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# A systematic review of methods, study quality, and results of economic evaluation for childhood and adolescent obesity intervention

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## A systematic review of methods, study quality, and results of economic evaluation for childhood and

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11 Abstract: Many suggested policy interventions for childhood and adolescent obesity have costs 12 and effects that fall outside the health care sector. These cross-sectorial costs and consequences 13 have implications for how economic evaluation is applied and although previous systematic 14 reviews have provided a summary of cost-effectiveness, very few have conducted a review of 15 methods applied. We undertook this comprehensive review of economic evaluations, appraising 16 the methods used, assessing the quality of the economic evaluations and summarising 17 cost-effectiveness. Nine electronic databases were searched for full-economic evaluation studies 18 published between January 2001 and April 2017 with no language or country restrictions. 39 19 economic evaluation studies were reviewed and quality assessed. Almost all the studies were from 20 Western countries and methods were found to vary by country, setting and type of intervention. 21 The majority, particularly "behavioural and policy" preventive interventions, were cost-effective, 22 even cost-saving. Only four interventions were not cost effective. This systematic review suggests 23 that economic evaluation of obesity interventions is an expanding area of research. However, 24 methodological heterogeneity makes evidence synthesis challenging. Whilst upstream 25 interventions show promise, an expanded and consistent approach to evaluate cost-effectiveness is 26 needed to capture health and non-health costs and consequences.

- 27 Keywords: cost effectiveness; methods; children; adolescents; obesity; prevention; treatment
- 28

29 **1. Introduction** 

Childhood obesity is a major global public health problem with associated health, social and emotional consequences, as well as long term direct and indirect costs [1-4]. Effective obesity prevention and treatment in children and adolescents is therefore a priority as it is far more cost-effective to prevent the onset of obesity in childhood compared to a lifetime of obesity-associated costs. However, despite an increasing number of intervention studies, there are relatively few published economic evaluations [5-7].

36 In many countries, the scarcity of public resources requires decision makers to seek information 37 on cost-effectiveness as well as clinical effectiveness in the knowledge that the use of resources in 38 one way prevents their use in others [8]. Economic evaluation is a means to aid decisions about 39 public resource allocation [9, 10] and as obesity prevention and treatment often involves lifestyle 40 interventions that have costs and consequences that fall outside the health care sector, a societal 41 perspective for evaluation is usually recommended [10]. This means that all relevant resource 42 use/costs and consequences are measured, outlining how these fit within a given sector, such as 43 health, education or the wider community [11]. However, when incorporating costs and outcomes 44 that span across multiple sectors, it is not always clear how much society is willing to pay for a

- 45 'non-health' effect caused by an intervention funded from a 'health care budget'. Also, the valuation46 of resources for which no market exists, such as informal care, or patient time costs, requires specific
- 47 methods [8].

48 Seven recent reviews [12-18] have summarised the cost-effectiveness of obesity prevention 49 and/or treatment interventions in young people however none were designed to offer a rigorous 50 review of methods applied for economic evaluation. Five reviews had language restrictions [12-15, 51 17] and four excluded studies that were conducted in developing countries [12, 13, 15, 17], limiting 52 global interpretation. Only two reviews appraised methods for handling inter-sectoral costs [13, 17]. 53 Just three of the reviews used established criteria e.g. Drummond checklist [19] to assess the quality 54 of the primary studies [13, 14, 17]. The search strategy was inadequate (e.g. search terms not fully 55 reported) in three reviews [12, 15, 20], and in the remaining four there were omissions of relevant 56 databases, which means that relevant studies could have been missed [13, 14, 16, 17]. Furthermore, 57 the most recent review, which only focused on interventions in pre-school children, included studies 58 reported up to November 2015 and, at least 3 new economic evaluation studies of childhood obesity 59 interventions have been published since then [21-23].

60 This paper reports on a systematic review of published economic evaluations of obesity 61 prevention and/or treatment interventions in children and adolescents (0-19 years) with the primary 62 objective of appraising the methods used and assessing the quality of the economic evaluations 63 using the Drummond checklist [19]. A secondary objective was to undertake a narrative synthesis of 64 the evidence of the cost-effectiveness.

