



# Modelled Distributional Cost-Effectiveness Analysis of Childhood Obesity Interventions: A Demonstration

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## Abstract

**Objective** To demonstrate how distributional cost-effectiveness analyses of childhood obesity interventions could be conducted and presented for decision makers.

**Methods** We conducted modelled distributional cost-effectiveness analyses of three obesity interventions in children: an infant sleep intervention (POI–Sleep), a combined infant sleep, food, activity and breastfeeding intervention (POI–Combo) and a clinician-led treatment for primary school-aged children with overweight and obesity (High Five for Kids). For each intervention, costs and socioeconomic position (SEP)-specific effect sizes were applied to an Australian child cohort ( $n = 4898$ ). Using a purpose-built microsimulation model we simulated SEP-specific body mass index (BMI) trajectories, health-care costs and quality-adjusted life years (QALYs) from age 4 to 17 years for control and intervention cohorts. We examined the distribution of each health outcome across SEP and determined the net health benefit and equity impact accounting for opportunity costs and uncertainty due to individual-level heterogeneity. Finally, we conducted scenario analyses to test the effect of assumptions about health system marginal productivity, the distribution of opportunity costs and SEP-specific effect sizes. The results of the primary analyses, uncertainty analyses and scenario analyses were presented on an efficiency–equity impact plane.

**Results** Accounting for uncertainty, POI–Sleep and High Five for Kids were found to be ‘win–win’ interventions, with a 67% and 100% probability, respectively, of generating a net health benefit and positive equity impact compared with control. POI–Combo was found to be a ‘lose–lose’ intervention, with a 91% probability of producing a net health loss and a negative equity impact compared with control. Scenario analyses indicated that SEP-specific effect sizes were highly influential on equity impact estimates for POI–Combo and High Five for Kids, while health system marginal productivity and opportunity cost distribution assumptions primarily influenced the net health benefit and equity impact of POI–Combo.

**Conclusions** These analyses demonstrated that distributional cost-effectiveness analyses using a fit-for-purpose model are appropriate for differentiating and communicating the efficiency and equity impacts of childhood obesity interventions.

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## Key Points for Decision Makers

This study models and presents the cost effectiveness and equity impact of three childhood obesity interventions.

Two interventions generated a net health benefit and reduced inequities (a ‘win–win’) and one intervention generated a net health loss and widened inequities (a ‘lose–lose’).

The demonstrated methods allow for the fair comparison of candidate interventions and can support decision making that addresses inequities in childhood obesity.

## 1 Introduction

In recent years, considerable progress has been made in methods to incorporate equity considerations into economic evaluation of health interventions, in line with an increased prominence of equity objectives on health policy agendas worldwide [1]. In a systematic review of applied equity-informative economic evaluations published before late 2019, 80% of the 53 studies identified were published on or after 2015 [2]. Various analyses were used in these studies including assessing impacts on inequalities, using weights to prioritise those most at need, assessing financial protection effects or a combination of each of these. The phrase ‘distributional cost-effectiveness analysis’ (DCEA) [3] has been used as an umbrella term to describe many of these approaches. DCEA has been defined as a group of techniques which evaluate the impact of an intervention on the distribution of costs and benefits over an equity-relevant variable [4]. Distinctive attributes of DCEA include accounting for distributions of opportunity cost across equity characteristics, the presentation of results on an equity–efficiency impact plane [5] and consideration of trade-offs between equity and efficiency.

While equity-informative economic evaluations have become more common, few have been conducted in childhood obesity prevention. Only three of the included studies in the review by Avanceña, et al. [2] evaluated obesity interventions [6–8], and only one of these were targeted to children [7]. This is not due to a lack of need. According to the World Health Organization, in 2016 approximately 340 million children aged 5–19 years were living with overweight or obesity globally, a prevalence of 18%. Socioeconomic inequalities in this burden are wide and persistent in many countries. In high-income countries such as the UK [9, 10], USA [11], Australia [12] and New Zealand [13], children experiencing greater socioeconomic disadvantage are at considerably greater risk of overweight and obesity. For example, the most recent national statistics reported in Australia indicate that children aged 2–17 years living in the lowest socioeconomic quintile areas are more than twice as likely to have obesity than children in the highest socioeconomic quintiles [12]. As childhood obesity is associated with a number of health conditions [14, 15] and poorer psychosocial outcomes in childhood [16–18], as well as excess morbidity and mortality in adulthood [19, 20], these inequalities in obesity are a potential mediator of inequalities in overall health, wellbeing and longevity. Inequalities in overweight, obesity and other health outcomes can be considered unfair as they likely arise out of differences in social and physical environments that those affected have little capacity to control [21]. Hence, these socioeconomic inequalities are regarded here as inequities.

