly captured.
Another difficulty may arise in the identification of appropriate articles. Conducting a miniature literature review before the systematic review will allow for one to ensure that research has been conducted and is available on the area of interest.

## 3.9 Strength and Limitations

The main strength of a systematic review is that it allows for one to provide a comprehensive overview of a topic through the evaluation of existing literature and synthesis of data. This allows for one to not only determine trends but identify gaps and limitations in existing research. The use of predefined protocols also assists in minimising bias, as a systematic search strategy is used and predefined eligibility criteria allow for an unbiased selection of studies to be included. The availability of guidelines, such as Preferred Reporting Items for Systematic Reviews and Meta-Analyses and the Cochrane Handbook (Higgins, et al., 2019), allow for one to ensure that rigorous and appropriate methodology is used and therefore enhance replicability and reliability of data analysis and synthesis.

The major limitation of systematic review is that the findings rely heavily on the quality and availability of existing studies. Another major limitation is the variety of studies that one includes in the review – differing methodologies, populations, interventions, and outcome will make synthesis and comparison of data difficult. This will limit the reliability and accuracy of the findings.

## Section 4: Ethical Considerations

Owing to the study being a systematic review, no primary data collection is required. For this reason, there are limited guidelines around ethical considerations and approval. This section discusses the steps that will, however, still be taken to ensure that the review is conducted in an ethical manner.

### 4.1 Study Approval

Approval for the study to be conducted will be sought by the School of Public Health Departmental Research Committee of University of Cape Town, as the study will be conducted under this research department.

As prior mentioned, the proposed review does not involve any primary data collection. There is, therefore, no involvement of tests on humans or other animals. For this reason, the Ethics Committee does not need to be consulted for approval.

### 4.2 Selected Studies

The study is a systematic review and therefore requires the use of research conducted and published by other parties. An extensive bibliography will be included in the review, as well as in-text references, to ensure that all authors are properly acknowledged.
The ethical considerations for each study will also be included in the data section, to highlight any potential insufficiencies.

### 4.3 Conflicts of Interest

All conflicts of interest will be declared in the final systematic review. In order to ensure transparency, the sources of funding will be made evident. Any relations to any authors of published reviews will also be stated. No other potential conflicts of interest have been identified.

## Section 5: Timeline

| | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|
| **Protocol** | | | | | | | | |
| **Literature Review** | | | | | | | | |
| **Data collection** | | | | | | | | |
| **Data analysis** | | | | | | | | |
| **Writing Up** | | | | | | | | |
| **Editing** | | | | | | | | |
| **Submission** | | | | | | | | |

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# PART B: STRUCTURED LITERATURE REVIEW

## 1. Objectives

The objectives of the review are highlighted in the protocol. In summary, the study aims to assess existing economic evaluations involving childhood obesity, as well as the methodologies and setting thereof. It further aims to describe the findings and identify gaps in knowledge.

## 2. Literature Search Strategy

The search strategy followed has been described in detail in the protocol. Although the review intended to search multiple databases, the initial search conducted on PubMed (which covers MEDLINE) yielded a high quantity of results. As previously stated – MEDLINE has been recognised as one of the most useful sources for reviews of economic evaluations, and Pubmed was therefore the first interface used. Owing to time and resource constraints, and the significant number of relevant articles identified from this initial search, no further databases were searched owing to the quantity of results rendered by the search on this database.

The search was conducted as follows: ((((((("Pediatrics"[Mesh]) OR "Child"[Mesh]) OR "Infant"[Mesh]) OR "Infant, Newborn"[Mesh]) AND ( "Obesity"[Mesh] ) OR "Overweight"[Mesh]) OR "Metabolic Syndrome"[Mesh]) OR "Body Mass Index"[Mesh]) AND ("economic evaluation" OR "economic" OR "costs" OR "cost analyses" OR "cost-effectiveness" OR "cost-effectiveness analysis" OR "cost-effectiveness analyses" OR "cost utility" OR "cost-utility analysis" OR "cost-utility analyses" OR "economic burden of disease" OR "financial" OR "health technology assessment"). The following filters were applied: Humans, English, Newborn: birth-1 month, Infant: birth-23 months, Infant: 1-23 months, Preschool Child: 2-5 years, Child: 6-12 years; Year 2000-2024.

## 2.1 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria are those described in the protocol. The summary thereof is as follows:

Inclusion criteria: Economic evaluations pertaining to childhood obesity

Exclusion criteria: Study designs other than economic evaluations; study population older than 12 years; studies not conducted in English; studies conducted before 2000

## 2.2 Risk of Bias

A risk of bias assessment was conducted according to the Cochrane Criteria, thereby examining the articles for selection bias, performance bias, detection bias, attrition bias and reporting bias. Of the included articles, none demonstrated a high risk of any form of bias. A table illustrating the risk of bias assessment can be found in the appendices.

## 2.3 Conceptual Framework for Systematic Literature Review

By assessing and consolidating findings of existing literature, systematic reviews allow for researchers to draw conclusions based on wider research and guide policy makers and future researchers.

This systematic review included quantitative papers in the form of economic evaluations. Data were then extracted from identified papers and grouped into common themes. Findings of the various papers were described, highlighting similarities and differences and aiding in drawing conclusions. Lastly, consolidated findings are presented in a formal and concise manner (Figure 1).

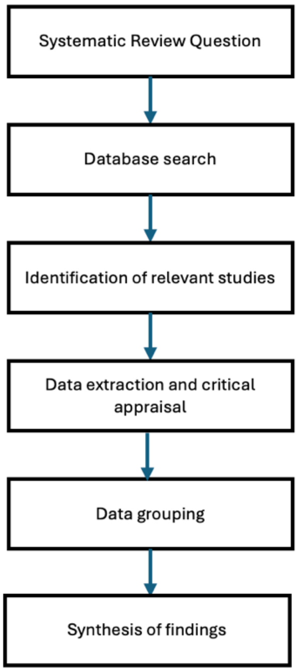


*Figure 1: Flow Diagram of Conceptual Framework for Systematic Literature Review*

# 3. Summary and Interpretation of Literature

## 3.1 Methodological Review

Two broad categories of studies were noted during the assessment of the literature: those examining the economic consequences of the disease, and those assessing interventions targeting the disease. Different study designs were noted in the evaluation of these two categories

### *3.1.1 Economic Consequences of Disease*

Of the 105 studies included in the review, 39 of them assessed the economic consequences of childhood obesity.

Majority of these studies were cost analyses (37 out of 39 studies). Within the cost analyses, 27 focused on healthcare costs attributable to childhood obesity. The other studies assessing the economic consequence of disease were cost-of-illness analyses.

### *3.1.2 Healthcare Interventions*

66 of the included studies assessed healthcare interventions targeting childhood obesity. These included both prevention and treatment strategies and involved ranging levels of care.

Of these studies, 47 were cost-effectiveness analyses. Incremental cost-effectiveness ratios were used in the majority of these studies to assess the cost-effectiveness of the intervention being examined. 8 of the studies were pure cost-analyses. 3 of the studies were combined cost- and cost-effectiveness analyses. 4 were combined cost-utility and cost-effectiveness analyses. 2 cost-consequence analyses were included, and 1 cost-benefit analysis. 1 budget impact analysis was included.

## 3.2 Empirical Review

### *3.2.1 Economic Consequences*

Multiple studies conducted in Australia have demonstrated the economic consequences of childhood obesity in the country. A mathematical model based in Australia estimated that the total direct medical expenditures attributable to childhood overweight/ obesity was 6.24 billion AUD (Trasande, 2010). A 1-percentage-point reduction in obesity among the 12-year old cohort would save 86 million AUD in childhood and 174.4 million AUD in adulthood (Trasande, 2010). This highlights the financial burden of childhood obesity throughout one's lifetime.

A large part of the financial burden of childhood obesity rests on the increased healthcare costs. An assessment of the Medicare scheme in Australia and the associated costs demonstrated that overweight and obese children had significantly higher (10-14%) Medicare expenditures (Clifford et al., 2015). The annual Medicare cost attributable to obese and overweight 6-13 year olds was estimated to be 5264 and 8839 million AUD respectively (Black et al., 2018). A study specifically focusing on non-hospital Medicare costs found that overweight children had a combined cost difference of 12.92% (Au, 2012). Another study conducted in Australia demonstrated that 3-year healthcare costs for obese children were approximately 4124 AUD, compared to 2516 AUD for healthy weight children (Hayes et al., 2016). However, underweight children were found to be the most cost-intensive at 6774 AUD (Hayes et al., 2016).

Studies were also conducted in the United States of America to assess the economic consequences of childhood obesity. One study focusing specifically on private health care users demonstrated that youths in the overweight and obese categories had higher total medical expenditures and higher out-of-pocket expenditures (Kumar et al., 2023). Total expenditures based on an adjusted model illustrated that those with severe obesity had 909 USD higher total expenditures than those of healthy weights, with OOP expenditures being 121 USD of this total (Kumar et al., 2023). Another study focusing on the Medicaid population found that obese children had higher outpatient expenditures and acute care expenditures than their healthy weight counterparts (Janicke et al., 2010). A study conducted over 2 years illustrated that children who fell in the obese category for both years of the study had 194 USD higher outpatient visit expenditures, 114 USD higher emergency room expenditures and 12 USD higher emergency room expenditures (Trasande and Chatterjee, 2009). Different research found that obese children had an average excess cost per person of 116 USD, with a population level excess cost of 1.32 billion USD (Ward et al., 2021). A similar study demonstrated similar findings, with annual per-child medical costs attributable to excess weight being approximately 180 USD (Finkelstein and Trogdon, 2008).

Further research assessed healthcare service utilisation in relation to the increased expenditures in the United States. It was found that a child with obesity averaged 15% longer hospital stays and 15% higher cost of these stays (Wong Ramsey et al., 2020). Another study conducted between 2006 and 2016 in the USA found that children with a primary obesity diagnosis had a 1.8 day lower average stay, but the mean charges were 20 879 USD higher and the mean cost was 6049 USD higher (Kompaniyets et al., 2020). A similar study had similar findings, with an average increment in charges being 1634 USD higher and increment costs being 727 USD higher for patients with a secondary obesity diagnosis (Trasande et al., 2009).

A simulation conducted in the United States of America focused on determining the affordability of population-based interventions against targeted interventions. It initially estimated the breakeven point for an intervention (described as being the cost savings from interventions that can achieve a 1 percentage point reduction in the prevalence of obesity) as ranging between 1.4 and 1.7 billion USD. It further went on to estimate the per capita cost-savings per child, and found a population based intervention to be more cost-effective, with cost ranges between 280 USD and 339 USD per child as opposed to the targeted interventions (aimed only at children with abnormal weights) whose costs ranged between 1648 USD and 2735 USD per child (Ma and Frick, 2011).

In Israel, a study was also conducted to determine healthcare utilisation by children with increased BMI. It was determined that the average cost of care is approximately 6.6% higher for these children, with increased rates of physician visits and laboratory tests (Meyerovitch et al., 2007).

In Germany, a Markov model illustrated that the indirect excess costs attributable to childhood overweight and obesity were approximately 4209 Euros per male and 2445 Euros per female (Sonntag et al., 2016). It further went on to estimate that the expected cost savings to the German population, if there is a 14% reduction in childhood obesity (which was deemed achievable based on other studies), would be 27 million Euros (Sonntag et al., 2016). A similar study used a Markov model to estimate the lifetime excess costs of childhood overweight and obesity and calculated these to be 4262 Euros for males and 7028 Euros for females (Sonntag et al., 2015). However, a different cost-analysis suggested that being underweight is significantly more costly than being obese in Germany, with the median costs per BMI being as follows: very underweight 572 Euros, underweight 274 Euros, normal weight 438 Euros, overweight 540 Euros, obese 443 Euros (Wenig, 2012).

A modelled study conducted in Mexico estimated the total lifetime health and economic costs of childhood obesity to be approximately 1.8 trillion USD, with potential savings of 124.3 billion USD if obesity prevention intervention strategies are implemented. The cost per DALY averted over 65 years when combining fiscal interventions, marketing restrictions, social marketing, breastfeeding promotion and school-based interventions was calculated to be 28 USD. (Brero et al., 2023)

Various research studies also found obesity to be associated with increased healthcare utilisation, when children were admitted for a different diagnosis. In the United States, a study examining expenditures in the obese, paediatric Medicaid population found the following factors to be associated with the highest spending: adolescent age, obesity co-morbid conditions, complex chronic conditions or mental health conditions (Kyler et al., 2023). Further research found that children with obesity as a secondary diagnosis had higher hospital charges for their stays for other admissions (Woolford et al., 2007). Those admitted with appendicitis had a mean average charge of 1723 USD higher when obese, those with pneumonia demonstrated a difference of 2540 USD, schizoaffective disorders 523 USD and appendicitis 3085 USD (Woolford et al., 2007). A similar study in the USA confirmed these findings, illustrating an incremental cost difference of between 1323 USD and 3627 USD for admissions with common conditions and a secondary diagnosis of obesity (Woolford et al., 2009).

A study conducted in Canada highlighted the increased incidence of certain childhood diseases (internalising disorders, asthma, other respiratory disorders, otitis media, chronic adenoid/ tonsil disorder) in overweight and obese children (Kirk et al., 2012). This resulted in not only higher health care utilisation, but higher health care costs for the treatment of these conditions (Kirk et al., 2012). Obesity hypertension was found to be associated with a higher total cost of health care in a study conducted in America (28 596 USD vs 15 242 USD) (Jerrell and Sakarcan, 2009).

A study conducted in the USA focused specifically on increased health care costs of obese children admitted with respiratory tract infections and found the average cost to be 383 USD higher (Okubo et al., 2018). However, in Japan, a study illustrated that overweight or obese children admitted with respiratory tract infections had lower mean hospitalisation costs than their normal weight or underweight counterparts. The respective costs were calculated to be as follows: underweight 290 Yen, normal weight 276 Yen, overweight 262 Yen, obese 267 Yen (Okubo et al., 2018).

Another study in the USA, focusing specifically on admissions with acute asthma exacerbations, found total inpatient costs for obese children to be 1588 USD higher than their non-obese counterparts (Okubo et al., 2016). This differed from findings of a study conducted in Japan, which found a higher rate of readmission and longer length of stay amongst obese children, but little differences in total costs (Okubo et al., 2017).

Research conducted in Japan found that obesity also had an impact on the medical costs of children admitted with acute pancreatitis, whose average costs were 14 169 USD in comparison to 7547.7 USD (Murata et al., 2016). A study in the USA had similar findings, with total costs for treating AP being 9983 USD without morbid obesity and 12 194 USD with morbid obesity (Thavamani et al., 2020). A similar study in the USA confirmed these findings, with a total hospital cost for obese patients averaging 11 827 USD as opposed to 9327 USD for their healthy counterparts (Thavamani et al., 2020). However, the average costs for a child with undernutrition was found to be even higher at 34 089 USD (Thavamani et al., 2020).

A different study demonstrated that obese children admitted with urinary tract infections had higher mean total hospital costs (7785 USD as opposed to 6033 USD) (Okubo and Handa, 2017). Obesity also resulted in higher per capita physician costs in the diagnosis and treatment of otitis media, according to a study conducted in Canada (47 CDN$ vs 24 CDN$) (Kuhle et al., 2012).

A different study conducted in the United States suggested that hospital utilisation costs for children presenting to the emergency department, regardless of whether or not they were admitted, were not significantly different (Fleming-Dutra et al., 2013). Admitted children with asthma or fractures did have slightly higher median costs (4617 USD vs 4177 USD and 9855 USD vs 8137 USD respectively), but were the only significant group (Fleming-Dutra et al., 2013).

A study focusing specifically on pharmaceuticals in Germany illustrated that the mean pharmaceutical costs of overweight and obese children per year were 172 and 211 Euros respectively (Wenig et al., 2011). This was only slightly more than the cost of normal weight children (170 Euros) and less than those very underweight (392 Euros) or underweight (392 Euros) (Wenig et al., 2011).

Alternative research has further suggested that childhood obesity is becoming an increasing economic concern. A study conducted in Alabama focusing on costs for lower income families demonstrated that the average total costs (including inpatient, outpatient and emergency department care) have been progressively increasing (Sen et al., 2020). In 1999, the total costs were 1161.83 USD for those without obesity-related conditions and 2871.53 USD for those with obesity-related conditions(Sen et al., 2020). In 2015, it was predicted that the total costs would be 1572.86 USD for those without, and 5670.61 USD for those with obesity related conditions. It therefore increased from 2.5 times to 3.6 times the cost (Sen et al., 2020). A study conducted in the United Kingdom suggested that the Covid-19 pandemic will result in a lifelong cost (including healthcare costs, productivity losses and losses in QoL0 of 8691 billion GBP) owing to increase in childhood overweight during this time (Ochoa-Moreno et al., 2024).

It is important to note that research has suggested that different models may be overestimating the use of medical services by obese youths and suggested that the medical expenditures may not be significantly higher for those with childhood obesity (Wright and Prosser, 2014).

One study touched on an indirect cost of childhood obesity. A study in Australia estimated the costs of childhood obesity owing to school absenteeism and lost carer productivity, and found that obese children missed an extra day of school per year, resulting in a national cost of approximately 64 million AUD (Carrello et al., 2021).

### *3.2.2 Interventions*

#### 3.2.2.1 Early Childhood Interventions

A study conducted in Australia demonstrated the cost-effectiveness of an intervention involving SMSing “Health Beginnings” advice to pregnant women, continuing with the activity until their infants are 2 years old (Killedar et al., 2022). The cost was calculated to be 5154 AUD per unit BMI and 979 AUD per 0.1 BMI-z score avoided, with total upscaling costs of 7.65 million AUD (Killedar et al., 2022). Home visits promoting "Healthy Beginnings" advice in the first 2 years of life was shown to be another effective early-childhood intervention, with an ICER of 607 AUD per 0.1 BMI unit avoided (Hayes et al., 2014). The cost of implementing the "Healthy Beginnings" advice in comparison to other early childhood interventions in Australia demonstrated that promoting the advice per SMS was cheaper than standard implementation owing to saving time costs. The comparative costs per participant were 80 AUD for the SMS intervention and 1135 AUD for the original Healthy Beginnings intervention (Brown et al., 2020).