#### 65 2. Materials and Methods

The systematic review follows the reporting guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [24] and a completed PRISMA checklist is presented in Section A (see Supplementary Material). The protocol is registered with the international prospective register of systematic reviews (PROSPERO) database ref (CRD42017062236) and has previously been published [25].

#### 71 2.1. Literature Search

72 The following electronic health economics/biomedical databases were searched: MEDLINE 73 (Ovid); EMBASE (Ovid); Web of Science; CINAHL Plus; EconLit; PsycINFO; Cochrane Database of 74 Systematic Reviews (CDSR); Database of Abstracts of Reviews of Effects (DARE); the National 75 Health Service Economic Evaluation Database (NHS EED); Health Technology Assessment (HTA) 76 and Cost-Effectiveness Analysis (CEA) Registry. The following sources were also used to identify 77 potential additional studies: Google Scholar; relevant National Institute for Health and Care 78 Excellence (NICE) guidelines; the reference lists of eligible studies and review articles; and Grey 79 literature such as OpenSIGLE, National Obesity Observatory, NHS Evidence, National Technical 80 Information Service, Healthcare Management Information Consortium (HMIC) and RePEC 81 (Economic Working papers) database. The search was conducted in May 2017 and studies were 82 sought between January 2001 and April 2017. The year 2001 was chosen since the first study 83 evaluating the cost-effectiveness of a childhood obesity treatment intervention was published then 84 followed 2 years later by the first economic evaluation of a childhood obesity prevention 85 intervention [16]. Search strategies included Medical Subject Headings (MeSH) terms and text words 86 of key papers that were identified beforehand. The search terms and text words were adapted for 87 use within other bibliographic databases. The full search strategy is presented in Section B (see 88 Supplementary Material).

#### 89 2.2. Inclusion and Exclusion Criteria

90 Economic evaluations were included or excluded based on the following criteria:

91 Types of study: Primary full economic evaluations were included (studies in which both the 92 costs and outcomes of the alternatives are examined and in which a comparison of two or more 93 interventions or case alternatives are undertaken) including trial-based and model-based (using trial 94 data) evaluations. Partial economic evaluations; qualitative studies; conference abstracts; and study 95 protocols were excluded.

96 Participants/ population: Children and adolescents aged 0-19 years at the start of the 97 intervention and/or their parents/guardians were included. Family based interventions were also 98 included when the target participants were the children. Economic evaluations undertaken within 99 any country context were included. Interventions to tackle obesity due to a secondary cause (e.g. 100 Prader-Willi syndrome) were excluded.

101 Intervention(s), exposure(s): All behavioural (focused on individual behaviour change 102 techniques), environmental (focused on modifying the local environment) or policy (focused on 103 population-wide legislative or fiscal action) interventions for the treatment or prevention of 104 overweight/obesity in children and/or adolescents were included. Pharmacological or surgical 105 interventions were excluded.

Comparator(s)/control: Only studies with a clearly defined comparator were included with norestrictions on the types of comparator(s).

108 Outcome(s): No restrictions on outcomes measures. Potentially relevant outcomes were: 109 Disability Adjusted Life Years (DALYs); Quality Adjusted Life Years (QALYs); effectiveness 110 outcomes such as kilogramme weight loss; % Body Fat; Body Mass Index (BMI) z-score; waist 111 circumference; overweight and obesity cases avoided; additional minute of Moderate to Vigorous

112 Physical Activity (MVPA); increase in overall physical activity level and Metabolic Equivalent

113 (MET) hour gained.

114 Other criteria: There were no restrictions based on language.

#### 115 2.3. Study Selection Procedure

116 The review followed a two-stage method. First, the main researcher and an independent 117 researcher individually screened titles and abstracts of identified publications against the selection 118 criteria. If in doubt, the full text version was requested. Second, full-text papers were reviewed by 119 both researchers and a final decision made with respect to the inclusion/exclusion criteria. There was 120 85% agreement between the 2 reviewers. Any disagreements between the reviewers over the 121 eligibility of specific studies were resolved by discussion between all authors. To aid study selection 122 and analysis of non-English language articles, translation either in part or in whole was undertaken 123 by academic colleagues with the appropriate language skills. The literature search results were 124 managed using Endnote 7 (Thomson Reuters).