Expert commentators have highlighted the need to direct research and policy resources towards efforts to resolve such inequalities [22–25]. Conducting DCEA of childhood obesity prevention strategies could provide key evidence to support these efforts. However, one of the challenges in conducting DCEA in this area is that the health and economic benefits of prevention strategies are often realised after the resources are spent and beyond the follow-up period of trials testing these strategies. Hence, trial-based evaluations of these strategies may underestimate their cost effectiveness, and possibly their equity impact. One way to overcome this challenge is to conduct evaluations which model health and economic outcomes over a relevant timeframe.

The primary aim of this study was to demonstrate a method by which modelled distributional cost-effectiveness analysis can be conducted for obesity interventions in children and presented for decision makers in an easily comprehensible format. We also aim to identify and discuss key challenges of using this approach.

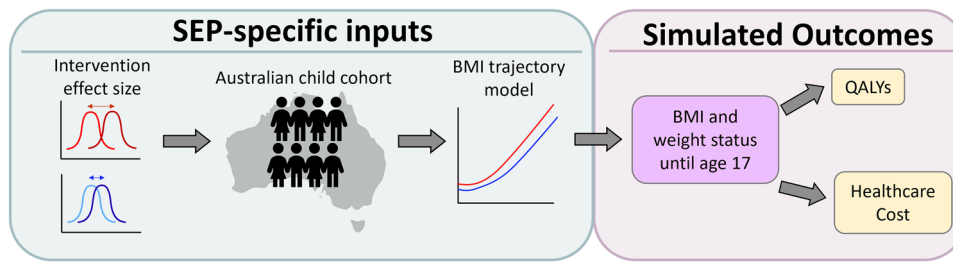
## 2 Methods

### 2.1 Overview of Analysis Approach

A common methodology was used to conduct a modelled distributional cost-effectiveness analysis of three obesity interventions (two prevention, one treatment) for Australian children (Fig. 1), with socioeconomic position (SEP) as the equity variable of interest. Briefly, a simulated cohort for each intervention was created by applying SEP-specific effects to a nationally representative cohort of Australian children from the Longitudinal Study of Australian Children (LSAC) [26]. A cohort with no intervention costs or effects applied was used as a control. Then, using an SEP-specific microsimulation model, body mass index (BMI), overweight and obesity, quality adjusted life years (QALYs) and health-care costs were modelled from age 4 to 17 years for all four cohorts (three intervention cohorts and one control cohort). The net health benefit and equity impact of each intervention was then calculated and plotted on an equity–efficiency impact plane. Each evaluation took an Australian health-funder perspective, and the base year of each analysis was 2018.

### 2.2 Australian Child Cohort

We used BMI and SEP measurements from 4898 children from wave 1 of the kindergarten (K) cohort of LSAC, when they were aged 4–5 years. In the LSAC, BMI was derived from direct anthropometric measurements taken during study interviews. The measure of SEP, a continuous  $z$ -score,



**Fig. 1** Schematic of modelling process. SEP-specific intervention effects were applied to an Australian child cohort and an SEP-specific BMI model was used to simulate BMI, weight status, QALYs

and healthcare costs for each child in the cohort until age 17 years. *SEP* socioeconomic position, *BMI* body mass index, *QALYs* quality-adjusted life years

was derived from parents’ education and occupation and family income [27]. At all stages of our analysis, population survey weights were applied such that the modelled population was representative of the total population of Australian children in the relevant age cohort [28]. This cohort was used as a ‘control’ cohort for this analysis, representing children who had not received any of the interventions being investigated.

**2.3 Interventions**

We evaluated three interventions as part of this demonstration (Supplementary Appendix 1). Two were primary prevention interventions (including all children regardless of weight status) from the Prevention of Overweight in Infancy (POI) trial [29, 30] in New Zealand: one was a sleep intervention (POI–Sleep) and the other a sleep intervention combined with a food, physical activity and breastfeeding intervention (POI–Combo) that ran from before birth until 2 years of age with follow-up at 5 years of age. The third intervention was a treatment (only for children already experiencing overweight or obesity) tested in the High Five for Kids (H54K) trial [31] conducted in paediatric practices in the USA in 2–6-year-old children. This treatment intervention targeted obesity-related behaviours such as food and drink consumption, screen time and physical activity.