A program focusing on preventing overweight in infancy (specifically targeting sleep, nutrition and physical activity interventions) found a sleep-only intervention to be more cost-effective than a combined intervention, with comparative ICERs of 18 125 AUD and 94 667 AUD per QALY gained (Tan et al., 2020).

Another study based in Australia examined an intervention focused on promoting healthy eating, active play, fruit and vegetable consumption and reduction in screen time in children aged 0 to 5 years old(Tran et al., 2022). This study specifically focused on the cost-effectiveness of scaling up an early childhood intervention to a community level, and found this to be effective with an ICER of 1126 AUD per BMI unit avoided and 26 399 AUD per QALY gained (Tran et al., 2022).

A study in Germany assessed the cost-effectiveness of low-protein infant formula in comparison to high protein infant formula, and found that low protein formula would result in a net monetary benefit of 750 Euros with willingness to pay of 0 Euros (Sonntag et al., 2019). The QALYs per person differed only slightly between the two formulas, suggesting that they are as effective as each other and the more affordable option is therefore more financially viable.

#### 3.2.2.2 School-Based Prevention

Various school-based prevention strategies have been examined. A cost-effectiveness analysis conducted in China, focussing on the CHIRPY DRAGON trial, further highlighted the effectiveness of school-based interventions. From a public sector perspective, the cost was determined to be 272.2 Yuan per BMI z-score change and 8 888 Yuan per QALY gained (Zanganeh et al., 2021) . From a societal perspective, the cost was estimated to 73 831 Yuan per QALY gained (Zanganeh et al., 2021). A similar study confirmed the cost-effectiveness of the CHIRPY DRAGON intervention, with an estimated ICER of 1760 GBP per QALY (well below the 20 000 GBP threshold) (Li et al., 2019).

In Portugal, the "Planning Health in School" program was also found to effectively reduce BMI and WC in adolescents, with a net cost of 36.14 Euros per capita (significantly less than the obesity attributable medical costs of 3849.15 Euros per adult per year) (Vieira and Carvalho, 2019).

A cost-analysis of the High Five for Kids motivational interviewing program found that this school based program cost an additional 196 USD per child, with further studies needed to determine if this is cost-effective (Wright et al., 2014).

Programs focusing specifically on promotion of a healthy lifestyle and physical activity in schools have been explored in multiple studies. A cost analysis study found that implementing a school-based lifestyle and activity program (AVHPS) would cost approximately 7830 USD per school in direct public funding (Ohinmaa et al., 2011).

A cost-utility and cost-benefit analysis conducted in China indicated the effectiveness of school-based obesity prevention programs. A combined nutrition and physical activity program proved to be the only intervention with net savings, which were estimated to be 73 659.6 Chinese Yen (Xu et al., 2020). This intervention also demonstrated an ICER of 10 335.20 Yen and a cost-benefit ratio of 1.2 Yen (Xu et al., 2020).

A study comparing various childhood obesity interventions in Australia highlighted the effectiveness of school-based interventions – the most cost-saving interventions were found to be a program focussing on nutrition and physical activity with an active component (14M AUD), a program to encourage the reduction of carbonated beverage consumption (26.7M AUD) and an education program targeted at reducing television viewing (43.8M AUD) (Carter et al., 2009).

A cost-effectiveness analysis conducted in Germany also found that the URMEL-ICE intervention, focussing on metabolism, exercise and lifestyle, was cost effective with an ICER of 11.11 Euros per cm reduction in waist circumference and 18.55 Euros per unit waist-to-height ratio reduced (Kesztyüs et al., 2013).

In China, a study demonstrated that a combined nutrition and physical activity program, in comparison to a focussed nutrition or physical activity program, was the only one to bring significant changes to BMI (Meng et al., 2013). The cost per change in BMI unit was 120.3 USD, with a cost of 1308 USD for each case of overweight and obesity prevention (Meng et al., 2013).

Various studies have also focused on interventions targeting physical activity only. An analysis comparing various school-based interventions found childhood obesity prevention programs targeting physical activity to be cost-effective, with the most cost-effective being daily supervised afterschool programs involving 2 hours of physical activity. It was found to have a negative total cost of 46 200 USD and an average cost per person of -1423 USD. (Cradock et al., 2017). A study examining the Active Physical Education program, endorsing increasing physical activity in schools in the USA, found the cost per BMI unit saved to be 401 USD and 10-year healthcare cost-saving of 60.5 million USD (Barrett et al., 2015).

Focus on increasing physical activity and reduction in sedentary behaviours in schools was also found to be cost-effective in a trial conducted in Australia, with estimated healthcare cost savings of 641M AUD for physical activity increase and 654M AUD for reduction in sedentary behaviour (Brown et al., 2024). Furthermore, the ICERs (in net cost per HALY saved) were found to be 10 374 AUD and 10 444 AUD for the physical activity increase and reduction in sedentary time respectively – well below the 50 000 AUD threshold (Brown et al., 2024).

In New Zealand, the APPLE project (A Pilot Program for Lifestyle and Exercise) was found to cost approximately 1708 NZD per kilogram-weight gain prevented in 7-year-old children (McAuley et al., 2010). No significant change to HUI was noted, suggesting a costly intervention with limited quality of life improvement (McAuley et al., 2010)

Another study conducted in the USA found a school-based physical activity program to be ineffective in increasing children's physical activity, with a change in percentage time spent at different physical activity levels being -3.4 for low-moderate vigorous activity and -1.6 for moderate vigorous activity, in comparison to the community-based program which showed increase in both areas (LMVPA +3.0, MVPA +2.8) (Gesell et al., 2013). The community program was slightly more costly (19.25 USD per participant, compared to 17.67 USD per participant) but did bring about positive change (Gesell, Sommer et al. 2013). A similar study in the UK, analysing the feasibility of the Action 3:30 extracurricular physical activity intervention, found the program to have an extremely limited effect on physical activity and BMI (Jago et al., 2014). The FitKid Project (conducted in the USA) was also assessed and determined to have an ICER of 317 USD per 0.76% decrease in body fat percentage (Wang et al., 2008)

Interventions targeting only nutrition and lifestyle have also been assessed. The USA conducted a cost-effectiveness analysis on a school-based intervention focussing on nutrition and found it to have a ICER of 275 USD per QALY therefore cost-effective (below the threshold of 50 000 USD per QALY) (Graziose et al., 2017). Another nutrition based program in the United States (SnAX) found that the costs of changing nutritional behaviours in a school cafeteria using a 5-week program are as follows: 1.20 USD per additional fruit serving; 8.43 USD per additional full priced lunch served; 2.11 USD per additional free/reduced-priced lunch served; and 1.69 USD per reduction in snacks sold (Ladapo et al., 2016).

A program specifically targeting increasing water consumption in the USA found that placing water dispensers in school cafeterias may result in a net benefit of 174 USD per student, with lifetime cost savings coming to 13.1 billion USD (An et al., 2018). Another study examining interventions targeting increasing water consumption estimated that installing water jets in school cafeterias could save 0.31 USD per dollar invested and would cost 105.43 USD per BMI unit prevented if only 39.3% of eligible schools adopted the intervention (Kenney et al., 2019)

In Spain, a school-based program focussing on lifestyle education was found to be cost-effective, with a cost of 968.66 Euros to avoid one case of obesity, and 44.68 Euros to decrease BMI by one unit (Conesa et al., 2018). A similar study in Germany, examining the "Join the Healthy Boat" lifestyle program for primary school children, found the cost of obesity case averted to range between 1515 Euros and 1993 Euros (Kesztyüs et al., 2017).

The method of delivering the interventions has also been analysed. Group treatments in schools were found to be cost-saving in comparison to individualised counselling sessions in a study conducted in Finland (Kalavainen et al., 2009). The ICER was determined to be 266 Euros for a 0.1 BMI-SDS decrease (Kalavainen et al., 2009).

One study specifically examined BMI report cards as a means of addressing childhood obesity. A societal cost study conducted in the USA illustrated that BMI report cards are an ineffective method of addressing childhood obesity, with implementation costs of 115 million USD but negative cases of obesity prevented (Poole et al., 2023).

In the United Kingdom, a study was conducted to determine the cost-effectiveness of a school-based intervention on quality of life and was found to have an ICER of 26 815 GBP per QALY (Canaway et al., 2019). A different study (WAVES) found another intervention to be ineffective, with an ICER of 46 083 GBP per QALY (Adab et al., 2018).

#### 3.2.2.3 Family-Based Prevention

Family-based prevention has also been researched as an intervention strategy for childhood obesity.

Prior to introducing a program, an assessment of the costs is necessary to determine affordability. A budget impact analysis conducted in USA found that the implementation costs of a FCU for Health (a family check-up program) amounted to approximately 60 589 USD per site, with replication costs of 16 475 USD per site (Jordan et al., 2019).

Bright Bodies, a high-intensity family-based intervention, was assessed using a microsimulation model and was found to have an intervention cost of 1122 USD, with savings in healthcare expenditure associated with obesity of 1126 USD and cost savings per person 766 USD (Pryor et al., 2023). It further demonstrated an ICER of per BMI point decrease of 363 USD (Pryor et al., 2023).

A study conducted in Germany assessing a family-based multicomponent treatment found the ICER to be 2367 Euros per BMI-SDS reduction of greater than 0.25, with a return on investment of between 3.3 and 7% (Lier et al., 2020).

"Families for Health" is another family-based intervention introduced in the United Kingdom, which focussed on a 12-week group program (Robertson et al., 2012). It determined the cost per reduction BMI unit to be 2543 GBP (Robertson et al., 2012). Another study assessing the cost-effectiveness of the "Families for Health" intervention found the ICER to be 55 2175 GBP per QALY gained, above the determined cost-effectiveness ratio (Robertson et al., 2017). The lack of cost-effectiveness of the Families for Health intervention was confirmed with a health technologies assessment, which found the ICER per QALY gained to be 511.68 GBP more in comparison to usual care from an NHS and PPS perspective, and 518.30 GBP more from a societal perspective (Robertson et al., 2017).

In the United States, an intervention focussed on group parent and one-on-one counselling found the cost per % BMI decreased to be approximately 116 USD in comparison to information based child-only intervention (Quattrin et al., 2017). Another study in the USA found the internal rate of return on family-based group interventions to be negative with more conservative models, but did have a positive return on investment (Borner et al., 2016).

A study conducted in rural counties in USA compared a family-based group intervention with a parent-only group intervention, and determined the with parent-only intervention to be more cost-effective with ICERs (cost per 0.2 decrease in BMI score) of 758 USD and 579 USD respectively (Janicke et al., 2009). Another study had similar results, where two interventions with similar effectiveness were compared, but the family-based treatment was found to cost 4279 USD per child-parent dyad, while the parent-only based treatment cost 3231USD per child parent dyad (Boutelle et al., 2021). This differed from the results of a different study conducted in USA, which had an ICER of 209.17 USD per percent BMI change in the parent and child intervention, but a ICERS of 1036.50 USD and 973.98 USD respectively for the parent-centred interventions (Epstein et al., 2014).

Another study examining a family based intervention illustrated that combined group and individual sessions are as effective at bringing about dietary changes as group-only sessions (Raynor et al., 2002). It further went on to determine that dietary costs decreased over time, with cost of the combined intervention being 6.19 USD at baseline but 4.86 USD at 12 months (Raynor et al., 2002). A similar trend was shown with group sessions, with a baseline cost of 7.35 USD but a 12 month cost of 5.22 USD (Raynor et al., 2002).

In New Zealand, a cost-effectiveness analysis was conducted comparing a home-based multidisciplinary program with conventional childhood obesity prevention methods (Anderson et al., 2018). The program was found to be more affordable, with mean costs per child of 859.22 NZD and 1642.70 NZD for the low and high intensity programs as opposed to 1798.12 NZD for the conventional method of prevention (Anderson et al., 2018). The mean BMI SDS reduction was also slightly better for the home-based program at 0.08, compared to 0.05 for the conventional program (Anderson et al., 2018).

#### 3.2.2.4 Primary Care Based

Primary care is another area which can be used to address childhood obesity. One study focussed on determining the implementation costs of a primary care based intervention, "Connect for Health", aimed at clinical decision support, educational handouts, and community resources  (Smith et al., 2023). The costs of implementation ranged by district, from 77 103 USD to 14 2721 USD (Smith et al., 2023).

Motivational interviewing has also been assessed as a method of primary prevention for childhood obesity. A study comparing motivational interviewing to standard primary care practices illustrated an intervention cost of 1051 USD per two years, with an ICER of 363 USD per BMI percentile point decrease (Woolford et al., 2022).

A cost-consequence analysis conducted in Australia assessed the LEAP (Live, Eat and Play) trial, a secondary prevention intervention delivered by family physicians in Australia (Wake et al., 2008). The combined health sector and family cost per child of initiating such an intervention was found to be 4094 AUD (873 AUD being attributable to the health care sector) with only a -0.03 change in BMI score  (Wake et al., 2008). The LEAP trial also underwent a cost-effectiveness analysis from a societal perspective,  and was found to be cost-effective with a net cost per DALY saved of 4670 AUD  (Moodie et al., 2008).

#### 3.2.2.5 Active Lifestyle

Promotion of an active lifestyle is another intervention aimed at reducing childhood obesity. Australia's government launched a childhood obesity prevention program focusing on promoting after school physical activity, however, it was not found to be cost-effective (Moodie et al., 2010). The net cost per DALY saved was found to be AUD 82 000 AUD, above the 50 000 AUD threshold (Moodie et al., 2010).

A different community-based program (Be Active Eat Well) that encouraged healthy eating and an active lifestyle in 4 to 12 year olds was found to be affordable with a net cost per DALY saved of 29 798 AUD (Moodie et al., 2013).

A study focusing specifically on active transport to school illustrated that focusing on active transport is not cost-effective, with a net cost per DALY saved found to be 117 000 AUD (Moodie et al., 2011).

A day-camp intervention encouraging healthy eating and lifestyle to Danish children found such a program to be costly, although effective, with an ICER per point decrease in BMI of 24 928 DDK (Larsen et al., 2017).

#### 3.2.2.6 Sleep Interventions

Sleep interventions have also been suggested as a method of addressing childhood obesity. A modelled distributional cost-effectiveness analysis used microsimulation models to assess the effectiveness of two primary interventions and one treatment for childhood obesity. The two primary prevention strategies were sleep interventions, one of which also involved other lifestyle interventions. They were determined to cost approximately 184 AUD and 601 AUD respectively, with both showing a net health benefit of 0.003 QALYs. (Killedar et al., 2023)

Another study conducted in Australia further demonstrated that the cost-effectiveness of sleep interventions is dependent on socioeconomic position, with the ICER per unit BMI avoided and QALY gained being lowest in the mid-socioeconomic position group, at 806 AUD and 18 206 AUD respectively (Killedar et al., 2023).

#### 3.2.2.7 Policy Changes

Policy changes are a common strategy for addressing public health concerns. In the USA, a modelled study demonstrated that a combined policy-change intervention focusing on reducing screen time and sugar-sweetened beverage consumption, as well as increasing physical activity, would have an ICER of approximately 57.8 USD per BMI unit avoided (Wright et al., 2015). The healthcare cost savings have the potential to amount to 51.6 million USD, with a 94.7% chance of being cost-saving (Wright et al., 2015).

Another study focusing on sugar-sweetened beverage tax found that implementation of 0.02 USD/oz SSB excise tax could result in net cost-savings of -4.5 billion USD, while preventing 42 700 cases of childhood obesity and a gain of 114 000 QALYs over a 10 year period (Lee et al., 2024).

A microsimulation model illustrated the costs and cost-effectiveness of interventions focused on limiting television time to improve childhood obesity (Kenney et al., 2021). It examined 5 interventions, and projected that eliminating the TV advertising tax subsidy would be the most effective at reducing childhood obesity incidence (with 78 700 cases being prevented) and would save more in health care related costs, with the net costs calculated to be -149 million USD (Kenney et al., 2021). Motivational interviewing was also expected to save 11.9 million USD over the 10-year period (Kenney et al., 2021).

A study conducted in Australia highlighted the effectiveness of television reduction on reducing childhood obesity and associated costs, demonstrating that legislation to implement time-based restrictions of unhealthy food and beverage marketing to children under 16 years of age on FTA TV until 9:30 pm resulted in approximately 88 396 HALYs saved over a child’s lifetime, and total net-cost savings of approximately 777.6 million AUD (Brown et al., 2018). A study comparing various childhood obesity interventions demonstrated similar results, with an estimated cost-saving of 299 million AUD with the reduction of unhealthy food advertising (Carter et al., 2009).

A similar study conducted in Australia illustrated that removing unhealthy TV food-advertising to children has an ICER of 3.70 AUD per DALY saved, and is therefore cost-effective (Magnus et al., 2009).

Reduction of unhealthy food advertising was also found to be cost-effective in USA, with a model suggesting that such an intervention may lead to 352 million USD in healthcare cost savings over 10 years and a total increase of 4540 QALYs (Sonneville et al., 2015).

### 3.2.2.8 Treatment

Although majority of the intervention methods discussed have been focused on prevention, research has also been conducted examining treatment methods. As previously discussed, a modelled distributional cost-effectiveness analysis using microsimulation models was used to assess the effectiveness of two primary interventions and one treatment for childhood obesity. The treatment intervention involved targeting "obesity-related behaviors" at paediatric practices (Killedar et al., 2023). This intervention was determined to cost approximately 231 AUD per child and resulted in a net health benefit of 0.007 QALYs.

An economic evaluation of lifestyle interventions targeting obesity found a discounted cost of 13 589 GBP per life year gained, however these benefits were only noticeable in later years (Hollingworth et al., 2012).

A study conducted in England illustrated the effectiveness of nurse-led primary clinics, but demonstrated that the ICER in comparison to hospital based interventions illustrated an additional cost of 175 Stirlings per 0.1 BMI SDS point change (Hollinghurst et al., 2014). The additional cost of using a Mandometer (a behavioural device) illustrated that although costly, these technologies are often effective, and may be an alternative treatment, and thus primary care interventions are generally deemed more cost-effective (Hollinghurst et al., 2014).