#### 125 2.4. Data Extraction

126 The study characteristics and findings were recorded using a standardised, pre-piloted data 127 extraction form (see Tables S1 (i) – S1 (iv) and Tables S2-4 (i) – S2-4 (iv) in Supplementary Material). 128 This process was checked for completeness and accuracy by an independent researcher. Any 129 discrepancies between the reviewers over the data extraction process was identified and resolved by 130 discussion or by consensus with all authors.

#### 131 2.5. Quality Assessment of Included Studies

132 The quality of the economic evaluations were judged against standard criteria (Drummond 133 checklist) [19], see Table S5 (see Supplementary Material). Quality assessment of the included 134 studies was independently checked for completeness and accuracy by an independent researcher 135 and any discrepancies were resolved by discussion with all authors.

#### 136 **3. Results**

- 137 From the 4,185 references initially identified, 39 economic evaluations were included see
- 138 Figure 1. The most common reasons for exclusion were the lack of (full) economic evaluations, being

a protocol study, or including an ineligible target population.



140

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowdiagram.

#### 143 3.1. Details about Study Context

Full details about study context are presented in Tables S1 (i) – S1 (iv) (see Supplementary Material), and summarised in Table 1.

#### 146

Table 1. Summary of general characteristics of the studies.

Study characteristics		Number of studies identified (%)	
Year of publication			
2001-2009		17 (44)	
2010-2017		22 (56)	
Study approach			
Trial-based	Prevention	9 (23)	
	Treatment	7 (18)	
Model-based	Prevention	19 (49)	
	Treatment	4 (10)	
Comparator selected			

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33 (85)			
6 (15)			
Country			
15 (38.5)			
2 (5)			
12 (31.5)			
1 (2.5)			
4 (10)			
2 (5)			
1 (2.5)			
1 (2.5)			
1 (2.5)			
Setting			
21 (54)			
5 (13)			
1 (2.5)			
1 (2.5)			
9 (23)			
1 (2.5)			
1 (2.5)			
	33 (85)  6 (15)  buntry  15 (38.5)  2 (5)  12 (31.5)  1 (2.5)  4 (10)  2 (5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  etting  21 (54)  5 (13)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.5)  1 (2.		

#### 147 3.1.1. Intervention and Comparator

148 Approximately half of the economic evaluations (23/39) were model-based [12, 23, 26-41] 149 compared to trial-based evaluations. A range of interventions were identified, all containing 150 individual behaviour change elements (Figure 2). A large proportion (25/39) (including all treatment 151 interventions) were focused exclusively on behaviour change techniques, the rest combined 152 individual behaviour change elements with either an environmental component (modifying the 153 local environment e.g. active school transport) [22, 30-34, 42, 43] or a policy component 154 (population-wide legislative or fiscal interventions such as banning unhealthy food advertising or a 155 physical education policy) [26, 28, 29, 36, 39, 44]. Approximately half of the interventions (21/39; 12 156 prevention and 9 treatment) targeted a combination of physical activity and dietary behaviours [12, 157 21, 27, 33, 37-43, 45-51], the rest focused on either physical activity [22, 26, 30-32, 34, 44, 52-54] or 158 dietary habits only [12, 23, 28, 29, 36, 55].





Figure 2. Summary of the interventions.

161 The intensity of the interventions differed considerably. For prevention interventions, this 162 ranged from one session per 3 months [45] to approximately 2 sessions per month [52]; and for 163 treatment interventions, ranged from one [21] to 12 sessions per week [47]. The duration of the 164 interventions also differed, ranging from 8 months [54] to 4 years [53] for prevention studies; and 165 from 3 months [21] to 1 year [47] for treatment studies. Overall therefore, the treatment interventions 166 were generally more intensive but delivered over a shorter time period compared to prevention 167 interventions. The comparison or control group was not always clearly specified but was assumed to 168 be "usual care" in most of the studies (33/39) and often the studies did not justify their rationale for 169 choosing the comparator.