These trials were selected due to the availability of data on their SEP-specific effects on child BMI and the cost of the intervention per child. In both trials investigating the three interventions, child height and weight were measured by trained staff using calibrated scales and stadiometers [31, 32]. As we had access to individual-level data from the POI trial, we derived SEP-specific effect sizes at the 5 year follow-up for POI–Sleep and POI–Combo groups. We calculated the mean and standard error of the difference in BMI between intervention and control groups within three SEP groups, based on the New Zealand Deprivation Index 2013 [33] (Supplementary Appendix 2). The cost of POI–Sleep and POI–Combo has previously been established [34]. The costing accounted for staff training and salaries, educational

materials, group sessions and personalised interventions that included home visits and vehicle running costs. For H54K, intervention effects were reported for children above and below USD\$50,000 [31], the approximate median household income at the time of the trial [35], and intervention costs were reported in a separate study [36]. We used the provider-related costs reported in this study and similar to POI, this costing accounted for staff time and material and equipment such as forms, newsletters, scales and stadiometers. The costs for all three interventions were valued in or converted to 2018 Australian Dollars using OECD purchasing power parity [37] and inflators from the Australian total health price index [38], where appropriate.

**2.4 Applying Effect Sizes and Intervention Costs to the LSAC Cohort**

The Australian child cohort (see Sect. 2.2) was not involved in the trials measuring the effectiveness of the three interventions. Instead, we simulated the effect of the interventions on the Australian child cohort by applying a one-time reduction in BMI to the individuals in the cohort based on each intervention’s BMI effect size determined from trials. These effect sizes were applied according to the SEP categorisation, target group and age of the trial populations. For POI–Sleep and POI–Combo, the LSAC cohort was categorised into three groups based on deciles of the SEP *z*-score: deciles 1–3, 4–7 and 8–10 corresponded to the lowest, middle and highest SEP groups respectively. As the mean age of the trial participants at the follow-up measurements was 5 years, we applied the effect sizes to the baseline LSAC cohort when children were aged 4–5 years (mean age 4.9 years). For each child within each SEP group, we randomly selected an effect size (a BMI difference) from a normal distribution based on the appropriate SEP group in the trial and adjusted each child’s BMI accordingly.

Similar methods were used for H54K. Children in the LSAC cohort were identified as high or low SEP based on above and below the median SEP *z*-score to correspond

to the above and below median income groups in H54K, respectively. The target group for this intervention was children with existing overweight or obesity, and the 1 year follow-up results were calculated at mean age 6 years. Hence, effect sizes for high and low SEP were applied only to those children in the LSAC cohort with overweight or obesity when their mean age was 6 years. As with POI, effect sizes were randomly selected from a normal distribution based on the appropriate income group in the trial and each child's BMI was adjusted accordingly. Simulated outcomes were generated for the whole LSAC child cohort including children with healthy weight who had no intervention effect applied. Mean intervention costs were applied to the children targeted in the intervention. That is, for POI–Sleep and POI–Combo, the costs were applied to all children while for H54K, costs were only applied to those with overweight or obesity at age 6 years.

## 2.5 Modelling BMI, Healthcare Costs and QALYs

For the control cohort (with no effect size applied) and the three intervention cohorts, each of the same size (4898 children), BMI, healthcare costs and utilities were simulated annually until children were aged 16–17 years. Simulations were conducted using the EQuity-informative Early Prevention of Obesity in CHildhood (EQ-EPOCH) model, described elsewhere [39, 40]. This model predicts BMI trajectories and prevalence of overweight and obesity for children in high and low SEP groups defined by LSAC SEP  $z$ -score  $\geq 0$  and SEP  $z$ -score  $< 0$  respectively (Table 1). The model has good face validity, predicting faster BMI growth for children at lower SEP, and good internal validity (Supplementary Appendix 3). At each 1 year cycle, healthcare costs and utilities were modelled from child weight status. Weight status specific healthcare costs were estimated from

national data on government-funded healthcare using a top-down approach (Supplementary Appendix 4). Weight status specific utility decrements were derived from a recent systematic review [41] (Supplementary Appendix 5). We simulated costs and outcomes for the control and each intervention cohort until children were aged 17 years, discounting QALYs, healthcare costs and intervention costs at 5% per year as per Australian standards [42].

## 2.6 Equity Impact and Net Health Benefit

The socioeconomic distribution of BMI, overweight and obesity and QALYs at age 17 years were examined in each intervention and the control cohort by calculating mean values for the highest and lowest SEP quintiles (least and most socially disadvantaged, respectively). For QALYs, the slope index of inequality (SII) [43] was also calculated for each cohort. To calculate the net health benefit [44] and equity impact [4], accounting for opportunity costs, we assumed an opportunity cost of \$50,000 for each QALY gained [45]; the approximate threshold for cost effectiveness used in Australia. However, as the appropriate threshold is not explicit in the Australian setting, an alternative cost-effectiveness threshold to \$50,000 per QALY gained was tested in scenario analysis (described below). As per DCEA methodology, the distribution of opportunity costs across the equity variable of interest should be accounted for when determining the 'net' equity impact of an intervention [4]; if the alternative use of the extra funds needed for the intervention are more likely to be spent on the lower SEP groups, then the net benefit of the intervention in the lower SEP groups will be diminished, affecting the equity impact. However, analyses quantifying the distribution of these opportunity costs are rare, and not available for Australia. Hence, in the base case analysis, we assumed opportunity costs were distributed evenly across socioeconomic groups. With this assumption,