In the United Kingdom, the costs to implement the WATCH IT Program (a non-health-professional community-based obesity treatment program) were assessed (Spoor et al., 2013). The cost per patient was found to be 858.12 GBP without including venue costs, which added up to 396.82 GBP per patient (Spoor et al., 2013).

A program introduced in Poland (6-10-14 for Health Weight Management Program) targeted those at risk of developing obesity through screening and then involved parents and specialists in trying to reduce weight. This program was found to be most cost-effective when removing children from the >90$^{th}$ and >95$^{th}$ percentile groups, with ICERS of 19 624 and 23 691 respectively (Bandurska et al., 2020).

A study conducted in the Netherlands assessed the effectiveness of inpatient childhood obesity treatment programs, and concluded that a short-term inpatient program can result in a BMI reduction of 0.24 points and 1.68 QALYs gained, with a cost of 22 320 Euros (Makkes et al., 2017). The ICERs were calculated to be 1 479 463 Euros per SDS BMI; 344 744 Euros per QALY (Makkes et al., 2017).

## D: Identification of Gaps or Needs for Further Research

### Setting

As per the results, all of the studies have been conducted in high- or middle-income countries. 46 of the 105 studies were conducted in the United States of America, 23 in Australia and New Zealand and 10 in the United Kingdom. None of the included studies were conducted in low-income countries. This reduces the applicability to a low-income country.

South Africa is currently classified as an upper-middle income country, as per the World Bank. The only countries represented by the studies with the same classification are China and Mexico. The setting of the studies therefore limits their applicability to a South African context. Further research would be needed to determine if results are similar in a different setting.

### Timeline

To ensure that relevant literature was included, studies were only examined if conducted after 2000. However, owing to the dynamic nature of economies and technologies, studies conducted in the early 2000s may have limited relevance in our current setting. Of the included studies, 65 were conducted after 2014 and 19 after 2020. A synthesis of more recent studies would be useful to ensure that the information is up to date and relevant.

## Human Error

Owing to this study being conducted by a single researcher, there is room for bias and error. Repeating the study with multiple researchers, in order to ensure that all relevant studies are included, and that the data is correctly recorded, would increase the reliability of the study.

## Exclusion and Inclusion Criteria

The inclusion and exclusion criteria used to identify relavent studies may have influenced the scope and generalisability of the findings.

Although the decision to limit studies to those conducted on children below 12 years old was based on South Africa's current Road-to-Health program, evaluations of interventions targeting adolescents would have been excluded. These studies may have provided further evidence and insight on different costs and interventions applicable to older children.

The choice to only include English studies may also have led to relevant studies being excluded, particularly in a South African context, as many low and middle-income countries are non-English speaking.

## Single Database

Owing to the review being conducted by a single researcher, and there being various time constraints, only one database was searched. Relevant studies may, therefore, not have been included in the study. Future reviews may be conducted with an expanded database search to ensure all relevant studies are included.

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# PART C: MANUSCRIPT

## ABSTRACT

BACKGROUND: Owing to the limited resources in developing countries, effective use of funds is necessary in the health care sector. Understanding the economic burden of prevalent health problems and ensuring cost-effective treatment thereof is, therefore, an important part of policy development. In developing countries, childhood obesity is becoming increasingly prevalent and is associated with significant morbidity and mortality. This study, therefore, examines the economic evaluations around childhood obesity and its interventions.

METHODS: A search was conducted on PubMed. Economic evaluations reporting quantitative data were included in the review. Data was extracted and grouped according to common themes. Findings were then described and reported, highlighting similar findings and needs for further research.

RESULTS: 105 eligible articles were included in the systematic review. Of these articles, 39 assessed the economic consequences of childhood obesity, with 27 focusing on healthcare costs thereof. The other 66 studies were largely cost-effectiveness analyses of various interventions. The studies examining economic consequences demonstrated that children who were classified as overweight or obese had higher healthcare expenditures than their healthy weight counterparts. Key findings regarding interventions illustrated that the following are cost-effective in addressing childhood obesity: early childhood interventions, school-based interventions targeting physical activity, sleep interventions and policy changes. The lack of studies conducted in low and middle-income countries highlighted the need for further research.

CONCLUSION: It is evident that childhood obesity is a pressing health concern with substantial economic consequences within the healthcare sector. Various interventions have been studied, with regards to their effectiveness at managing this illness. Early childhood interventions and school-based programs seemed to have the most supporting evidence regarding their economic benefits, however, further research

is needed to determine their comparative effectiveness and their effectiveness in resource limited settings.

## INTRODUCTION

Childhood obesity has been highlighted as a rising public health concern owing to its increasing prevalence and negative associated outcomes (World Health Organisation, 2021). The negative outcomes of childhood obesity often affect the child into adulthood and are associated with increased risk of mortality (World Health Organisation, 2021). Although previously considered a disease of more economically affluent countries, childhood obesity is also becoming more prominent in developing countries (World Health Organisation, 2021).

Resource limitations and the need for targeted cost-effective interventions has made economic evaluations instrumental to policy makers and health care providers (Drummond et al., 2015). Systematic reviews further allow for assessment of quality and availability of evidence, and consolidate findings of previous studies .

This study is a systematic review on economic evaluations involving childhood obesity and interventions targeting the prevention and treatment thereof. The study will consider all aspects of childhood obesity and the economic implications thereof, including: risk factors, economic burden of disease, prevention measures, intervention strategies, and health education.

In doing so, the proposed study seeks to:

- Assess the availability and quality of existing economic evaluations involving childhood obesity.
- Identify and assess the methodologies used for the different economic evaluations.
- Identify the settings of the studies available and assess their applicability to a South African setting.

- Describe the findings of the studies and identify and analyse any differences which may exist across the different studies.
- Analyse the findings of the studies, and any policy implications thereof.
- Identify any gaps in knowledge, to advise on further research that may be needed.

The findings of the study should aid policy makers in making informed decisions regarding childhood obesity, providing insights on both the burden and treatment thereof.

# METHODS

This systematic review was conducted according to a five-step approach, described by Van Mastrigt in conducting systematic reviews of economic evaluations (Van Mastrigt et al., 2016).

## Search Strategy

The following search strategy was used to search the PubMed database between April 2024 and August 2024:

((((((("Pediatrics"[Mesh]) OR "Child"[Mesh]) OR "Infant"[Mesh]) OR "Infant, Newborn"[Mesh]) AND ( "Obesity"[Mesh] ) OR "Overweight"[Mesh]) OR "Metabolic Syndrome"[Mesh]) OR "Body Mass Index"[Mesh]) AND ("economic evaluation" OR "economic" OR "costs" OR "cost analyses" OR "cost-effectiveness" OR "cost-effectiveness analysis" OR "cost-effectiveness analyses" OR "cost utility" OR "cost-utility analysis" OR "cost-utility analyses" OR "economic burden of disease" OR "financial" OR "health technology assessment")

The following filters were applied: Humans, English, Newborn: birth-1 month, Infant: birth-23 months, Infant: 1-23 months, Preschool Child: 2-5 years, Child: 6-12 years; Year 2000-2024.

Initially, the aim was to search multiple databases. However, the quantity of results rendered by the initial search on one database (PubMed) resulted in there being adequate studies to include.

## Eligibility Criteria

The following table describes the inclusion and exclusion criteria according to the PICO approach, as recommended by Cochrane.

*Table 1: A table of the inclusion and exclusion criteria used to select studies to be included in the systematic review*

| | Inclusion | Exclusion |
|---|---|---|
| **Population** | Children | Older than 12 years old |
| **Intervention** | Pertaining to childhood obesity (screening, health promotion, weight-loss programs) | |
| **Comparators** | No action (including assessment of risk factors,<br>development of disease and the complications thereof);<br>Intervention (including prevention strategies and treatment of disease) | |
| **Outcome** | Costs<br>Cost-effectiveness and cost-utility ratios | Not economic related |
| **Setting** | Countries: low, middle and high-income<br>Care: Clinical (primary, secondary, tertiary); Community (community, school) | Nil |
| **Study types** | Cost-analysis, cost-effectiveness analysis, cost-utility analysis, cost-benefit analysis | Other studies |
| **Language** | English | Other languages |
| **Timeline** | 2000 to present | Older than 2000 |
| **Other** | | No full text available<br>Commentary or discussion paper |

## Information Sources

Electronic databases accessed through the University of Cape Town's library.

## Selection Process

All of the studies found in the initial search in Pubmed underwent a title and abstract screening.  Those found to be eligible were manually recorded in Excel, downloaded to OneDrive and exported to EndNote. These articles then underwent a full text screening. From the full text screening, articles were then selected to be included in the final review.

## Data Management

Articles were downloaded and stored on OneDrive according to title. Characteristics of all screened articles were recorded in Excel. References were stored in EndNote 21.

## Data Extraction

Microsoft Excel was the primary tool used to extract data. The full data extraction table can be found in the appendices.

The main study characteristics recorded were: Author, Study Title, Journal Name, Year, Country, Study Design, Study Population, Intervention Type/ Comparator, Level of Care, Outcome. Furthermore, results of the studies pertaining to the economic outcomes were extracted.

## Risk of Bias and Quality Assessment

Cochrane Collaboration's Tool for assessing risk of bias was applied to each of the selected studies in order to assess for this risk. The tool is described in the table (Higgins, 2011) below:

*Table 2: A table illustrating Cochrane Collaboration's Tool for Assessing Risk of Bias (Higgins, 2011)*

| Bias domain | Source of bias | Support for judgment | Review authors' judgment (assess as low, unclear or high risk of bias) |
|---|---|---|---|
| **Selection bias** | Random sequence generation | Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups | Selection bias (biased allocation to interventions) due to inadequate generation of a randomised sequence |
| | Allocation concealment | Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen before or during enrolment | Selection bias (biased allocation to interventions) due to inadequate concealment of allocations before assignment |
| **Performance bias** | Blinding of participants and personnel* | Describe all measures used, if any, to blind trial participants and researchers from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective | Performance bias due to knowledge of the allocated interventions by participants and personnel during the study |
| **Detection bias** | Blinding of outcome assessment* | Describe all measures used, if any, to blind outcome assessment from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective | Detection bias due to knowledge of the allocated interventions by outcome assessment |
| **Attrition bias** | Incomplete outcome data* | Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomised participants), reasons for attrition or exclusions where reported, and any reinclusions in analyses for the review | Attrition bias due to amount, nature, or handling of incomplete outcome data |
| **Reporting bias** | Selective reporting | State how selective outcome reporting was examined and what was found | Reporting bias due to selective outcome reporting |
| **Other bias** | Anything else, ideally prespecified | State any important concerns about bias not covered in the other domains in the tool | Bias due to problems not covered elsewhere |

A quality assessment was performed using the CHEERS checklist, included below (Evers, 2005)

*Table 3: A table Illustrating the CHEERS Checklist (Evers, 2005)*

| Section/topic | Item No | Guidance for reporting |
|---|---|---|
| **Title** | | |
| Title | 1 | Identify the study as an economic evaluation and specify the interventions being compared. |
| **Abstract** | | |
| Abstract | 2 | Provide a structured summary that highlights context, key methods, results, and alternative analyses. |
| **Introduction** | | |
| Background and objectives | 3 | Give the context for the study, the study question, and its practical relevance for decision making in policy or practice. |
| **Methods** | | |
| Health economic analysis plan | 4 | Indicate whether a health economic analysis plan was developed and where available. |
| Study population | 5 | Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics). |
| Setting and location | 6 | Provide relevant contextual information that may influence findings. |
| Comparators | 7 | Describe the interventions or strategies being compared and why chosen. |
| Perspective | 8 | State the perspective(s) adopted by the study and why chosen. |
| Time horizon | 9 | State the time horizon for the study and why appropriate. |
| Discount rate | 10 | Report the discount rate(s) and reason chosen. |
| Selection of outcomes | 11 | Describe what outcomes were used as the measure(s) of benefit(s) and harm(s). |
| Measurement of outcomes | 12 | Describe how outcomes used to capture benefit(s) and harm(s) were measured. |
| Valuation of outcomes | 13 | Describe the population and methods used to measure and value outcomes. |
| Measurement and valuation of resources and costs | 14 | Describe how costs were valued. |
| Currency, price date, and conversion | 15 | Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion. |
| Rationale and description of model | 16 | If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed. |
| Analytics and assumptions | 17 | Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used. |

| | | |
|---|---|---|
| Characterising heterogeneity | 18 | Describe any methods used for estimating how the results of the study vary for subgroups. |
| Characterising distributional effects | 19 | Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations. |
| Characterising uncertainty | 20 | Describe methods to characterise any sources of uncertainty in the analysis. |
| Approach to engagement with patients and others affected by the study | 21 | Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study. |
| **Results** | | |
| Study parameters | 22 | Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions. |
| Summary of main results | 23 | Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure. |
| Effect of uncertainty | 24 | Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable. |
| Effect of engagement with patients and others affected by the study | 25 | Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study |
| **Discussion** | | |
| Study findings, limitations, generalisability, and current knowledge | 26 | Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice. |
| **Other relevant information** | | |
| Source of funding | 27 | Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis |
| Conflicts of interest | 28 | Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements. |

## Data Analysis and Synthesis

In order to meet the objectives outlined, two forms of data analysis took place.

The first three objectives look at availability of studies, as well as the assessment of methodologies and settings. To meet this objective, data tables highlighting the number of studies, study design, and countries were developed.

The last 3 objectives focus on the findings of the studies. Outcome data was grouped into common themes. The two large groups found were studies examining economic burden of the disease and studies examining interventions for childhood obesity. The findings of the selected studies in these groups were analysed and compared separately.

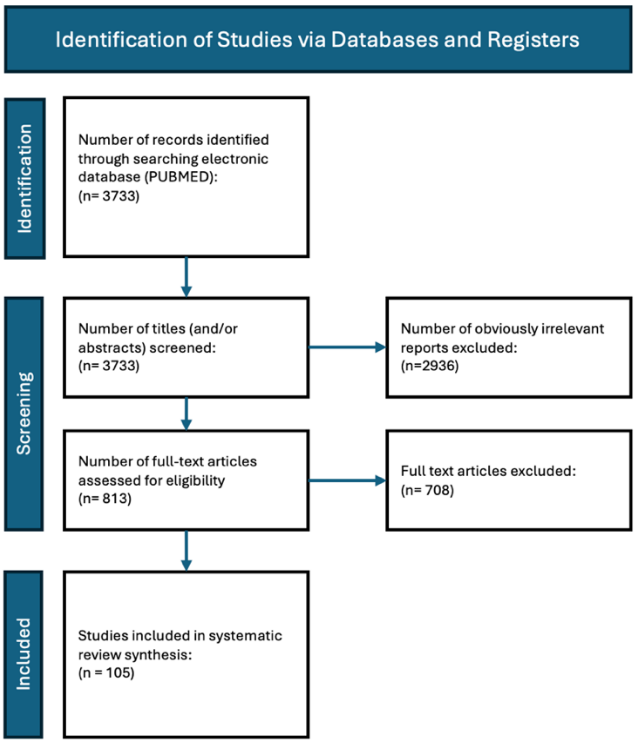
# RESULTS

## Search Results

The initial PubMed search rendered 3733 results. From this, 2936 were excluded based on Title and Abstract Screening. Majority of these articles were excluded as they were not economic evaluations (2882). Other reasons for exclusion included: not pertaining to children (incorrect population), not pertaining to obesity (incorrect intervention or comparator) and outcomes not involving economics.

813 were eligible for full-text screening. Of these, 105 were found to be eligible for inclusion in the systematic review. Reasons for exclusion are mentioned previously.

The PRISMA diagram below indicates the process of study selection.



*Quality Assessment Results*

Using the CHEERS Checklist, articles were given a score out of 28 based on presenting and missing items. 38 of the articles had 22 of the items present, and the rest had 23 items present. This suggests that none of the articles were of particularly low quality.

105 of the articles lost points for missing the following: Discount Rates, Characterising Distributional Effects, Approach to Engagement with Patients and Others, Effects of Engagement. 104 lost points for not including Rationale and Description of the Model. 39 lost points for not having a Health Economic Analysis Plan.