#### 170 3.1.2. Country and Setting

171 The evaluations were spread across a wide range of countries and study settings. The vast 172 majority (38/39) originated from high-income countries, mainly Australasia (Australia (n=15) [12, 22, 173 29-33, 41, 45, 51] and New Zealand (n=2) [35, 42]), with 13 from North America (USA (n=12) [23, 174 26-28, 36-39, 43, 44, 47, 50], Canada (n=1) [48]) and 8 from Europe (UK (n=4) [21, 34, 40, 49], Germany 175 (n=2) [52, 53], Finland (n=1) [55], Spain (n=1) [54]). Only one study was from a developing country 176 context - China [46]. In terms of study setting, the majority of prevention interventions (21/28) were 177 school-based [22, 23, 27, 30-33, 35, 37, 38, 42, 43, 46, 50, 52-54] and for treatment interventions, most 178 (9/11) took place in clinical settings [12, 21, 40, 41, 47-49, 51, 55].

179 3.2. *Review of Economic Evaluation Methods* 

180 A detailed account of the economic evaluation methods are presented in Tables S2-4 (i) – S2-4
181 (iv) (see Supplementary Material).

#### 182 3.2.1. Type of Economic Evaluation and Measures of Effectiveness

183 The majority of studies that conducted a Cost-Effectiveness Analysis (CEA) used raw or 184 standardised BMI as a measure of clinical outcome (26/39) (18 prevention and 8 treatment), whilst 185 other studies used one or more measures from: cases of overweight/obesity prevented; unit increase 186 in MET minutes; reduction in body fat or waist circumference. Approximately half of the studies 187 that undertook a CEA also conducted a Cost-Utility Analysis (CUA) [21, 28-34, 36, 41] with QALYs 188 as the primary outcome measure. The review found that the vast majority of trial-based economic 189 evaluations (15/16) did not use QALYs/DALYs whereas most model-based evaluations (n=20) 190 tended to report QALYs/DALYs as the primary economic outcome. When QALYs were used, the 191 age of the participants was between 6 and 11 years in the trial-based economic evaluation [21], and 192 between 2 and 19 years in the model-based economic evaluations.

193 A pattern with preferred type of economic evaluation by country context was apparent. Within 194 Australasia (13/17) a CUA or a combination of CUA and CEA [12, 29-33, 35, 41] was most popular, 195 whereas the majority of studies from North America (7/13) [26, 39, 43, 44, 47, 48, 50], and the only 196 study from China [46] conducted a CEA only. Across Europe, only UK-based studies used CUA [21, 197 34]. In terms of study setting, a CEA was most common in clinical settings (7/9), whereas within 198 school settings a mixed approach was applied with around half conducting a CEA (12/22). There 199 was no clear pattern found in terms of approach taken to evaluate prevention or treatment 200 interventions.

201 3.2.2. Evaluation Perspective Taken

Most (35/39) studies clearly reported the study perspective. The majority (n=29) were from a societal perspective. Interestingly, none of the UK studies [21, 34, 40, 49], compared to most of those conducted within Australia and the USA, applied a societal perspective. Two studies reported using a health care perspective, but from the data reported it was clear that wider societal costs were included within a secondary analysis [21, 51].

For all interventions that included either a policy or environmental component (12/14), the perspective was societal, whereas for interventions focused exclusively on individual behaviour change a combination of societal (17/25) and healthcare (6/25) perspectives was undertaken. A

- 210 societal perspective was also adopted by the vast majority of interventions implemented in school 211 settings (19/22).
- 212 3.2.3. Time Horizon Considered and Type of Modelling Approach Taken

213 The time durations for the trial-based economic evaluations were predicted by the period of the 214 trial. Of interest this ranged from 8 months [54] to 6 years [53] in the prevention studies; and from 215 10 months [50] to 15 months [51] for the treatment interventions. For the model-based evaluations, 216 the time horizon was more at the analysts discretion and within this review ranged from at least 10 217 years (n=5) [26, 28, 36, 38, 39] to a lifetime (15/23) [12, 23, 29-33, 35, 40, 41]. The time horizon was also 218 found to be much shorter within clinical settings (6/9) [21, 47-49, 51, 55] compared to the other study 219 settings such as schools for example. The majority of the studies did not justify their choice of time 220 horizon.