*Bias Assessment Results*

Cochrane's Risk of Bias Assessment Tool was used to assess the articles. The results are presented in the table below:

Table 4: A table illustrating the Results of a risk of bias assessment conducted on the studies included in the systematic review

| **Type of Bias** | Selection Bias | Performance Bias | Detection Bias | Attrition Bias | Reporting Bias |
|---|---|---|---|---|---|
| **Low Risk** | 90 | 91 | 48 | 26 | 105 |
| **Moderate Risk** | 16 | 14 | 57 | 9 | |
| **Not applicable** | | | | 60 | |
| **Not clearly stated** | | | | 12 | |

## Summary of Findings

### *Economic Consequences*

Table 5: A table summarising the findings of the studies pertaining to economic consequences of childhood obesity

| Reference | Setting | Type of Study | Cost outcome | Primary Finding |
|---|---|---|---|---|
| Clifford et al. 2015 | Australia | Cost analysis | Medicare Expenditures | Higher expenditures for overweight and obese children |
| Hayes, Chevalier et al. 2016 | Australia | Cost analysis | Non-private healthcare expenditures | Higher expenditures for overweight and obese children; highest expenditures for underweight children |
| Kumar et al., 2023 | USA | Cost analysis | Private healthcare expenditures | Higher acute and outpatient expenditures for overweight and obese children |
| Janicke et al., 2010 | USA | Cost analysis | Private healthcare expenditures | Higher acute and outpatient expenditures for overweight and obese children |
| Kyler et al., 2023 | USA | Cost analysis | Medicaid healthcare costs | Higher total expenditures for overweight and obese children |
| Finkelstein and Trogdon, 2008 | USA | Cost analysis | Non-private healthcare expenditures | Higher outpatient and emergency room costs for overweight and obese children |
| Trasande and Chatterjee, 2009 | USA | Cost analysis | Non-private healthcare expenditures | Higher outpatient and emergency room costs for overweight and obese children |
| Ward et al., 2021 | USA | Cost analysis | Healthcare expenditures | Higher annual medical expenditures for oevrw3eight and obese children; higher population level excess cost |
| Sen et al., 2020 | USA | Cost analysis | Healthcare expenditures for lower income families | Higher inpatient and outpatient costs; progressively increasing expenditures |

| | | | | |
|---|---|---|---|---|
| Ma and Frick, 2011 | USA | Cost analysis | Simulation of healthcare costs | Population based savings at per capita cost savings per child |
| Sonntag et al., 2016 | Germany | Cost analysis | Indirect costs | Increased indirect costs of childhood obesity; costs savings to German population |
| Wenig, 2012 | Germany | Cost analysis | Healthcare costs | Increased costs for overweight and obesity; highest costs for underweight |
| Brero et al., 2023 | Mexico | Cost-of-illness analysis | Lifetime health and economic costs | Increased costs of childhood obesity; savings with obesity prevention intervention strategies |
| Meyerovitch et al., 2007 | Israel | Cost analysis | Healthcare utilisation | Higher average costs for children with obese BMI; increased physician visits and laboratory tests |
| Wenig et al., 2011 | Germany | Cost analysis | Pharmaceutical costs | Slightly higher pharmaceutical costs for overweight and obese children; highest costs for underweight children |
| Wong Ramsey et al., 2020 | USA | Cost analysis | Hospital admission outcomes | Longer hospital stay and cost of stay if overweight or obese |
| Kompaniyets et al., 2020 | USA | Cost analysis | Hospital admission outcomes | Shorter hospital stay if overweight or obese; higher mean charges and costs |
| Trasande et al., 2009 | USA | Cost analysis | Hospital admission outcomes with obesity as secondary diagnosis | Higher cost of stay |
| Woolford et al., 2007 | USA | Cost analysis | Hospital admission outcomes with obesity as secondary diagnosis | Higher cost of stay |
| Woolford et al., 2009 | USA | Cost analysis | Hospital admission outcomes with obesity as secondary diagnosis | Higher cost of stay |
| Fleming-Dutra et al., 2013 | USA | Cost analysis | Hospital utilisation costs for children presenting to | No significant differences (unless admitted with asthma or fractures) |

| | | | | |
|---|---|---|---|---|
| | | | emergency department | |
| Kirk et al., 2012 | Canada | Cost analysis | Healthcare utilisation and costs of obesity and associated medical conditions | Increased incidence of childhood illnesses; higher healthcare utilisation and costs |
| Jerrell and Sakarcan, 2009 | USA | Cost analysis | Healthcare expenditure of obesity hypertension | Higher total cost of health care |
| Okubo et al., 2018 | USA | Cost analysis | Healthcare expenditures associated with obesity and respiratory tract infections | Higher healthcare costs if overweight or obese |
| Okubo et al., 2018 | Japan | Cost analysis | Healthcare expenditures associated with obesity and respiratory tract infections | Lower hospitalisation costs if overweight or obese |
| Okubo et al., 2016 | USA | Cost analysis | Healthcare expenditures associated with obesity and acute asthma exacerbations | Higher inpatient costs if overweight or obese |
| Okubo et al., 2017 | Japan | Cost analysis | Healthcare expenditures associated with obesity and acute asthma exacerbations | Little difference in costs if overweight or obese |
| Murata et al., 2016 | Japan | Cost analysis | Healthcare expenditures associated with obesity and acute pancreatitis | Higher average costs if overweight or obese |
| Thavamani et al., 2020 | USA | Cost analysis | Healthcare expenditures associated with obesity and acute pancreatitis | Higher average costs if overweight or obese |
| Okubo and Handa, 2017 | USA | Cost analysis | Healthcare expenditures associated with obesity and urinary tract infections | Higher mean total hospital costs if overweight or obese |
| Kuhle et al., 2012 | Canada | Cost analysis | Healthcare expenditures associated with obesity and otitis media | Higher per capita physician costs in diagnosis and treatment if overweight or obese |

| | | | | |
|---|---|---|---|---|
| Ochoa-Moreno et al., 2024 | UK | Cost-of-illness analysis | Effect of Covid-19 on childhood obesity and associated costs | Increased lifelong cost owing to increase in childhood overweight rates |
| Carrello et al., 2021 | Australia | Cost analysis | Economic cost owing to lost productivity | Obese children result in increased costs owing to school absenteeism and lost carer productivity |
| Wright and Prosser, 2014 | USA | Cost analysis | Assessment of models used to calculate medical expenditures | Models may be overestimating costs of childhood obesity |

39 of the studies reported on the economic consequences of childhood obesity. Of these, 37 were cost analyses.

11 of the studies analysing the economic consequences of childhood obesity focused on assessing the healthcare costs of childhood obesity in various countries.

In Australia, multiple studies were conducted and yielded similar findings. Three of these studies, which focused on the Australian population on the Medicare scheme, found expenditures to be up to 14% higher for overweight and obese children, with a 12.92% cost-difference in non-hospital expenses (Clifford et al., 2015). Another study, not specifically focused on the population making use of private health insurance, further highlighted the higher costs of obese children in comparison to healthy weight children (4124 AUD vs 2516 AUD), however, demonstrated that underweight children still led in terms of healthcare expenditure (Hayes et al., 2016).

Studies conducted in the USA illustrated similar trends. Those focusing on private health care user found both outpatient and acute care expenditures to be higher, with total expenditures to be up to 909 USD higher and OOP expenditures 121 USD of this (Kumar et al., 2023; Janicke et al., 2010). The following factors were found to be associated with the highest spending: adolescent age, obesity co-morbid conditions, complex chronic conditions or mental health conditions (Kyler et al., 2023). Those not making use of private medical schemes showed similar trends, with up to 194 USD higher outpatient visit expenditures and 114 USD higher emergency room expenditures per year and total excess medical costs attributable to excess weight being approximately 180 USD (Finkelstein and Trogdon, 2008; Trasande and Chatterjee, 2009). The population level excess cost has been further estimated to be approximately 1.32 billion USD (Ward et al., 2021). Furthermore, a study conducted in Alabama focusing on costs for lower income families demonstrated that the average total costs (including inpatient, outpatient and emergency department care) have been progressively increasing (Sen et al., 2020).

With the increased costs, and rising rates of childhood obesity, a simulation conducted in the United States of America focused on determining the affordability of population-based interventions against targeted interventions. It estimated the per capita cost-savings per child, and found a population based intervention to be more cost-effective, with cost ranges between 280 USD and 339 USD per child as opposed to the targeted interventions (aimed only at children with abnormal weights) whose costs ranged between 1648 USD and 2735 USD per child (Ma and Frick, 2011).

Studies conducted in Germany also highlighted the increased indirect costs of childhood obesity, and further estimated the expected cost savings to the German population, if there is a 14% reduction in childhood obesity (which was deemed achievable based on other studies), would be 27 million Euros (Sonntag et al., 2016). However, a different cost-analysis suggested that being underweight is significantly more costly than obese in Germany, with the median costs per BMI being as follows: very underweight 572 Euros, underweight 274 Euros, normal weight 438 Euros, overweight 540 Euros, obese 443 Euros (Wenig, 2012).

Similar findings were demonstrated in middle-income countries. A modelled study conducted in Mexico estimated total lifetime health and economic costs of childhood obesity to be approximately 1.8 trillion USD, with potential savings of 124.3 billion USD if obesity prevention intervention strategies are implemented (Brero et al., 2023). In Israel, a study was also conducted to determine healthcare utilisation by children with increased BMI. It was determined that the average cost is approximately 6.6% higher for these children, with increased rates of physician visits and laboratory tests (Meyerovitch et al., 2007).

A study focusing specifically on pharmaceuticals in Germany illustrated that the mean pharmaceutical costs of overweight and obese children per year were 172 and 211 Euros respectively (Wenig et al., 2011). This was only slightly more than the cost of normal weight children (170 Euros) and less than those very underweight (392 Euros) or underweight (392 Euros) (Wenig et al., 2011).

Further studies have highlighted the increase costs associated with childhood obesity, if children are treated for other primary diagnoses.

In the United States, it was found that a child with obesity averaged a 15% longer hospital stay and 15% higher cost of stay (Wong Ramsey et al., 2020). Although another study found that children with a primary obesity diagnosis had lower average length of stay, the mean charges and costs were still significantly higher (Kompaniyets et al., 2020). Three other studies confirmed these findings, with higher costs of stays with children who had obesity as a secondary diagnosis (Trasande et al., 2009; Woolford et al., 2007; Woolford et al., 2009). A different study suggested that hospital utilisation costs for children presenting to the emergency department, regardless of whether or not they were admitted, were not significantly different (Fleming-Dutra et al., 2013). Admitted children with asthma or fractures did have slightly higher median costs, but were the only significant group (Fleming-Dutra et al., 2013).

In Canada, the increased incidence of certain childhood illnesses (internalising disorders, asthma, other respiratory disorders, otitis media, chronic adenoid/ tonsil disorder) in overweight and obese children resulted in not only higher health care utilisation, but higher health care costs for the treatment of these conditions (Kirk et al., 2012). Obesity hypertension was found to be associated with a higher total cost of health care in a study conducted in America (28 596 USD vs 15 242 USD) (Jerrell and Sakarcan, 2009).

With regards to childhood illnesses, respiratory disorders are a common presentation, and multiple studies have examined the correlation with obesity. A study conducted in the USA found the health care costs of obese children admitted with respiratory tract infections to be 383 USD higher on average (Okubo et al., 2018). This differed from findings in Japan, where overweight or obese children admitted with respiratory tract infections had lower mean hospitalisation costs that their normal weight or underweight counterparts (Okubo et al., 2018). Another study in the USA, focusing specifically on admissions with acute asthma exacerbations, found total inpatient costs for obese children to be 1588 USD higher than their non-obese counterparts (Okubo et al., 2016). This, again, differed from findings of a study conducted in Japan, which found a higher rate of readmission and longer length of stay, but little differences in total costs (Okubo et al., 2017).

A similar study conducted in Japan found that obesity also had an impact on the medical costs of children admitted with acute pancreatitis, whose average costs were almost 7000 USD higher (Murata et al., 2016). Two studies in the USA had similar findings, with total costs for treating AP being significantly higher for those with obesity (Thavamani et al., 2020). However, the average costs for a child with undernutrition was found to be even higher at 34 089 USD (Thavamani et al., 2020).

A different study demonstrated that obese children admitted with urinary tract infections had higher mean total hospital costs (Okubo and Handa, 2017). Obesity also resulted in higher per capita physician costs in the diagnosis and treatment of otitis media, according to a study conducted in Canada (Kuhle et al., 2012).

One of the studies went on to examine the effect of Covid-19 on childhood obesity, and suggested that the Covid-19 pandemic will result in a lifelong cost (including healthcare costs, productivity losses and losses in QoL) of 8691 billion GBP owing to increase in childhood overweight during this time (Ochoa-Moreno et al., 2024).

One study also focused on the economic consequences of lost productivity, estimating the costs of childhood obesity owing to school absenteeism and lost career productivity, and found that obese children missed an extra day of school per year, resulting in a national cost of approximately 64 million AUD (Carrello et al., 2021).

However, one study did go on to assess the models used to calculate medical expenditures, and found that different models may be overestimating the use of medical services by obese youths and suggested that the medical expenditures may not be significantly higher for those with childhood obesity (Wright and Prosser, 2014).

*Interventions*

Table 6: A table summarising the findings of the studies pertaining to interventions of childhood obesity

| Reference | Setting | Type of Study | Type of Intervention | Primary Finding |
|---|---|---|---|---|
| **Early Childhood Interventions** | | | | |
| Killedar et al., 2022 | Australia | Cost-effectiveness analysis | SMSing Health Beginnings Advice | Cost effective |
| Hayes et al., 2014 | Australia | Cost and cost-effectiveness analysis | Home visits implementing "Healthy Beginnings" | Cost effective |
| Brown et al., 2020 | Australia and New Zealand | Cost analysis | Various strategies to implement "Healthy Beginnings" | SMSing cheaper than standard interventions; cost-effective |
| Tran et al., 2022 | Australia | Cost-effectiveness analysis | Romp and Chomp: Healthy eating, active play, fruit and vegetable consumption, reduction in screen time | Cost effective |
| Tan et al., 2020 | Australia | Cost-effectiveness and cost-utility analysis | Prevention of overweight in infancy: Sleep, nutrition and physical activity | Sleep-only interventions more cost-effective than combined |
| Sonntag et al., 2019 | Germany | Cost-effectiveness analysis | Low-protein infant formula | Cost-effective |
| **School-Based Prevention** | | | | |
| Ohinmaa et al., 2011 | USA | Cost analysis | AVHPS Program: School-based lifestyle and activity program | Approximated costs of programs; further research required to determine efficiency |

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| Wright et al., 2014 | USA | Cost analysis | High Five for Kids: Motivational Interviewing | Approximated costs of programs; further research required to determine efficiency |
| Cradock et al., 2017 | USA | Cost-effectiveness analysis | 1. Active Physical Education (50% of time during PE be moderate-vigorous activity); 2. Active Recess (district-level, voluntary); 3. Active School Days (provide opportunities for 150 min of PA); 4. Healthy Afterschool (voluntary recognition program); 5. New Afterschool Programs (daily supervised programs); 6. Hip Hop to Health Jr (mandatory structured physical activity promotion) | Cost effective; daily supervised afterschool program most effective |
| Barrett et al., 2015 | USA | Cost-effectiveness analysis | Active Physical Education program | Cost-saving |
| Wang et al., 2008 | USA | Cost-effectiveness analysis | FItKid Project | Cost-effective |
| Brown et al., 2024 | Australia | Cost-effectiveness analysis | Increase in physical activity and reduction in sedentary behaviour | Overall healthcare cost savings |
| Kesztyüs et al., 2013 | Germany | Cost-effectiveness analysis | URMEL-ICE: Metabolism, exercise and lifestyle | Cost-effective |
| Gesell et al., 2013 | USA | Cost-effectiveness analysis | School-based vs community based physical activity program | School-based ineffective in increasing physical activity; Community-based program more costly but more effective |
| Jago et al., 2014 | UK | Cost-effectiveness analysis | Action 3:30: extracurricular physical activity intervention | Limited effect on physical activity |
| McAuley et al., 2010 | New Zealand | Cost-effectiveness analysis | APPLE project: A Pilot Program for Lifestyle and Exercise | Costly intervention; limited effectiveness |

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|---|---|---|---|---|
| Xu et al., 2020 | China | Cost-utility and cost-effectiveness analysis | Nutrition vs Physical activity vs combined nutrition and physical activity program | Combined program the only cost-effective one |
| Meng et al., 2013 | China | Cost-effectiveness analysis | Nutrition vs Physical activity vs combined nutrition and physical activity program | Combined program the only cost-effective one |
| Zanganeh et al., 2021 | China | Cost-effectiveness analysis | CHIRPY DRAGON intervention | Cost-effective |
| Carter et al., 2009 | Australia | Cost-utility and cost-effectiveness analysis | 1. Active After School Communities Program; 2. Multi-faceted program (including education to improve nutrition and increase physical activity, without an active physical education component); 3. Multi-faceted program (including education to improve nutrition and increase physical activity, with an active physical education component); 4. Multi-faceted program targeted at overweight and obese children; 5. Education program to reduce consumption of carbonated (fizzy) drinks; 6. Education program to reduce TV viewing; 7. TravelSmart Schools; 8. Walking school bus; 9. Reduction of TV advertising of high fat and/ or high sugar foods & drinks to children; 10. Family-based GP program targeted at overweight and moderately obese children; 11. Family-based targeted program for obese children; 12. Orlistat therapy for obese adolescents; 13. | Most cost-saving interventions: program focussing on nutrition and physical activity with an active component; a program to encourage reduction of carbonated beverage consumption; education program targeted on reducing television viewing |

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| | | | Laparoscopic adjustable gastric banding (LAGB) for morbidly obese adolescents | |
| Graziose et al., 2017 | USA | Cost-effectiveness analysis | School-based nutrition program | Cost-effective |
| Ladapo et al., 2016 | USA | Cost and cost-effectiveness analysis | SnAX | Costs of changing behaviours determined |
| An et al., 2018 | USA | Cost-benefit analysis | Plain water access intervention | Lifetime cost-savings |
| Kenney et al., 2019 | USA | Cost-effectiveness analysis | 1. Installation of water jet dispensers on school cafeteria lunch lines; 2. Grab a Cup, Fill It Up: promotional signage and permanent cup dispensers; 3. Portable Water Dispensers; 4. Bottle-less water coolers; | Installing water jets is cost saving |
| Vieira and Carvalho, 2019 | Portugal | Cost-effectiveness analysis | "Planning Health in School" program | Cost-effective |
| Conesa et al., 2018 | Spain | Cost-effectiveness analysis | Lifestyle education | Cost-effective |
| Kesztyüs et al., 2017 | Germany | Cost-effectiveness analysis | "Join the Healthy Boat" | Cost-savings |
| Kalavainen et al., 2009 | Finland | Cost-effectiveness analysis | Family-based group treatment | Group treatments cost-saving in comparison to individualized sessions |
| Canaway et al., 2019 | UK | Cost-effectiveness analysis | WAVES: School-based intervention (school based physical activity; dietary activity; 6-week programme from a sporting institution; family signposting) | Not cost-effective |
| Adab et al., 2018 | UK | Cost-effectiveness analysis | WAVES | Not cost-effective |
| Poole et al., 2023 | USA | Cost analysis | BMI report cards | Negative cases of obesity prevented |
| **Family-Based Prevention** | | | | |
| Jordan et al., 2019 | USA | Budget-impact analysis | FCU for Health: Family check-up program | Implementation costs determined |

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| Pryor et al., 2023 | USA | Cost-effectiveness analysis | Bright Bodies: high-intensity family-oriented intervention | Cost-effective |
| Quattrin et al., 2017 | USA | Cost-effectiveness analysis | Group parent and one-on-one counselling: targeting diet, lifestyle activity, self-monitoring and positive reinforcement; Compared to Information Control Group | More cost-effective than child-only intervention |
| Borner et al., 2016 | USA | Cost-effectiveness analysis | Family-based behavioural interventions | Positive return on investment |
| Raynor et al., 2002 | USA | Cost analysis | Families attending meetings focussing on diet, activity and behavioural principles (group and individual vs group) | Combined group and individual session as effective as group-only sessions |
| Janicke et al., 2009 | USA | Cost-effectiveness analysis | Family-based (group sessions focussing on diet and physical activity, attend by parent-child dyads); Parent only (group meetings with parents only) | Parent-only interventions more cost-effective |
| Boutelle et al., 2021 | USA | Cost-effectiveness analysis | Family based treatment vs Parent only treatment | Family based treatment more costly with similar effectiveness |
| Epstein et al., 2014 | USA | Cost-effectiveness analysis | Family based group treatment (fifteen 60-minute sessions with parent and child together, focussing on diet, activity and behaviour change) vs. parent-centred | Parent-only intervention more cost-effective |
| Robertson et al., 2012 | UK | Cost-effectiveness analysis | "Families for Health": 12 week program with parallel groups for parents addressing parenting skills, healthy lifestyles and emotional well-being | Less cost-effective than alternative programs |
| Robertson et al., 2017 | UK | Cost-effectiveness analysis | "Families for Health" | Not cost-effective |
| Robertson et al., 2017 | UK | Health technologies assessment | "Families for Health" | Not cost-effective |

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|---|---|---|---|---|
| Lier et al., 2020 | Germany | Cost-effectiveness analysis | Family-based multicomponent treatment | Cost-effective |
| Anderson et al., 2018 | New Zealand | Cost-effectiveness analysis | Home-based 12 month multidisciplinary obesity prevention program: High intensity (weekly sessions for 12 months with home-based assessments and advice); Low intensity (home-based assessments and advice only) | Cost-effective |
| **Primary Care Based** | | | | |
| Smith et al., 2023 | USA | Cost analysis | Connect for Health: clinical decision support, educational handouts, and community resources. | Costs determined; further studies needed to determine effectiveness |
| Woolford et al., 2022 | USA | Cost-effectiveness analysis | Motivational interviewing vs. standard primary care practises | Cost-effective |
| Wake et al., 2008 | Australia | Cost-consequence analysis | LEAP (Live, Eat and Play): secondary prevention intervention delivered by family physicians | Not cost-effective |
| Moodie et al., 2008 | Australia | Cost-effectiveness | LEAP trial | Cost-effective from a societal perspective |
| **Active Lifestyle** | | | | |
| Moodie et al., 2010 | Australia | Cost-effectiveness analysis | "Active After School" community program | Not cost-effective |
| Moodie et al., 2011 | Australia | Cost-effectiveness analysis | TravelSMART Schools Curriculum Program: Increase in active transport | Not cost-effective |
| Larsen et al., 2017 | Denmark | Cost-effectiveness analysis | Day-camp (physical activity; health education; healthy meals) | Not cost-effective |
| Moodie et al., 2013 | Australia | Cost-effectiveness analysis | Be Active Eat Well Program | Cost-effective |
| **Sleep Interventions** | | | | |
| Killedar et al., 2023 | Australia | Cost-effectiveness analysis | 1. Primary prevention: sleep intervention; 2. Primary prevention: | Sleep interventions found to be the most cost-effective |

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| | | | sleep intervention combined with food, physical activity, breastfeeding; 3. Treatment: obesity related-behaviours | |
| Killedar et al., 2023 | Australia | Cost-effectiveness and cost-utility analysis | Early childhood sleep intervention | Cost-effectiveness dependent on socio-economic position |
| **Policy Changes** | | | | |
| Wright et al., 2015 | USA | Cost-effectiveness analysis | Hypothetical state-level regulatory policy: Beverage component (freely available water; SSBs replaced with water; limitation of 100% juice; whole milk replaced with reduced-fat milk); Physical activity component (at least 90 minutes of moderate to vigorous physical activity (MVPA) per day); Screen time component (limited to 30 minutes per week) | Cost-effectiveness with potential cost savings |
| Kenney et al., 2021 | USA | Cost-effectiveness analysis | Reduction in television (1. Eliminating TV advertisement tax subsidy; 2. Home visits; 3. Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) motivational interviewing to reduce television time; 4. Fit5Kids child care curriculum to reduce television time at home; 5. Policy to reduce TV time in licensed early child care and education (ECE) settings) | Eliminating TV advertising tax subsidy found to be most cost-effective |
| Brown et al., 2018 | Australia | Cost-effectiveness analysis | Legislation to implement time-based restrictions of unhealthy food and beverage marketing to | Total net cost-savings |

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|---|---|---|---|---|
| | | | children under 16 years of age on FTA TV until 9:30 pm | |
| Carter et al., 2009 | Australia | Cost-effectiveness analysis | As above | Unhealthy food advertising is cost-effective |
| Magnus et al., 2009 | Australia | Cost-effectiveness analysis | Extension of existing regulations within Children's Television Standards to preclude advertising for EDNP foods, as well as for beverages and fast food outlets, during specified children's TV viewing hours | Cost-effective |
| Sonneville et al., 2015 | USA | Cost-effectiveness analysis | Elimination of the tax subsidy of TV advertising costs for nutritionally poor foods and beverages advertised to children and adolescents | Cost-effective |
| Lee et al., 2024 | USA | Cost-effectiveness analysis | $0.02/oz SSB excise tax | Net-cost savings |
| **Treatment** | | | | |
| Killedar et al., 2023 | Australia | Cost-effectiveness analysis | As above | More costly than alternative interventions |
| Hollinghurst et al., 2014 | UK | Cost-effectiveness analysis | Mandometer | Primary care interventions more cost-effective |
| Bandurska et al., 2020 | Poland | Cost-effectiveness analysis | 6-10-14 for Health Weight Management Program (screening; specialist care; parental education; specialist consultations) | Cost-effective |
| Spoor et al., 2013 | UK | Cost analysis | WATCH IT Program | Determined cost of intervention; further studies needed to determine effectiveness |
| Hollingworth et al., 2012 | UK | Cost-effectiveness analysis | Lifestyle interventions | Cost-effective; benefits noticeable in later years |
| Makkes et al., 2017 | Netherlands | Cost-effectiveness | Intensive inpatient lifestyle treatment (nutrition, physical activity and behaviour change) | Not cost-effective |

### Early Childhood Interventions

Multiple studies conducted in Australia have assessed "Healthy Beginnings" advice. One assessed the costs of SMSing the advice to pregnant women up to 2 years of age, and it was calculated to be 979 AUD per 0.1 BMI-z score avoided (Killedar et al., 2022). Home visits were also found to be effective with an ICER of 607 AUD per 0.1 BMI unit avoided (Hayes et al., 2014). Another study found that promoting the advice by SMS was cheaper than standard implementation owing to saving time costs (Brown et al., 2020).

Further research went on to examine the cost-effectiveness of an intervention focused on promoting healthy eating, active play, fruit and vegetable consumption and reduction in screen time in children aged 0 to 5 years old and found this to be effective with an ICER of 1126 AUD per BMI unit avoided and 26 399 AUD per QALY gained (Tran et al., 2022). However, a different study in Australia examining a program focusing on preventing overweight in infancy (specifically targeting sleep, nutrition and physical activity interventions) found a sleep-only intervention to be more cost-effective than a combined intervention (Tan et al., 2020).

Low-protein infant formula was also found to be a cost-effective intervention in Germany, with a net monetary benefit of 750 Euros with willingness to pay of 0 Euros (Sonntag et al., 2019).

### 3.2.2.2 School-Based Prevention

Two cost analyses studies were conducted in the USA and found that implementing a school-based lifestyle and activity program (AVHPS) would cost approximately 7830 USD per school in direct public funding (Ohinmaa et al., 2011). The High Five for Kids motivational interviewing program was found to cost an additional 196 USD per child (Wright et al., 2014).

Multiple other studies examining school-based physical activity programs have been conducted in USA. An analysis comparing various school-based interventions found childhood obesity prevention programs targeting physical activity to be cost-effective, with the most cost-effective being daily supervised afterschool programs involving 2 hours of physical activity (Cradock et al., 2017). Another study examining the Active Physical Education program estimated a 10-year healthcare cost-saving of 60.5 million USD for the program (Barrett et al., 2015). A similar study in the USA examining the FitKid Project showed that the program had an ICER of 317 USD per 0.76% decrease in body fat percentage, below the cost-effectiveness threshold (Wang et al., 2008).

Focussing on increasing physical activity and reduction in sedentary behaviours in schools was also found to be cost-effective in a trial conducted in Australia, with estimated healthcare cost savings of 641M AUD for physical activity increase and 654M AUD for reduction in sedentary behaviour (Brown et al., 2024). A cost-effectiveness analysis conducted in Germany also found that the URMEL-ICE intervention, focussing on metabolism, exercise and lifestyle, to be cost effective (Kesztyüs et al., 2013).

A few studies did, however, have contrasting findings. A study conducted in the USA found a school-based physical activity program to be ineffective in increasing children's physical activity (Gesell et al., 2013). The community program was slightly more costly (19.25 USD per participant, compared to 17.67 USD per participant) but did bring positive change (Gesell et al., 2013). A similar study in the UK, analysing the feasibility of the Action3:30 extracurricular physical activity intervention, found the program to have an extremely limited effect on physical activity and BMI (Jago et al., 2014). In New Zealand, the APPLE project found no significant change to HUI, suggesting a costly intervention with limited quality of life improvement (McAuley et al., 2010).

Two studies conducted in China found combined nutrition and physical activity programs to be the only interventions with net savings and significant changes to BMI (Xu et al., 2020; Meng et al., 2013). The CHIRPY DRAGON intervention was assessed in multiple studies and found to be cost-effective with a cost of 8 888 Yuan per QALY gained or 1760 GBP per QALY (Zanganeh et al., 2021).

A study comparing various childhood obesity interventions in Australia illustrated similar findings, with the most cost-saving interventions being a program focussing on nutrition and physical activity with an active component (14M AUD), a program to encourage reduction of carbonated beverage consumption (26.7M AUD) and an education program targeted on reducing television viewing (43.8M AUD) (Carter et al., 2009).

Programs focussing on nutrition only were also found to be cost-effective in a few studies. A cost-effectiveness analysis conducted in USA found a school-based intervention focussing on nutrition to have a ICER of 275 USD per QALY, well below the threshold of 50 000 USD per QALY (Graziose et al., 2017). Another nutrition based program in the United States (SnAX) found that the costs of changing nutritional behaviours in a school cafeteria using a 5-week program are as follows: 1.20 USD per additional fruit serving; 8.43 USD per additional full priced lunch served; 2.11 USD per additional free/reduced-priced lunch served; 1.69 USD per reduction in snacks sold (Ladapo et al., 2016).

A few studies also examined programs focussing specifically on targeting increasing water consumption in the USA. One found that placing water dispensers in school cafeterias may result in a net benefit of 174 USD per student, with lifetime cost savings coming to 13.1 billion USD (An et al., 2018). Another study examining interventions targeting increasing water consumption estimated that installing water jets in school cafeterias could save 0.31 USD per dollar invested (Kenney et al., 2019)

In Europe, multiple programs focussed on overall healthy lifestyle were assessed. In Portugal, the “Planning Health in School” program was found to effectively reduce BMI and WC in adolescents, with a net cost of 36.14 Euros per capita (significantly less than the obesity attributable medical costs of 3849.15 Euros per adult per year) (Vieira and Carvalho, 2019). In Spain, a school-based program focussing on lifestyle education was found to be cost-effective with a cost of 968.66 Euros to avoid one case of obesity, and 44.68 Euros to decrease BMI by one unit (Conesa et al., 2018). A similar study in Germany, examining the “Join the Healthy Boat” lifestyle program for primary school children, found the cost of obesity case averted to range between 1515 Euros and 1993 Euros (Kesztyüs et al., 2017). Group treatments in schools were found to be cost-saving in comparison to individualised counselling sessions in a study conducted in Finland (Kalavainen et al., 2009).

Findings were contradicting in studies conducted in the UK. One study conducted to determine the cost-effectiveness of a school-based intervention on quality of life and was found to have an ICER of 26 815 GBP per QALY (Canaway et al., 2019). A different study (WAVES) found another intervention to be ineffective, with an ICER of 46 083 GBP per QALY (Adab et al., 2018).

A societal cost study conducted in the USA illustrated that BMI report cards are an ineffective method of addressing childhood obesity, with implementation costs of 115 million USD but negative cases of obesity prevented (Poole et al., 2023).

#### 3.2.2.3 Family-Based Prevention

One budget impact analysis conducted in USA found that the implementation costs of a FCU for Health (a family check-up program) amounted to approximately 60 589 USD per site, with replication costs of 16 475 USD per site (Jordan et al., 2019).

Multiple other studies assessed the cost-effectiveness of various family-based interventions in USA. Bright Bodies, a high-intensity family-based intervention was found to have savings in healthcare expenditure associated with obesity of 1126 USD and cost savings per person 766 USD (Pryor et al., 2023). It further demonstrated an ICER of per BMI point decrease of 363 USD (Pryor et al., 2023). A different study assessing an intervention which focussed on group parenting and one-on-one counselling found the cost per % BMI decrease to be approximately 116 USD in comparison to information based child-only intervention (Quattrin et al., 2017). Another study in the USA found the internal rate of return on family-based group interventions to be negative with more conservative models, but did have a positive return on investment (Borner et al., 2016). A study examining a family based intervention illustrated that combined group and individual sessions are as effective at bringing about dietary changes as group-only sessions (Raynor et al., 2002).

This, however conflicted with results from other studies which suggested that parent-only interventions are more cost-effective. A study conducted in rural counties in USA suggested that parent-only interventions are more cost-effective with ICERs (cost per 0.2 decrease in BMI score) of 758 USD and 579 USD respectively (Janicke et al., 2009). Another study had similar results, where two interventions with similar effectiveness were compared, but the family-based treatment was found to cost 4279 USD per child-parent dyad, while the parent-only based treatment cost 3231USD per child parent dyad (Boutelle et al., 2021). This differed from the results of a study conducted in USA, which had an ICER of 209.17 USD per percent-BMI-change in the parent and child intervention, but ICERS of 1036.50 USD and 973.98 USD respectively for the parent-centred interventions (Epstein et al., 2014).

Studies conducted in the United Kingdom highlighted that family-based interventions are not the most cost-effective treatment strategies for childhood obesity. "Families for Health" focusses on a 12-week group program, and was found to have a cost per reduction BMI unit to be 2543 GBP (Robertson et al., 2012). Another study assessing the cost-effectiveness of the "Families for Health" intervention found the ICER to be 552 175 GBP per QALY gained, above the determined cost-effectiveness ratio (Robertson et al., 2017). The lack of cost-effectiveness of the Families for Health intervention was confirmed with a health technologies assessment, which found the ICER per QALY gained to be 511.68 GBP more in comparison to usual care from an NHS and PPS perspective, and 518.30 GBP more from a societal perspective (Robertson et al., 2017).

A study in Germany had different results, with a family-based multicomponent treatment, which found the ICER to be 2367 Euros per BMI-SDS reduction of greater than 0.25, with a return on investment of between 3.3 and 7% (Lier et al., 2020).

In New Zealand, a cost-effectiveness analysis was conducted comparing a home-based multidisciplinary program with conventional childhood obesity prevention methods (Anderson et al., 2018). The program was found to be more affordable, with mean costs per child of 859.22 NZD and 1642.70 NZD for the low and high intensity programs as opposed to 1798.12 NZD for the conventional method of prevention (Anderson et al., 2018). The mean BMI SDS reduction was also slightly better for the home-based program at 0.08, compared to 0.05 for the conventional program (Anderson et al., 2018).

#### 3.2.2.4 Primary Care Based

Multiple studies have examined various primary care based interventions. "Connect for Health", aimed at clinical decision support, educational handouts, and community resources had various costs of implementation per district, ranging from 77 103 USD to 142 721 USD (Smith et al., 2023). A study comparing motivational interviewing to standard primary care practices illustrated an intervention cost of 1051 USD per two years, with an ICER of 363 USD per BMI percentile point decrease (Woolford et al., 2022).

A cost-consequence analysis conducted in Australia assessed the LEAP (Live, Eat and Play) trial, a secondary prevention intervention delivered by family physicians in Australia, and found it to be ineffective with a cost of 4094 AUD with only a -0.03 change in BMI score (Wake et al., 2008). The LEAP trial also underwent a cost-effectiveness analysis from a societal perspective, and was found to be cost-effective with a net cost per DALY saved of 4670 AUD (Moodie et al., 2008).

#### 3.2.2.5 Active Lifestyle

Programs focusing specifically on active lifestyle were, in general, found to not be cost-effective.

Australia's government launched an childhood obesity prevention program focusing on promoting after school physical activity, however, the net cost per DALY saved was found to be 82 000 AUD, above the 50 000 AUD threshold (Moodie et al., 2010). A study focusing specifically on active transport to school illustrated that focusing on active transport is also not cost-effective, with a net cost per DALY saved found to be 117 000 AUD (Moodie et al., 2011). A day-camp intervention in Denmark was also found to be costly, with an ICER per point decrease in BMI of 24 928 DDK (Larsen et al., 2017).

Only one program, the Be Active Eat Well program, which encouraged healthy eating and an active lifestyle in 4 to 12 year olds was found to be affordable with a net cost per DALY saved of 9 798 AUD (Moodie et al., 2013).

#### 3.2.2.6 Sleep Interventions

Sleep interventions were, in general, found to be cost-effective. In Australia, two primary prevention strategies were sleep interventions, one of which also involved other lifestyle interventions, and were determined to cost approximately 184 AUD and 601 AUD respectively, with both showing a net health benefit of 0.003 QALYs (Killedar et al., 2023). Another study conducted in Australia found that the cost-effectiveness of sleep interventions is dependent on socioeconomic position, with the ICER per unit BMI avoided and QALY gained being lowest in the mid-socioeconomic position group, at 806 AUD and 18 206 AUD respectively (Killedar et al., 2023).

#### 3.2.2.7 Policy Changes

Reduction of screen time through policy changes has been found to be cost-effective through multiple studies.

In the USA, a combined policy-change intervention focusing on reducing screen time and sugar-sweetened beverage consumption, as well as increasing physical activity, would have an ICER of approximately 57.8 USD per BMI unit avoided and potential cost savings of 51.6 million USD (Wright et al., 2015).