- With respect to modelling, the vast majority of model-based studies (18/23) applied Markov
  modelling [12, 26, 28-33, 35, 36, 39-41] compared to decision analytic modelling [23, 27, 34, 37, 38].
  The majority of the model-based studies did not justify their model choice and the description of
  model details was suboptimal in most of them.
- 225 3.2.4. Choice of Discount Rate

226 For the majority of the trial-based studies (10/16) (4 prevention and 6 treatment), discounting 227 was not appropriate as the time horizons considered were relatively short (less than one year) [21, 228 43, 46-50, 52, 54, 55]. For all the trial-based studies of more than one year, all reported using a 229 discount rate in accordance with the relevant country guidelines apart from one prevention trial 230 from New Zealand [42], which used a 5% discount rate per year for costs, rather than the 3.5% 231 discount rate per year for both costs and outcomes recommended [56]. Most model-based studies 232 (22/23) applied a discount rate for both costs and outcomes (3% per year for Australia (n=12) [12, 233 29-33, 41], the USA (n=8) [23, 26-28, 36-39] and the UK (n=1) [40], and 3.5% per year for New Zealand 234 (n=1) [35]. Interestingly, the rates used for studies from Australia and the UK were not in accordance 235 with their respective country guidelines (which is 5% per year for Australia according to PBAC and 236 3.5% per year for the UK according to NICE) [57, 58]. However, different state governments in 237 Australia recommend different rates and the discount rate used in the included Australian and UK 238 studies was consistent with the US panel recommendations [59]. Most of the studies did not justify 239 their choice of discount rate.

240 3.2.5. Methods for Collecting and Estimating Resource Use/Costs

Half of the trial-based evaluations (8/16) (4 prevention and 4 treatment) reported their methods
for collecting resource use [21, 22, 45, 47, 49, 51-53], while only 10 out of 23 model-based evaluations
(9 prevention and 1 treatment) did so [23, 26, 28, 30-33, 36, 39, 41].

As expected, the choice of inclusion of a particular type of cost varied considerably according to the study purpose, perspective, setting and the nature of the intervention being evaluated. Costs tended to be categorised into programme delivery, direct medical (e.g. healthcare visits), direct non-medical (e.g. travel time/cost for participants) and indirect (e.g. productivity losses because of parents' absence from work). In line with recommendations for CEA [60], the development/set up costs were not considered in the vast majority of studies, apart from one trial-based prevention study from the USA [44].

Of the 9 studies (5 prevention and 4 treatment) that included indirect costs incurred by parents [21, 30, 31, 33, 41, 43, 47, 51, 53], these were mainly from Australia (n=5) and most of them were for preventive "behavioural" interventions within a school-based setting (5/9). Also, direct non-medical costs were reported by 4 prevention studies from Australia [30, 33, 41, 51] and 1 treatment study from the USA [47]. Most of these types of costs (3/5) were for "behavioural" interventions implemented within a clinical setting.

257 3.2.6. Sensitivity Analysis Undertaken

The majority of the trial-based studies (10/16) conducted a deterministic sensitivity analysis to assess the robustness of the results [21, 22, 42, 43, 45, 51-55]. Most of the model-based studies (22/23) apart from the study by Pringle et al (2010) from the UK [34], conducted at least one type of sensitivity analysis with the majority (n=20) applying both deterministic and probabilistic sensitivity analysis in line with recommendations. Half of these studies however did not justify the choice of covariates for the sensitivity analysis.

#### 264 3.3. Narrative Synthesis of Cost-Effectiveness Evidence

265 The most common method for presenting cost-effectiveness evidence was the Incremental 266 Cost-Effectiveness Ratio (ICER) (30/39). The vast majority of the studies (33/37), excluding the CCA 267 ones, reported results that were cost-effective. Some of these (13 of the model-based 268 prevention/treatment studies including 5 by Carter et al (2009)), [12, 28, 29, 34, 36-40] illustrated cost 269 saving results. For instance, Long et al (2015) concluded that a sugar-sweetened beverage excise tax 270 would increase benefits in terms of DALYs averted and result in healthcare cost savings in the USA 271 [28]. Almost half of these 13 studies that illustrated cost-savings were from Australia, followed by 5 272 from the USA and 2 from the UK. None of the trial-based evaluations reported cost saving results, 273 probably due to shorter time horizons. Whilst the findings are not directly comparable between 274 studies due to the heterogeneous nature of the methods used, all of the studies which evaluated 275 interventions targeting only dietary habits (8/8) and the majority of the studies targeting both 276 physical activity and dietary habits (19/21) indicated cost-effective or cost saving results. However, 277 the studies which focused on only physical activity indicated a proportionally smaller number of 278 cost-effective or cost saving results (7/10). Furthermore, the evidence suggests that the majority of 279 behavioural interventions supported by a policy intervention (4/6) were cost-saving [28, 29, 36, 39].