Specific focus on limiting advertising of unhealthy foods was found to be effective. A study examined 5 interventions and projected that eliminating the TV advertising tax subsidy would be the most effective at reducing childhood obesity incidence with the net costs calculated to be -149 million USD (Kenney et al., 2021). A study conducted in Australia further demonstrated that legislation to implement time-based restrictions of unhealthy food and beverage marketing resulted in total net-cost savings of approximately 777.6 million AUD (Brown et al., 2018). A study comparing various childhood obesity interventions demonstrated similar results, with an estimated cost-saving of 299 million AUD with the reduction of unhealthy food advertising (Carter et al., 2009). A similar study conducted in Australia illustrated that removing unhealthy TV food-advertising to children has an ICER of 3.70 AUD per DALY saved, and is therefore cost-effective (Magnus et al., 2009). Reduction of unhealthy food advertising was also found to be cost-effective in USA, with a model suggesting that such an intervention may lead to 352 million USD in healthcare cost savings over 10 years and a total increase of 4540 QALYs (Sonneville et al., 2015).

Another study focusing on sugar-sweetened beverage tax found that implementation of 0.02 USD/oz SSB excise tax could result in net cost-savings of -4.5 billion USD, while preventing 42 700 cases of childhood obesity and a gain of 114 000 QALYs over a 10 year period (Lee et al., 2024).

#### 3.2.2.8 Treatment

In Australia, a treatment intervention involving targeting "obesity-related behaviors" at paediatric practices was found to be ineffective, costing approximately 231 AUD per child and resulting in a net health benefit of 0.007 QALYs (Killedar et al., 2023). In the UK, an assessment of the Mandometer found that that although costly technologies are often effective, and may be an alternative treatment, primary care interventions are generally deemed more cost-effective (Hollinghurst et al., 2014). Similar conclusions were drawn from a study in Poland, which assessed the 6-10-14 for Health Weight Management Program and was found to be most cost-effective when removing children from the >90$^{th}$ and >95$^{th}$ percentile groups, with ICERS of 19 624 and 23 691 respectively (Bandurska et al., 2020).

Another study in the United Kingdom found the costs to implement the WATCH IT Program (a non-health-professional community-based obesity treatment program) as follows: cost per patient 858.12 GBP without including venue costs, which added up to 396.82 GBP per patient (Spoor et al., 2013).

An economic evaluation of lifestyle interventions targeting obesity found a discounted cost of 13 589 GBP per life year gained, however these benefits were only noticeable in later years (Hollingworth et al., 2012).

A study conducted in the Netherlands assessed the effectiveness of inpatient childhood obesity treatment programs and concluded that a short-term inpatient program had ICERs of 1 479 463 Euros per SDS BMI; 344 744 Euros per QALY (Makkes et al., 2017). This program was, therefore, also found to be costly.

## DISCUSSION

This review set to assess the availability and quality of existing economic evaluations involving childhood obesity. As stated in the results section, many studies were available, and none were excluded owing to them being of inadequate quality.

It also went on to assess the methodologies used for different economic evaluations. The types of the studies included were as follows: 47 cost-effectiveness analyses, 45 cost analyses, 4 combined cost-effectiveness and cost-utility analyses, 3 combined cost and cost-effectiveness analyses, 2 cost-of-illness analyses, 2 cost-consequence analyses, 1 budget impact analysis.

The review also aimed to assess the setting of the studies available and their applicability to a South African setting. As per the results tables included in the appendices, all of the studies have been conducted in high- or middle-income countries. 46 of the 105 studies were conducted in the United States of America, 23 in Australia and New Zealand and 10 in the United Kingdom. South Africa is currently classified as an upper-middle income country as per the WorldBank. The only countries represented by the studies with the same classification are China and Mexico. The setting of the studies therefore limits their applicability to a South African context.

The review also sought to describe the findings of the included studies, and to identify and analyse any differences which may exist across the different studies. The findings of the studies have been described in the results section, and the differences compared and contrasted.

Multiple included studies highlighted the higher healthcare expenditures of overweight and obese children (Clifford et al., 2015; Black et al., 2018; Au, 2018; Hayes et al., 2016). Both outpatient and emergency care expenditures were found to be higher in these groups, and the trends were found in those using both private and public medical schemes (Kumar et al., 2023; Janicke et al., 2010; Ward et al., 2021; Finkelstein and Trogdon, 2008; Trasande and Chatterjee, 2009). The following factors were found to be associated with the highest spending: adolescent age, obesity co-morbid conditions, complex chronic conditions or mental health conditions (Kyler et al., 2023). Furthermore, costs have been found to be progressively increasing (Sen et al., 2020). Studies also demonstrated the increased indirect and lifetime costs associated with childhood obesity (Sonntag et al., 2016). This was found in high- and middle-income countries (Brero et al., 2023; Meyerovitch et al., 2007).

Further studies have highlighted the increased costs associated with childhood obesity during treatment for other primary diagnoses. This is generally owing to increased length of stay and mean charges (Kirk et al., 2012; Jerrell and Sakarcan, 2009; Okubo et al., 2018; Murata et al., 2016; Thavamani et al., 2020; Okubo and Handa, 2017; Kuhle et al., 2012; Wong Ramsey et al., 2020; Woolford et al., 2007; Woolford et al., 2009; Okubo et al., 2016). One study did, however, demonstrate that hospital utilisation costs for children presenting to the emergency department, regardless of whether or not they were admitted, were not significantly different (Fleming-Dutra et al., 2013). Two studies in Japan also found that overweight or obese children admitted with respiratory disorders had either similar or lower mean hospitalisation costs that their normal weight or underweight counterparts (Okubo et al., 2018; Okubo et al., 2017). Loss of productivity was found to be another cost of childhood obesity (Carrello et al., 2021).

One must, however, note that one study did go on to assess the models used to calculate medical expenditures, and found that different models may be overestimating the use of medical services by obese youths, suggesting that the medical expenditures may not be significantly higher for those with childhood obesity (Wright and Prosser, 2014).

Various childhood obesity interventions were also analysed in many of the included studies. Early childhood interventions were, in general, found to be financially viable. Home visits and SMSing pregnant mothers were two methods assessed, and although both were deemed cost-effective, SMSing was found to be more so (Killedar et al., 2022). One study did, however, suggest that a sleep only intervention in infancy is more cost-effective than a combined intervention(Tan et al., 2020). Focus on healthy eating, active play, fruit and vegetable consumption and reduction in screen time in children aged 0 to 5 years old was also found to be cost-effective (Tran et al., 2022). Specific focus on low-protein infant formula was proven to be a cost-effective intervention (Sonntag et al., 2019).

School-based prevention and intervention strategies were also assessed. Many of these assessed programs targeting physical activity, and majority of these studies found these programs to be cost saving (Cradock et al., 2017). Few did have conflicting findings, with the assessed programs being deemed ineffective and costly (Gesell et al., 2013). Programs focussing on nutrition were also found to be cost-effective in a few studies (Graziose et al., 2017). Specific focus on water consumption was another intervention examined and, in general, found to effectively reduce BMI at appropriate costs (An et al., 2018; Kenney et al., 2019). Other studies assessed combined nutrition and physical activity programs, and majority were also found to be economically beneficial (Xu et al., 2020; Meng et al., 2013; Zanganeh et al., 2021). Lifestyle education is also a means of promoting health behaviours, and programs focussing on nutrition were found to be cost-effective in a few studies (Ladapo et al., 2016; Graziose et al., 2017). Two studies did have contrasting findings, however, suggesting that not all lifestyle interventions are equally effective (Adab et al., 2018; Canaway et al., 2019). BMI report cards were found to be another ineffective method of addressing childhood obesity (Poole et al., 2023).

Family-based prevention is also a means of addressing childhood obesity. Conflicting results were found when assessing these interventions, as some found group-based family sessions to be more cost-effective, other suggested that parent-only programs were more cost-effective (Raynor et al., 2002; Janicke et al., 2009; Borner et al., 2016; Quattrin et al., 2017; Boutelle et al., 2021). Others suggested that family-based interventions are not economically beneficial in comparison to standard treatment (Robertson et al., 2012; Robertson et al., 2017; Robertson et al., 2017). Home-based multidisciplinary programs were found to be cost-effective in one study (Anderson et al., 2018).

Primary care interventions are another means of addressing childhood obesity. Motivational interviewing was one intervention found to be cost effective in comparison to standard practices (Woolford et al., 2022). However, secondary prevention through family physicians was determined to be ineffective (Wake et al., 2008).

Programs focusing specifically on active lifestyle were, in general, found to be costly with limited effect on childhood obesity (Moodie et al., 2010; Moodie et al., 2011; Larsen et al., 2017). Only one study, assessing the Be Active Eat Well Program, was found to be affordable (Moodie et al., 2013). Sleep interventions were, on the other hand, found to be cost-effective (Killedar et al., 2023; Killedar et al., 2023). Similar findings were found with studies assessing interventions in the early childhood period.

Policy changes are another method of addressing childhood obesity on a wide scale. Reduction of screen time through policy changes has been found to be cost-effective through multiple studies (Wright et al., 2015). Specific focus on limiting advertising of unhealthy foods was also found to be effective (Carter et al., 2009; Magnus et al., 2009; Sonneville et al., 2015; Brown et al., 2018; Kenney et al., 2021). Taxation on sugar-sweetened beverages was also found to be cost-saving on a population level (Lee et al., 2024).

Treatment of childhood obesity was often found to be more costly than prevention, with technologies being effective but expensive (Hollinghurst et al., 2014; Killedar et al., 2023). Inpatient programs were found to follow similar trends (Makkes et al., 2017).

There are, therefore, clear gaps in knowledge. Further research is needed in comparing different types of interventions, as most focus on assessing a specific type and very little compare between groups. Furthermore, the studies are largely based in high- and middle-income countries, and very little focus on developing countries. Limited research on specific treatments has been conducted.

## CONCLUSION

It is, therefore, evident that childhood obesity is a pressing health concern. There is available research around the economic impact thereof, and the evidence highlights the higher cost faced by children diagnosed with obesity. Various interventions have been studied, with regards to their effectiveness at managing this illness. Early childhood interventions and school-based programs seemed to have the most supporting evidence regarding their economic benefits, however, further research is needed to determine their comparative effectiveness and their effectiveness in setting with fewer research.

## DECLARATIONS

### Ethics Approval and Consent to Participate

Owing to systematic reviews not involving primary data or animal or human subjects, ethics approval was not required. This was confirmed through submission to the School of Public Health Research Committee at the University of Cape Town.

### Consent for Publication

Not applicable

### Availability of data and materials

All data and materials used during this study are available on the mentioned databases.

## Competing interests

No competing interests are noted in the undertaking of this review.


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# PART D: POLICY BRIEF

## A Systematic Review of Economic Evaluations Involving Childhood Obesity

### About the Study

The study conducted was a systematic review of economic evaluations involving childhood obesity. It included studies assessing the economic effects of childhood obesity, as well as assessment of interventions targeting this health concern. Owing to the rising rates of childhood obesity, and the long-term consequences thereof, this review aimed to highlight the financial implications thereof and assess the costs and cost-effectiveness of the various methods used to address this public health concern. It further aimed to identify further research needed in this area. This would assist in advising policy makers not only on the need for interventions and the cost-effectiveness thereof but identify gaps for further targeted research.

***What economic evaluations involving childhood obesity are available, and what do the findings thereof suggest?***

### Introduction

The World Health Organisation has recently highlighted the growing rates of childhood and adolescent obesity indicating that it is a rising public health concern globally (World Health Organisation, 2021). Childhood obesity is also associated with many negative health outcomes, which can extend into adulthood (World Health Organisation, 2021). The negative outcomes of childhood obesity, both in youths and adults, place substantial economic burden on individuals and families. Effective interventions are, therefore, needed to address this concern.

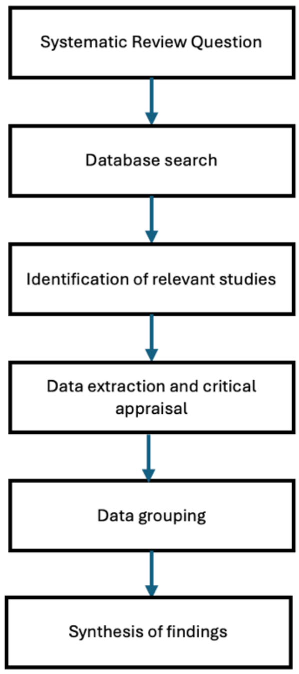
The increasing rates of childhood obesity in developing countries further highlights the need for research around the economic implications, owing to the limited resources available in these settings (World Health Organisation, 2021).

## Methods

A search was conducted on PubMed for economic evaluations involving childhood obesity. The initial PubMed search rendered 3733 results. From these, 813 were found to be eligible for full-text screening. Using the review's inclusion and exclusion criteria, 105 were found to be eligible for inclusion in the systematic review.

The included studies were downloaded and stored on OneDrive according to title. Characteristics of all screened articles were recorded in Excel. References were stored in EndNote 21. Data was extracted using Microsoft Excel, with data extraction tables being designed to capture data relevant to the objectives of the study. All included studies also underwent a risk of bias and quality assessment. Analysis was performed by the primary reviewer.

Figure 1 Flow Diagram of Conceptual Framework for Systematic Literature Review



## Key Findings

- Of the studies included, 39 assessed the economic consequences of childhood obesity, with 27 focusing on healthcare costs thereof. The other studies were largely cost-effectiveness analyses of various interventions.
- The various types of studies noted were as follows: cost-effectiveness analyses, cost analyses, combined cost-effectiveness and cost-utility analyses, combined cost and cost-effectiveness analyses, cost-of-illness analyses, cost-consequence analyses and a budget impact analysis.
- With regards to the setting, all of the studies were conducted in high- or middle-income countries. South Africa is currently classified as an upper-middle income country, as per the WorldBank, and the only countries represented by the studies with the same classification are China and Mexico. The setting of the studies therefore limits their applicability to a South African context.
- Multiple studies highlighted the higher healthcare expenditures of overweight and obese children (Clifford et al., 2015; Black et al., 2018; Au, 2012; Hayes et al., 2016). Both outpatient and emergency care expenditures were found to be higher in these groups, and the trends were found in those using both private and public medical schemes (Kumar et al., 2023; Janicke et al., 2010; Ward et al., 2021; Finkelstein and Trogdon, 2008; Trasande and Chatterjee, 2009). Higher inpatient costs for patients admitted with other primary diagnoses, but having obesity as a secondary diagnosis, was also noted owing to increased length of stay and mean charges (Kirk et al., 2012; Jerrell and Sakarcan, 2009; Okubo et al., 2018; Murata et al., 2016; Thavamani et al., 2020; Okubo and Handa, 2017; Kuhle et al., 2012; Wong Ramsey et al., 2020; Woolford et al., 2007; Woolford et al., 2009, Okubo et al., 2016).
- Many of the studies further went on to assess various interventions targeted at preventing and treating childhood obesity. The interventions studied included early childhood interventions, school-based interventions, family-based interventions, primary care interventions, active lifestyle changes, sleep interventions, policy changes and treatment options. The findings are summarised in Table 1.
- There are gaps in research conducted in high-middle income countries, limiting the applicability of the research in a South African context. Recent research is also limited, which prevents the applicability in the present economic climate.

## Table 1: A table illustrating the findings of studies assessing childhood obesity interventions

| Intervention | Summary of Findings |
|---|---|
| **Early childhood** | Early childhood interventions were, in general, found to be cost effective. Home visits and SMSing pregnant mothers were two methods assessed, and although both were deemed cost-effective, SMSing was found to be more so (Hayes et al., 2014; Brown et al., 2020; Killedar et al., 2022). Focus on healthy eating, active play, fruit and vegetable consumption and reduction in screen time in children aged 0 to 5 years old was also found to be cost-effective (Tran et al., 2022). |
| **School-based** | School-based prevention and intervention strategies targeting physical activity were also found to be cost-saving in majority of the studies included, although a few did offer conflicting results (Wang et al. 2008; McAuley et al., 2010; Gesell et al., 2013; Kesztyüs et al. 2013; Jago et al., 2014; Barrett et al., 2015; Cradock et al., 2017; Brown et al., 2024). Specific focus on water consumption was another intervention assessed, and interventions were in general found to be cost-saving (An et al., 2018; Kenney et al., 2019; Kalavainen et al., 2009; Kesztyüs et al., 2017; Conesa et al., 2018). Combined nutrition and physical activity programs were also found to be economically beneficial (Xu et al., 2020; Meng et al., 2013; Carter et al., 2009; Zanganeh et al., 2021). |
| **Family-Based** | Family-based prevention was assessed through multiple studies, but conflicting results were found, as some found group-based family sessions to be more cost-effective, other suggested that parent-only programs were more cost-effective, and some suggested that family-based interventions are ineffective in comparison to standard practice (Raynor et al., 2002; Janicke et al., 2009; Borner et al., 2016; Quattrin et al., 2017; Boutelle et al., 2021; Robertson et al., 2012; Robertson et al., 2017). |
| **Primary Care** | Conflicting results were also found when assessing primary care interventions (Woolford et al., 2022; Wake et al., 2008). |
| **Active Lifestyle** | Programs focusing specifically on active lifestyle were, in general, found to be costly with limited effect on childhood obesity (Moodie et al., 2010; Moodie et al., 2011; Larsen et al., 2017). |
| **Sleep Interventions** | Sleep interventions were, on the other hand, found to be cost-effective (Killedar et al., 2023; Killedar et al., 2023). |
| **Policy Changes** | Policy changes were found to be a cost-effective method of addressing childhood obesity on a wider scale. Reduction of screen time through policy changes has been found to be cost-effective through multiple studies (Wright et al., 2015). Specific focus on limiting advertising of unhealthy foods was also found to be effective (Carter et al., 2009; Magnus et al., 2009; Sonneville et al., 2015; Brown et al., 2018; Kenney et al., 2021). Taxation on sugar-sweetened beverages was also found to be cost-saving on a population level (Lee et al., 2024). |
| **Treatment** | Treatment of childhood obesity was often found to be more costly than prevention, with technologies being effective but expensive (Hollinghurst et al., 2014; Killedar et al., 2023). Inpatient programs were found to follow similar trends (Makkes et al., 2017). |

## Conclusion

This review highlights that adequate quality literature is available in the form of childhood economic evaluations. The findings of these evaluations highlight the financial burden on both the individual and health sector surrounding childhood obesity, and early childhood and school-based interventions, as well as policy changes, have the most supporting evidence around their cost-effectiveness. Targeted research in a South African context is, however, needed in order to confirm that the findings are applicable.

## Policy Recommendations

- Research focusing on the cost of childhood obesity, and the cost-effectiveness of interventions, is needed in a South African context.
- The financial burden of childhood obesity is high, and therefore targeted interventions are needed to address this health concern.
- Early-childhood interventions, such as SMSing health advice to expectant moms, as well as school-based interventions, such as physical activity programs and encouraging water consumption, may be introduced at community levels as means of prevention.
- Policy changes surrounding screen-time and advertising of unhealthy food may also aid in preventing the growing endemic.
- Evidence-based changes should be implemented to ensure effective use of resources.

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Wong Ramsey K, Davis J, Okihiro M. A Comparison of Length of Hospitalization and Costs in Obese and Non-Obese Pediatric Patients at a Single Hospital in Honolulu. Hawaii J Health Soc Welf. 2020;79(5 Suppl 1):91-5.

Woolford SJ, Gebremariam A, Clark SJ, Davis MM. Incremental hospital charges associated with obesity as a secondary diagnosis in children. Obesity (Silver Spring). 2007;15(7):1895-901.

Woolford SJ, Gebremariam A, Clark SJ, Davis MM. Persistent gap of incremental charges for obesity as a secondary diagnosis in common pediatric hospitalizations. J Hosp Med. 2009;4(3):149-56.

Woolford SJ, Resnicow K, Davis MM, Nichols LP, Wasserman RC, Harris D, et al. Cost-effectiveness of a motivational interviewing obesity intervention versus usual care in pediatric primary care offices. Obesity (Silver Spring). 2022;30(11):2265-74.

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Xu H, Li Y, Du S, Zhang Q, Liu A, Sun J, et al. Cost-utility and cost-benefit analyses of school-based obesity prevention program. BMC Public Health. 2020;20(1):1608.

Zanganeh M, Adab P, Li B, Pallan M, Liu WJ, Hemming K, et al. Cost-Effectiveness of a School-and Family-Based Childhood Obesity Prevention Programme in China: The "CHIRPY DRAGON" Cluster-Randomised Controlled Trial. Int J Public Health. 2021;66:1604025.

# PART E: APPENDICES

## Appendix 1: Results Tables

### Appendix 1A: Tables Illustrating the Identification Features of Included Studies

*Studies Examining Economic Consequences of Childhood Obesity*

| Author | Title | Journal | Year | Country |
|---|---|---|---|---|
| Au N. | The health care cost implications of overweight and obesity during childhood | Health Services Research | 2012 | Australia |
| Black N, et al. | The health care costs of childhood obesity in Australia: An instrumental variables approach | Economics and Human Biology | 2018 | Australia |
| Brero M, et al. | Investment case for the prevention and reduction of childhood and adolescent overweight and obesity in Mexico | Obesity Reviews | 2023 | Mexico |
| Carrello J, et al. | Relationship between obesity and school absenteeism in Australian children: Implications for carer productivity | Obesity Research and Clinical Practice | 2021 | Australia |
| Clifford SA, et al. | Health-care costs of underweight, overweight and obesity: Australian population-based study | Journal of Pediatrics and Child Health | 2015 | Australia |
| Finkelstein EA, et al. | Public health interventions for addressing childhood overweight: analysis of the business case | American Journal of Public Health | 2008 | USA |
| Fleming-Dutra KE, et al. | Acute care costs in overweight children: a pediatric urban cohort study | Childhood Obesity | 2013 | USA |
| Hayes A, et al. | Early childhood obesity: Association with healthcare expenditure in Australia | Obesity (Silver Spring) | 2016 | Australia |
| Janicke DM, et al. | The relationship among child weight status, psychosocial functioning, and pediatric health care expenditures in a medicaid population | Journal of Pediatric Psychology | 2010 | USA |
| Jerrell JM, et al. | Primary health care access, continuity, and cost among pediatric patients with obesity hypertension | Journal of the National Medical Association | 2009 | USA |
| Kirk SF, et al. | Health care utilization from prevalent medical conditions in normal-weight, overweight, and obese children | Journal of Pediatrics | 2012 | Canada |
| Kompaniyets L, et al. | Hospital Length of Stay, Charges, and Costs Associated With a Diagnosis of Obesity in US Children and Youth, 2006-2016 | Medical Care | 2020 | USA |
| Kuhle S, et al. | The association between childhood overweight and obesity and otitis media | Pediatric Obesity | 2017 | Canada |
| Kumar A, et al. | Body Mass Index and Associated Medical Expenditures in the US Among Privately Insured Individuals Aged 2 to 19 Years in 2018 | JAMA Pediatrics | 2023 | USA |
| Kyler KE, et al. | Medicaid Expenditures among Children with Documented Obesity | Childhood Obesity | 2023 | USA |

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|---|---|---|---|---|
| Ma S, Frick KD. | A simulation of affordability and effectiveness of childhood obesity interventions | Academic Pediatrics | 2011 | USA |
| Meyerovitch J, et al. | Primary care screening for childhood obesity: a population-based analysis | The Israel Medical Association Journal | 2007 | Israel |
| Murata A, et al. | Impact of obesity on outcomes of paediatric acute pancreatitis based on a national administrative database | Pediatric Obesity | 2016 | Japan |
| Ochoa-Moreno I, et al. | Projected health and economic effects of the increase in childhood obesity during the COVID-19 pandemic in England: The potential cost of inaction | PLoS One | 2024 | United Kingdom |
| Okubo Y, et al. | Dose-response relationship between weight status and clinical outcomes in pediatric influenza-related respiratory infections | Paediatric Pulmonology | 2018 | Japan |
| Okubo Y, et al. | The impact of obesity on pediatric inpatients with urinary tract infections in the United States | Journal of Pediatric Urology | 2017 | USA |
| Okubo Y, et al. | The impact of pediatric obesity on hospitalized children with lower respiratory tract infections in the United States | The Clinical Respiratory Journal | 2018 | USA |
| Okubo Y, et al. | Burden of Obesity on Pediatric Inpatients with Acute Asthma Exacerbation in the United States | Journal of Allergy and Clinical Immunology | 2016 | USA |
| Okubo Y, et al. | Impact of pediatric obesity on acute asthma exacerbation in Japan | Pediatric Allergy and Immunology | 2017 | Japan |
| Sen B, et al. | The Rise in Pediatric Obesity-Related Conditions and Costs in Public Insurance Programs: Evidence from Alabama | | 2020 | USA |
| Sonntag D, et al. | Estimating the lifetime cost of childhood obesity in Germany: Results of a Markov Model | Pediatric Obesity | 2015 | Germany |
| Sonntag D, et al. | Lifetime indirect cost of childhood overweight and obesity: A decision analytic model | Obesity (Silver Spring) | 2016 | Germany |
| Thavamani A, et al. | The increasing prevalence and adverse impact of morbid obesity in paediatric acute pancreatitis | Pediatric Obesity | 2020 | USA |
| Thavamani A, Umapathi KK, Sferra TJ, Sankararaman S. | Undernutrition and Obesity Are Associated with Adverse Clinical Outcomes in Hospitalized Children and Adolescents with Acute Pancreatitis | Nutrients | 2020 | USA |
| Trasande L, et al. | Effects of childhood obesity on hospital care and costs, 1999-2005 | Health Affairs (Project Hope) | 2009 | USA |
| Trasande L, et al. | The impact of obesity on health service utilization and costs in childhood | Obesity (Silver Spring) | 2009 | USA |
| Trasande L. | How much should we invest in preventing childhood obesity? | Health Affairs (Project Hope) | 2010 | Australia |
| Ward ZJ, et al. | Association of body mass index with health care expenditures in the United States by age and sex | PLoS One | 2021 | USA |

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|---|---|---|---|---|
| Wenig CM, et al. | Juvenile obesity and its association with utilisation and costs of pharmaceuticals--results from the KiGGS study | BMC Health Services Research | 2011 | Germany |
| Wenig CM. | The impact of BMI on direct costs in children and adolescents: empirical findings for the German Healthcare System based on the KiGGS-study | European Journal of Health Economics | 2012 | Germany |
| Wong Ramsey K, et al. | A Comparison of Length of Hospitalization and Costs in Obese and Non-Obese Pediatric Patients at a Single Hospital in Honolulu | Hawaii Journal of Health and Social Welfare | 2020 | USA |
| Woolford SJ, et al. | Incremental hospital charges associated with obesity as a secondary diagnosis in children | Obesity Silver Spring | 2012 | USA |
| Woolford SJ, et al. | Persistent gap of incremental charges for obesity as a secondary diagnosis in common pediatric hospitalizations | Journal of Hospital Medicine | 2009 | USA |
| Wright DR, et al. | The impact of overweight and obesity on pediatric medical expenditures | Applied Health Economics Policy | 2014 | USA |

### *Studies Examining Economic Consequences of Childhood Obesity*

| **Author** | **Title** | **Journal** | **Year** | **Country** |
|---|---|---|---|---|
| Li B, et al. | The CHIRPY DRAGON intervention in preventing obesity in Chinese primary-school--aged children: A cluster-randomised controlled trial | PLoS Medicine | 2019 | China |
| Adab P, et al. | The West Midlands ActiVe lifestyle and healthy Eating in School children (WAVES) study: a cluster randomised controlled trial testing the clinical effectiveness and cost-effectiveness of a multifaceted obesity prevention intervention programme targeted at children aged 6-7 years | Health Technology Assessment | 2018 | United Kingdom |
| An R, et al. | Projecting the impact of a nationwide school plain water access intervention on childhood obesity: a cost-benefit analysis | Pediatric Obesity | 2018 | USA |
| Anderson YC, et al. | Economic evaluation of a multi-disciplinary community-based intervention programme for New Zealand children and adolescents with obesity | Obesity Research and Clinical Practice | 2017 | New Zealand |
| Bandurska E, et al. | Cost-Effectiveness of an Obesity Management Program for 6- to 15-Year-Old Children in Poland: Data from Over Three Thousand Participants | Obesity Facts | 2020 | Poland |
| Barrett JL, et al. | Cost Effectiveness of an Elementary School Active Physical Education Policy | American Journal of Preventative Medicine | 2015 | USA |
| Borner KB, et al | Making the Business Case for Coverage of Family-Based Behavioral Group Interventions for Pediatric Obesity | Journal of Pediatric Psychology | 2016 | USA |

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|---|---|---|---|---|
| Boutelle KN, et al. | Comparative Costs of a Parent-Only and Parent and Child Treatment for Children with Overweight or Obesity | Obesity Silver Spring | 2021 | USA |
| Brown V, et al. | Cost comparison of five Australasian obesity prevention interventions for children aged from birth to two years | Pediatric Obesity | 2020 | Australia and New Zealand |
| Brown V, et al. | Cost-effectiveness of reducing children's sedentary time and increasing physical activity at school: the Transform-Us! intervention | International Journal of Behavioural Nutrition and Physical Activity | 2024 | Australia |
| Brown V, et al. | The Potential Cost-Effectiveness and Equity Impacts of Restricting Television Advertising of Unhealthy Food and Beverages to Australian Children | Nutrients | 2018 | Australia |
| Canaway A, et al. | Economic evaluation of a childhood obesity prevention programme for children: Results from the WAVES cluster randomised controlled trial conducted in schools | PLoS One | 2018 | United Kingdom |
| Carter R, et al. | Assessing cost-effectiveness in obesity (ACE-obesity): an overview of the ACE approach, economic methods and cost results | BMC Public Health | 2009 | Australia |
| Conesa M, et al. | Cost-Effectiveness of the EdAl (Educació en Alimentació) Program: A Primary School-Based Study to Prevent Childhood Obesity | Journal of Epidemiology | 2018 | Spain |
| Cradock AL, et al. | Using cost-effectiveness analysis to prioritize policy and programmatic approaches to physical activity promotion and obesity prevention in childhood | Preventative Medicine | 2017 | USA |
| Epstein LH, et al. | Cost-effectiveness of family-based group treatment for child and parental obesity | Childhood Obesity | 2014 | USA |
| Gesell SB, et al. | Comparative effectiveness of after-school programs to increase physical activity | Journal of Obesity | 2013 | USA |
| Graziose MM, et al. | Cost-effectiveness of a Nutrition Education Curriculum Intervention in Elementary Schools | Journal of Nutritional Education and Behaviour | 2017 | USA |
| Hayes A, et al. | Economic evaluation of "healthy beginnings" an early childhood intervention to prevent obesity | Obesity (Silver Spring) | 2014 | Australia |
| Hollinghurst S, et al. | Cost and effectiveness of treatment options for childhood obesity | Pediatric Obesity | 2014 | England |
| Hollingworth W, et al. | Economic evaluation of lifestyle interventions to treat overweight or obesity in children | International Journal of Obesity London | 2011 | United Kingdom |
| Jago R, et al. | Randomised feasibility trial of a teaching assistant led extracurricular physical activity intervention for 9 to 11 year olds: Action 3:30 | The International Journal of Behavioural Nutrition and Physical Activity | 2014 | United Kingdom |

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|---|---|---|---|---|
| Janicke DM, et al. | Comparison of program costs for parent-only and family-based interventions for pediatric obesity in medically underserved rural settings | Journal of Rural Health | 2009 | USA |
| Jordan N, et al. | Costs of Preparing to Implement a Family-Based Intervention to Prevent Pediatric Obesity in Primary Care: a Budget Impact Analysis | Preventative Science | 2019 | USA |
| Kalavainen M, et al. | Cost-effectiveness of routine and group programs for treatment of obese children | Pediatric International | 2009 | Finland |
| Kenney EL, et al. | Limiting Television to Reduce Childhood Obesity: Cost-Effectiveness of Five Population Strategies | Childhood Obesity | 2021 | USA |
| Kenney EL, et al. | Cost-Effectiveness of Water Promotion Strategies in Schools for Preventing Childhood Obesity and Increasing Water Intake | Obesity Silver Spring | 2019 | USA |
| Kesztyüs D, et al. | Economic evaluation of URMEL-ICE, a school-based overweight prevention programme comprising metabolism, exercise and lifestyle intervention in children | European Journal of Health Economics | 2013 | Germany |
| Kesztyüs D, et al. | Costs and effects of a state-wide health promotion program in primary schools in Germany - the Baden-Württemberg Study: A cluster-randomized, controlled trial | PLoS One | 2017 | Germany |
| Killedar A, et al. | Modelled Distributional Cost-Effectiveness Analysis of Childhood Obesity Interventions: A Demonstration | Applied Health Economics Policy | 2023 | New Zealand; USA |
| Killedar A, et al. | Economic evaluation of the Communicating Healthy Beginnings Advice by Telephone trial for early childhood obesity prevention | Obesity (Silver Spring) | 2022 | Australia |
| Killedar A, et al. | Is the cost-effectiveness of an early-childhood sleep intervention to prevent obesity affected by socioeconomic position? | Obesity (Silver Spring) | 2023 | Australia and New Zealand |
| Ladapo JA, et al. | Cost and Cost-Effectiveness of Students for Nutrition and eXercise (SNaX) | Academic Paediatrics | 2016 | USA |
| Larsen KT, et al. | Cost-effectiveness of a day-camp weight-loss intervention programme for children: Results based on a randomised controlled trial with one-year follow-up | Scandinavian Journal of Public Health | 2017 | Denmark |
| Lee MM, et al. | A Sugar-Sweetened Beverage Excise Tax in California: Projected Benefits for Population Obesity and Health Equity | American Journal of Preventative Medicine | 2024 | USA |
| Lier LM, et al. | Cost-effectiveness of a family-based multicomponent outpatient intervention program for children with obesity in Germany | Public Health | 2020 | Germany |
| Magnus A, et al. | The cost-effectiveness of removing television advertising of high-fat and/or high-sugar food and beverages to Australian children | International Journal of Obesity London | 2009 | Australia |
| Makkes S, et al. | Economic Evaluation of Intensive Inpatient Treatments for Severely Obese Children and Adolescents | Obesity Facts | 2017 | Netherlands |
| McAuley KA, et al. | Economic evaluation of a community-based obesity prevention program in children: the APPLE project | Obesity (Silver Spring) | 2010 | New Zealand |

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|---|---|---|---|---|
| Meng L, et al. | The costs and cost-effectiveness of a school-based comprehensive intervention study on childhood obesity in China | PLoS One | 2013 | China |
| Moodie M, et al. | Assessing cost-effectiveness in obesity: active transport program for primary school children--TravelSMART Schools Curriculum program | Journal of Physical Activity and Health | 2011 | Australia |
| Moodie M, et al. | Cost-effectiveness of a family-based GP-mediated intervention targeting overweight and moderately obese children | Economics and Human Biology | 2008 | Australia |
| Moodie ML, et al. | The cost-effectiveness of Australia's Active After-School Communities program | Obesity (Silver Spring) | 2010 | Australia |
| Moodie ML, et al. | The cost-effectiveness of a successful community-based obesity prevention program: the be active eat well program | Obesity (Silver Spring) | 2013 | Australia |
| Ohinmaa A, et al. | Costs of implementing and maintaining comprehensive school health: the case of the Annapolis Valley Health Promoting Schools program | Canadian Journal of Public Health | 2011 | USA |
| Poole MK, et al. | The societal costs and health impacts on obesity of BMI report cards in US schools | Obesity (Silver Spring) | 2023 | USA |
| Pryor S, et al. | Cost-Effectiveness and Long-Term Savings of the Bright Bodies Intervention for Childhood Obesity | Value Health | 2023 | USA |
| Quattrin T, et al. | Cost-effectiveness of Family-Based Obesity Treatment | Pediatrics | 2017 | USA |
| Raynor HA, et al. | A cost-analysis of adopting a healthful diet in a family-based obesity treatment program | Journal of American Dietetic Association | 2002 | |
| Robertson W, et al. | Two-year follow-up of the 'Families for Health' programme for the treatment of childhood obesity | Child: Care, Health and Development | 2011 | United Kingdom |
| Robertson W, et al. | Randomised controlled trial evaluating the effectiveness and cost-effectiveness of 'Families for Health', a family-based childhood obesity treatment intervention delivered in a community setting for ages 6 to 11 years | Health Technology Assessment | 2017 | United Kingdom |
| Robertson W, et al. | Randomised controlled trial and economic evaluation of the 'Families for Health' programme to reduce obesity in children | Archives of Disease in Childhood | 2017 | United Kingdom |
| Smith NR, et al. | Costs to Implement a Pediatric Weight Management Program Across 3 Distinct Contexts | Medical Care | 2023 | USA |
| Sonneville KR, et al. | BMI and Healthcare Cost Impact of Eliminating Tax Subsidy for Advertising Unhealthy Food to Youth | American Journal of Preventative Medicine | 2015 | USA |
| Sonntag D, et al. | Assessing the Lifetime Cost-Effectiveness of Low-Protein Infant Formula as Early Obesity Prevention Strategy: The CHOP Randomized Trial | Nutrients | 2019 | Europe; Germany |
| Spoor C, et al. | Costing a pilot complex community-based childhood obesity intervention | Journal of Human Nutrition and Diet | 2013 | United Kingdom |