A small number of studies (n=4) [21, 30-32] reported interventions to not be cost-effective. The UK trial-based treatment study [21], which targeted a combination of physical activity and dietary habits with the aim to reduce weight gain in children with obesity remained not cost-effective using a CEA/CUA approach regardless of the choice of perspective. Also, the 3 model-based studies that targeted only physical activity were not cost-effective, for example, the "Walking School Bus" programme which had a high cost of delivery coupled with low participation rates [30].

#### 286 3.4. Quality Assessment of the Included Studies

The quality of reporting the economic evaluations was assessed using the Drummond checklist. Full details of the quality assessment are presented in Tables S6 (i) – S6 (iv) (see Supplementary Material). None of the included studies fulfilled all of the quality criteria however only a small number of the studies were categorised as poor. One challenge regarding the quality assessment was that quality was judged based on the published data only and there might be a difference in what has been reported and what has actually been done. So a bad scoring study might just be due to lack of transparency rather than lack of quality.

294 Certain criteria were simply not applicable to each respective study (e.g. items 12–15, due to 295 different perspectives chosen), while others were not reported. The three criteria which were least 296 well addressed were the rationale for the comparator, the justification for the choice of discount rate, 297 and the model choice. Whilst the time horizon for each study was generally well specified, most 298 studies omitted to provide reasons for choice. Additionally, approximately half of the studies did 299 not justify the choice of economic evaluation nor offered justification for what was explored within a 300 sensitivity analysis.

#### 301 4. Discussion

To the best of our knowledge this is the first study to conduct a review of the methods for economic evaluation and to determine how these methods vary by setting, country and intervention design. The review identified some emerging patterns. We found that among the published economic evaluations, there was no consistent measure of outcomes. Around half of the studies reported clinical (e.g. BMI), rather than health-related outcome measures commonly used within economic evaluation (QALYs/DALYs). This suggests that the measurement of QALYs/DALYs within obesity trials is not firmly established. This heterogeneity of outcome measures will hinder comparability of cost-effectiveness.

No evaluation applied a Cost-Benefit Analysis (CBA) approach. Consideration of broader outcomes going beyond the health sector allows for inclusion of costs and effects from multiple sectors and is particularly relevant for obesity intervention. This is an emerging area of development within economic evaluation and efforts are being made to adapt methodologies to promote the use of CBA [61]. These approaches have been recommended by the UK Treasury guidance to evaluate (usually non-health) public sector projects [62].

317 Model-based evaluations offer the opportunity to improve the generalisability of results as they 318 combine data from a variety of sources. However the findings from five of the model-based 319 evaluations identified within this review were based on small samples [23, 27, 34, 37, 38] and only 320 one of these offered data based on a lifetime horizon. Furthermore, all of the model-based 321 evaluations were for interventions that targeted individual health behaviours and were therefore 322 highly dependent on cultural, infrastructural and other system-related aspects. So the 323 generalisability of results to other contexts, particularly from developed to developing country 324 settings, would be questionable [63]. The majority of the papers did not make explicit mention of 325 procedures for checking their models and no study assessed the sensitivity of their results to the 326 choice of model-type. Despite associated assumptions with modelling studies, the studies evaluated 327 are important as model-based health economic evaluations are today widely accepted as 328 policy-making tools that can inform resource allocation decisions. Almost half of the model-based 329 studies chose a lifetime perspective and the vast majority of them applied Markov modelling.

Most trial-based and model-based evaluations in this review applied recommended discount rates in accordance with the relevant country guidelines. Methods for collecting resource use and the type of cost included were found to vary across the studies. In particular, the indirect costs of overweight and obesity (e.g. productivity losses) were not generally collected alongside the trials. It is considered good practice to report results both with and without indirect costs. Including indirect costs (e.g. costs incurred by families) has the potential to alter the treatment recommendations.