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|---|---|---|---|---|
| Tan EJ, et al. | Cost-Effectiveness of a Novel Sleep Intervention in Infancy to Prevent Overweight in Childhood | Obesity (Silver Spring) | 2020 | New Zealand |
| Tran HNQ, et al. | Cost-effectiveness of scaling up a whole-of-community intervention: The Romp & Chomp early childhood obesity prevention intervention | Pediatric Obesity | 2022 | Australia |
| Vieira M, et al. | Costs and benefits of a school-based health intervention in Portugal | Health Promotion International | 2019 | Portugal |
| Wake M, et al. | Economic evaluation of a primary care trial to reduce weight gain in overweight/obese children: the LEAP trial | Ambulatory Pediatrics | 2008 | Australia |
| Wang LY, et al. | Cost-effectiveness of a school-based obesity prevention program | Journal of School Health | 2008 | |
| Woolford SJ, et al. | Cost-effectiveness of a motivational interviewing obesity intervention versus usual care in pediatric primary care offices | Obesity (Silver Spring) | 2022 | USA |
| Wright DR, et al. | The cost of a primary care-based childhood obesity prevention intervention | BMC Health Services Research | 2014 | USA |
| Wright DR, et al. | Modeling the Cost Effectiveness of Child Care Policy Changes in the U.S | American Journal of Preventative Medicine | 2015 | USA |
| Xu H, et al. | Cost-utility and cost-benefit analyses of school-based obesity prevention program | BMC Public Health | 2020 | China |
| Zanganeh M, et al. | Cost-Effectiveness of a School-and Family-Based Childhood Obesity Prevention Programme in China: The "CHIRPY DRAGON" Cluster-Randomised Controlled Trial | International Journal of Public Health | 2021 | China |

## Appendix 1B: Tables Summarising Results of CHEERS Assessment

### *Economic Consequences*

| Article | Title | Abstract | Background a | Health Econ | Study Popul | Setting and l | Comparators | Perspective | Time Horizo | Discount Rat | Selection of | Measureme | Valuation of | Measureme | Currency, Pr | Rationale an | Analytics and | Characterisin | Characterisin | Characterisin | Approach to | Study Param | Summary of | Effect of Unc | Effect of Eng | Study Findin | Source of Fu | Conflicts of Interest | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Au (2012) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Black et al. (2018) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Brero et al. (2023) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Carrello et al. (2021) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Clifford et al. (2015) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Finkelstein & Trogdon (2008) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Fleming-Dutra et al. (2013) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Hayes et al. (2016) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Janicke et al. (2010) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Jerrell & Sakarcan (2009) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Kirk et al. (2012) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Kompaniyets et al. (2020) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Kuhle et al. (2012) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Kumar et al. (2023) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Kyler et al. (2023) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Ma & Frick (2011) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Meyerovitch et al. (2007) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Murata et al. (2016) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Ochoa-Moreno et al. (2024) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Okubo & Handa (2017) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Okubo et al. (2016) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Okubo et al. (2017) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Okubo et al. (2018) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Okubo et al. (2018) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Sen et al. (2020) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Sonntag et al. (2015) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Sonntag et al. (2016) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Thavamani et al. (2020) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Thavamani et al. (2020) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Trasande (2010) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Trasande & Chatterjee (2009) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Trasande et al. (2009) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Ward et al. (2021) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Wenig (2012) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Wenig et al. (2011) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Wong Ramsey et al. (2020) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Woolford et al. (2007) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Woolford et al. (2009) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |
| Wright & Prosser (2014) | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 22 |

## *Interventions*

| Article | Title | Abstract | Background | Health Econ | Study Popul | Setting and | Comparators | Perspective | Time Horizo | Discount Ra | Selection o | Measureme | Valuation o | Measureme | Currency, P | Rationale ar | Analytics an | Characterisi | Characterisi | Characterisi | Approach to | Study Param | Summary of | Effect of Un | Effect of Eng | Study Findir | Source of Fu | Conflicts of Interest | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adab et al. (2018) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| An et al. (2018) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Anderson et al. (2018) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Bandurska et al. (2020) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Barrett et al. (2015) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Borner et al. (2016) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Boutelle et al. (2021) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Brown et al. (2018) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Brown et al. (2020) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Brown et al. (2024) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Canaway et al. (2019) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Carter et al. (2009) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Conesa et al. (2018) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Cradock et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Epstein et al. (2014) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Gesell et al. (2013) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Graziose et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Hayes et al. (2014) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Hollinghurst et al. (2014) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Hollingworth et al. (2012) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Jago et al. (2014) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Janicke et al. (2009) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Jordan et al. (2019) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Kalavainen et al. (2009) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Kenney et al. (2019) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Kenney et al. (2021) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Kesztyüs et al. (2013) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Kesztyüs et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Killedar et al. (2022) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Killedar et al. (2023) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Killedar et al. (2023) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Ladapo et al. (2016) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Larsen et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Lee et al. (2024) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Li et al. (2019) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Lier et al. (2020) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Magnus et al. (2009) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Makkes et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| McAuley et al. (2010) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Meng et al. (2013) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Moodie et al. (2008) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Moodie et al. (2010) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Moodie et al. (2011) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Moodie et al. (2013) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Ohinmaa et al. (2011) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Poole et al. (2023) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Pryor et al. (2023) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Quattrin et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Raynor et al. (2002) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Robertson et al. (2012) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Robertson et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Robertson et al. (2017) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Smith et al. (2023) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Sonntag et al. (2019) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Spoor et al. (2013) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Tan et al. (2020) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Tran et al. (2022) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Vieira & Carvalho (2019) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Wake et al. (2008) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Wang et al. (2008) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Woolford et al. (2022) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Wright et al. (2014) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Wright et al. (2015) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Xu et al. (2020) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |
| Zanganeh et al. (2021) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | 23 |

# Appendix 1C: Tables Summarising Results of Bias Risk Assessment

## *Economic Consequences*

| Article Citation | Selection Bias | Performance Bias | Detection Bias | Attrition Bias | Reporting Bias | Other Bias |
|---|---|---|---|---|---|---|
| Au N. (2012) | Low | Moderate | Moderate | Not applicable | Low | None identified |
| Black N et al. (2018) | Low | Low | Low | Not applicable | Low | None identified |
| Brero M et al. (2023) | Moderate | Moderate | Moderate | Not clearly stated | Low | None identified |
| Carrello J et al. (2021) | Moderate | Moderate | Moderate | Not clearly stated | Low | None identified |
| Clifford SA et al. (2015) | Low | Moderate | Moderate | Not clearly mentionec | Low | None identified |
| Finkelstein EA, Trogdon JG (2008) | Moderate | Low | Moderate | Not applicable | Low | None identified |
| Fleming-Dutra KE et al. (2013) | Low | Low | Moderate | Not applicable | Low | None identified |
| Hayes A et al. (2016) | Low | Moderate | Moderate | Not clearly stated | Low | None identified |
| Janicke DM et al. (2010) | Moderate | Moderate: Varied treat | Moderate | Not applicable | Low | None identified |
| Jerrell JM, Sakarcan A (2009) | Moderate | Moderate | Moderate | Not clearly stated | Low | None identified |
| Kirk SF et al. (2012) | Low | Low | Moderate | Not applicable | Low | None identified |
| Kompaniyets L et al. (2020) | Low | Low | Moderate | Not applicable | Low | None identified |
| Kuhle S et al. (2012) | Low | Low | Moderate | Not applicable | Low | None identified |
| Kumar A et al. (2023) | Low | Low | Moderate | Not applicable | Low | None identified |
| Kyler KE et al. (2023) | Low | Low | Moderate | Not applicable | Low | None identified |
| Ma S & Frick KD (2011) | Low | Low | Low | Not applicable | Low | None identified |
| Meyerovitch J et al. (2007) | Low | Moderate | Moderate | Not applicable | Low | None identified |
| Murata A et al. (2016) | Low | Low | Moderate | Not applicable | Low | None identified |
| Ochoa-Moreno I et al. (2024) | Moderate | Low | Moderate | Not applicable | Low | None identified |
| Okubo Y et al. (2016) | Low | Low | Moderate | Not applicable | Low | None identified |
| Okubo Y et al. (2017) | Low | Low | Moderate | Not applicable | Low | None identified |
| Okubo Y et al. (2018) | Low | Low | Moderate | Not applicable | Low | None identified |
| Okubo Y et al. (2018) (second article) | Low | Low | Moderate | Not applicable | Low | None identified |
| Okubo Y, Handa A (2017) | Low | Low | Moderate | Not applicable | Low | None identified |
| Sen B et al. (2020) | Moderate | Moderate | Moderate | Not clearly stated | Low | None identified |
| Sonntag D et al. (2015) | Low | Low | Moderate | Not applicable | Low | None identified |
| Sonntag D et al. (2016) | Low | Low | Moderate | Not applicable | Low | None identified |
| Thavamani A et al. (2020) | Moderate | Moderate | Moderate | Not applicable | Low | None identified |
| Thavamani A et al. (2020) (second article | Moderate | Moderate | Moderate | Not applicable | Low | None identified |
| Trasande L et al. (2009) | Low | Low | Moderate | Not applicable | Low | None identified |
| Trasande L, Chatterjee S (2009) | Moderate | Moderate | Moderate | Not applicable | Low | None identified |
| Trasande L. (2010) | Moderate | Moderate | Moderate | Not applicable (econo | Low | None identified |
| Ward ZJ et al. (2021) | Low | Low | Moderate | Not applicable | Low | None identified |
| Wenig CM (2012) | Low | Low | Moderate | Not applicable | Low | None identified |
| Wenig CM et al. (2011) | Low | Low | Moderate | Not applicable | Low | None identified |
| Wong Ramsey K et al. (2020) | Moderate | Moderate | Moderate | Not clearly stated | Low | None identified |
| Woolford SJ et al. (2007) | Low | Low | Moderate | Not applicable | Low | None identified |
| Woolford SJ et al. (2009) | Low | Low | Moderate | Not applicable | Low | None identified |
| Wright DR, Prosser LA (2014) | Low | Low | Moderate | Not applicable | Low | None identified |

## *Interventions*

| Article Citation | Selection Bias | Performance Bias | Detection Bias | Attrition Bias | Reporting Bias | Other Bias |
|---|---|---|---|---|---|---|
| Adab P et al. (2018) | Low | Low | Low | Low | Low | None identified |
| An R et al. (2018) | Low | Low | Moderate | Not applicable | Low | None identified |
| Anderson YC et al. (2018) | Low | Low | Moderate | Not applicable | Low | None identified |
| Bandurska E et al. (2020) | Low | Low | Low | Low | Low | None identified |
| Barrett JL et al. (2015) | Low | Low | Low | Not applicable | Low | None identified |
| Borner KB et al. (2016) | Low | Low | Low | Not applicable | Low | None identified |
| Boutelle KN et al. (2021) | Low | Low | Low | Not applicable | Low | None identified |
| Brown V et al. (2018) | Low | Low | Low | Low | Low | None identified |
| Brown V et al. (2020) | Low | Low | Moderate | Not applicable | Low | None identified |
| Brown V et al. (2024) | Low | Low | Moderate | Not clearly stated | Low | None identified |
| Canaway A et al. (2019) | Low | Low | Low | Low | Low | None identified |
| Carter R et al. (2009) | Low | Low | Moderate | Not applicable | Low | None identified |
| Conesa M et al. (2018) | Low | Low | Low | Not applicable | Low | None identified |
| Cradock AL et al. (2017) | Low | Low | Low | Not applicable | Low | None identified |
| Epstein LH et al. (2014) | Low | Low | Low | Not applicable | Low | None identified |
| Gesell SB et al. (2013) | Moderate | Low | Moderate | Not clearly stated | Low | None identified |
| Graziose MM et al. (2017) | Low | Low | Low | Not applicable | Low | None identified |
| Hayes A et al. (2014) | Low | Low | Moderate | Not clearly stated | Low | None identified |
| Hollinghurst S et al. (2014) | Low | Low | Low | Low | Low | None identified |
| Hollingworth W et al. (2012) | Low | Low | Low | Low | Low | None identified |
| Jago R et al. (2014) | Low | Low | Low | Low | Low | None identified |
| Janicke DM et al. (2009) | Low | Low | Low | Moderate | Low | None identified |
| Jordan N et al. (2019) | Low | Low | Low | Not applicable | Low | None identified |
| Kalavainen M et al. (2009) | Moderate | Low | Moderate | Not clearly stated | Low | None identified |
| Kenney EL et al. (2019) | Low | Low | Low | Not applicable | Low | None identified |
| Kenney EL et al. (2021) | Low | Low | Low | Low | Low | None identified |
| Kesztyüs D et al. (2013) | Low | Low | Moderate | Not applicable | Low | None identified |
| Kesztyüs D et al. (2017) | Low | Low | Moderate | Not applicable | Low | None identified |
| Killedar A et al. (2022) | Low | Low | Low | Low | Low | None identified |
| Killedar A et al. (2023) | Low | Low | Low | Low | Low | None identified |
| Killedar A et al. (2023) | Low | Low | Low | Moderate | Low | None identified |
| Ladapo JA et al. (2016) | Low | Low | Low | Not applicable | Low | None identified |
| Larsen KT et al. (2017) | Low | Low | Low | Moderate | Low | None identified |
| Lee MM et al. (2024) | Low | Low | Low | Low | Low | None identified |
| Li B et al. (2019) | Low | Low | Low | Low | Low | None identified |
| Lier LM et al. (2020) | Low | Low | Moderate | Not applicable | Low | None identified |
| Magnus A et al. (2009) | Low | Low | Low | Low | Low | None identified |
| Makkes S et al. (2017) | Low | Low | Low | Moderate | Low | None identified |
| McAuley KA et al. (2010) | Low | Low | Moderate | Not applicable | Low | None identified |
| Meng L et al. (2013) | Low | Low | Moderate | Not applicable | Low | None identified |
| Moodie M et al. (2008) | Low | Low | Low | Low | Low | None identified |
| Moodie M et al. (2011) | Low | Low | Low | Low | Low | None identified |
| Moodie ML et al. (2010) | Low | Low | Low | Low | Low | None identified |
| Moodie ML et al. (2013) | Low | Low | Low | Low | Low | None identified |
| Ohinmaa A et al. (2011) | Low | Low | Moderate | Not applicable | Low | None identified |
| Poole MK et al. (2023) | Low | Low | Low | Not applicable | Low | None identified |
| Pryor S et al. (2023) | Low | Low | Low | Not applicable | Low | None identified |
| Quattrin T et al. (2017) | Low | Low | Low | Not applicable | Low | None identified |
| Raynor HA et al. (2002) | Low | Low | Low | Not applicable | Low | None identified |
| Robertson W et al. (2012) | Moderate | Low | Low | Moderate | Low | None identified |
| Robertson W et al. (2017a) | Low | Low | Low | Moderate | Low | None identified |
| Robertson W et al. (2017b) | Low | Low | Low | Moderate | Low | None identified |
| Smith NR et al. (2023) | Low | Low | Low | Moderate | Low | None identified |
| Sonneville KR et al. (2015) | Low | Low | Low | Low | Low | None identified |
| Sonntag D et al. (2019) | Low | Low | Low | Low | Low | None identified |
| Spoor C et al. (2013) | Low | Low | Low | Low | Low | None identified |
| Tan EJ et al. (2020) | Low | Low | Moderate | Not clearly stated | Low | None identified |
| Tran HNQ et al. (2022) | Low | Low | Moderate | Not applicable | Low | None identified |
| Vieira M, Carvalho GS (2019) | Low | Low | Moderate | Not applicable | Low | None identified |
| Wake M et al. (2008) | Moderate | Low | Low | Moderate | Low | None identified |
| Wang LY et al. (2008) | Low | Low | Moderate | Not applicable | Low | None identified |
| Woolford SJ et al. (2022) | Low | Low | Low | Low | Low | None identified |
| Wright DR et al. (2014) | Low | Low | Moderate | Not clearly stated | Low | None identified |
| Wright DR et al. (2015) | Low | Low | Low | Low | Low | None identified |
| Xu H et al. (2020) | Low | Low | Moderate | Not applicable | Low | None identified |
| Zanganeh M et al. (2021) | Low | Low | Low | Low | Low | None identified |

# Appendix 2: Ethics Approval Letter

School of Public Health
Departement Openbare Gesondheid
Isikolo Sempilo Yoluntu

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

**Dr Tammy Phillips**
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University of Cape Town Faculty of Health Sciences
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E: tammy.phillips@uct.ac.za
W: www.publichealth.uct.ac.za

30 June 2023

**STUDENT NUMBER: KTTKIL001**

Dear Dr Killoran Kettles

Please be advised that this protocol has been reviewed by the School of Public Health Departmental Research Committee (DRC), agreeing that the study does not require Human Research Ethics Committee (HREC) approval.

**Title: A Systematic Review of Economic Evaluations involving Childhood Obesity**

Please upload this to Peoplesoft in the 'Copy of Ethics Approval Letter' section when you do your Intent to Submit.

Kind regards

Dr Tammy Phillips
**Chair: Departmental Research Committee**
**School of Public Health**

*Our vision is to be an inclusive, engaged and research-intensive African university.*