336 The narrative synthesis of the economic evidence and the quality assessment of the included 337 studies are useful for informing health economists/modellers and the direction for future research in 338 this area. In terms of judging cost-effectiveness of interventions, context-specific assessment is 339 problematic as there are different thresholds for cost-effectiveness in different countries. For 340 example, in the UK, NICE recommends a threshold willingness to pay of £20,000-£30,000 per QALY 341 [64], by contrast in Australia the recommendation is AU\$ 50,000 per QALY [30] and in many 342 countries there are no clearly defined thresholds at all. Whilst most interventions in this review 343 appear cost-effective using standard rules of cost-effectiveness, there is substantial variation by 344 intervention design.

#### 345 4.1. Comparison with Previous Systematic Reviews

346 Our finding that most interventions were cost-effective or even cost-saving, is similar to those 347 reported by two other reviews [14, 20], with some overlap between included studies. Other reviews 348 have focused on particular age groups (e.g. pre-schoolers [13]), specific interventions (e.g. only 349 physical activity [17]), or particular outcomes (e.g. anthropometric measurements [13]). Two 350 additional reviews from Australia [12] and the US [15] used the Assessing Cost-Effectiveness (ACE) 351 obesity approach to summarise and compare the cost-effectiveness of a range of interventions. 352 However, none of the previous studies reviewed the methods of the economic evaluations in the 353 way we have outlined.

355 One of the important strengths of this review is the comprehensive search strategy applied 356 encompassing a broad range of electronic bibliographic databases of published studies and the grey 357 literature (six additional studies were identified). Furthermore, the results were not limited to only 358 those published in English (two non-English publications identified) and there were no country 359 restrictions (there was one publication from china as a developing country), resulting in a more 360 complete review than those published previously. Also, the formal quality assessment of the 361 economic evaluations undertaken adds strength to the conclusions. The vast majority of the studies 362 were found to be of very good reporting quality.

363 The review had some limitations. As we focused on full economic evaluations, some important 364 data contained within partial evaluations may have been missed. Further limitations relate to the 365 shortcomings of the included studies and underlying evidence base. There was heterogeneity in 366 both the methods used and with the type of intervention being evaluated, which made synthesising 367 the evidence base challenging. Not all included studies used the same definition of obesity, which 368 may impact on the results. Most of the included studies reported an economic evaluation for an 369 intervention that had previously been reported as clinically effective. It is possible that any trial 370 which had ineffective results did not conduct an economic evaluation or, if they did, failed to get it 371 published, introducing potential publication bias.

#### 372 5. Conclusions

373 This systematic review suggests that current economic evaluations are mainly set in developed 374 countries and the majority focus on the prevention of obesity in children, compared to treatment. 375 Our findings show that the majority of published economic evaluations are for interventions with an 376 individual behaviour change component. The majority, particularly "behavioural and policy" 377 preventive interventions, were cost-effective, even cost-saving. However the review found 378 heterogeneity with respect to methods applied. So, to improve the evidence base further and to 379 enhance comparability across interventions, we recommend a consistent and expanded form of 380 economic evaluation which captures both health and non-health costs and consequences beyond 381 health-gain.

Supplementary Materials: Additional supporting information may be found online in the supplementary material file for this article. This file includes: Section A: Completed PRISMA checklist; Section B: Search strategy; Tables S1 (i) – S1 (iv): Data extraction (Details about study context); Tables S2-4 (i) – S2-4 (iv): Data extraction (Detailed account of the economic evaluation methods); Table S5: Drummond checklist for critically appraising relevant studies; and Tables S6 (i) – S6 (iv): Quality assessment of the included studies.

387 Author Contributions: MZ, PA, BL and EF led the development of the design of this study. PA, BL and EF 388 provided methodological advice and supervised the study. MZ conducted the literature search. Full-text 389 articles were assessed by MZ for eligibility. MZ extracted the data and assessed the quality of the included 390 studies. Any disagreements between the main researcher and the independent researcher (acknowledged 391 above) over the eligibility of specific studies, the data extraction process and the quality assessment process 392 were resolved by discussion between all authors. MZ analysed the data and interpreted the results. MZ drafted 393 the manuscript. All authors were actively involved in revising the drafts of the manuscript and interpreting the 394 results critically for important intellectual content. All authors read, commented on drafts and approved the 395 final manuscript.

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