**Table 1** SEP-specific characteristics from the LSAC K cohort and simulated outcomes under 'no intervention' scenario ( $n=4898$ )<sup>a</sup>

	SEP quintile				
	1	2	3	4	5
Age 4–5 (input population)					
Mean BMI	16.5 (16.3–16.6)	16.4 (16.3–16.5)	16.3 (16.2–16.5)	16.2 (16.1–16.3)	16.2 (16.1–16.3)
Prevalence of overweight and obesity (%)	36.4 (32.9–40.1)	35.5 (31.9–39.1)	33.4 (29.9–37.1)	30.5 (27.5–33.6)	28.7 (25.8–31.9)
Age 16–17 (endpoint)					
Mean BMI (actual)	24.8 (24.0–25.5)	24.0 (23.4–24.5)	23.4 (22.9–23.9)	23.0 (22.6–23.4)	22.4 (22.1–22.7)
Mean BMI (simulated)	24.1 (23.9–24.3)	24.0 (23.8–24.1)	23.8 (23.6–24.0)	22.8 (22.7–23.0)	22.8 (22.7–22.9)
Prevalence of overweight and obesity (%) (actual)	41.9 (35.1–49.0)	36.7 (31.5–42.2)	30.9 (26.3–35.9)	27.6 (23.9–31.7)	22.9 (19.8–26.4)
Prevalence of overweight and obesity (%) (simulated)	41.4 (37.9–45.1)	41.0 (37.4–44.7)	38.4 (34.7–42.3)	22.6 (20.1–25.3)	20.8 (18.2–23.7)

SEP socioeconomic position, LSAC Longitudinal Study of Australian Children, K Kindergarten, BMI body mass index

<sup>a</sup>All tabulated values are presented as means or prevalence with 95% confidence intervals in brackets

the equity impact could be calculated as the difference in the SII for QALYs at age 17 years between the intervention and control. The point estimate of the net health benefit and equity impact of each intervention were plotted on an equity–efficiency impact plane.

### 2.7 Uncertainty Analyses

To examine uncertainty due to individual-level heterogeneity, 1000 bootstrapped samples were taken from the simulated control and intervention cohorts, and the net health benefit and equity impact was recalculated for each sample. The estimates for each bootstrapped sample were plotted on the equity–efficiency impact plane with the point estimate, and used to calculate the probability of each intervention being in each quadrant of the plane.

### 2.8 Scenario Analyses

To identify which parameters may be influential to each intervention’s position on the equity–efficiency plane, we recalculated net health impact and equity impact in QALYs for each intervention under a number of scenarios. These included:

1. Using an alternative opportunity cost of \$28,033 per QALY gained according to a recent estimate of the Australian health system’s marginal productivity [46].
2. Assuming an uneven distribution of opportunity cost across SEP quintiles where those in the lowest SEP groups receive a greater proportion of new government health funding. It is likely that this is reflective of the Australian context which has a mixed public and private health system. However, as the distribution has not been quantified in an Australian setting, we tested the effect of using the same distribution estimated for England where those in the lowest socioeconomic quintile receive 26.4% of the QALY benefits from marginal health fund-

ing, and those in the highest quintile receive 13.9% [47]. Further details are provided in Supplementary Appendix 6.

3. Using the published overall effectiveness measure of each intervention (Supplementary Appendix 7), instead of SEP-specific effects. This was to assess whether using SEP-specific effect sizes is important for equity-informative economic evaluations.

## 3 Results

### 3.1 Australian Child Cohort

In the LSAC K cohort, mean BMI and prevalence of overweight and obesity decreased with increasing SEP quintile at baseline (age 4–5 years) and at the end of the follow-up period (age 16–17 years) (Table 1). At baseline, there was a 7.7% difference in the prevalence of overweight and obesity between the highest and lowest SEP quintiles. By age 16–17 years, this difference grew to 19% which was captured well in the simulated control cohort (20.6%).

### 3.2 Interventions

The relevant characteristics of each intervention evaluated are presented in Table 2. For POI–Sleep, there were little differences in effect size across the three SEP groups. For POI–Combo, the intervention effects were largest in the middle and high SEP groups. For H54K, as presented in the primary outcomes publication [31], the effect size was much larger in the low compared with high income groups.

### 3.3 Distribution of Modelled Outcomes

At the end of the simulated period, the inequality in BMI, overweight and obesity status and QALYs between the

**Table 2** Intervention characteristics

	Trial sample characteristics at entry	Sample size	Outcome measured	Intervention effect (kg/m <sup>2</sup> ) (Intervention – Control) Mean (SE)	Cost per child (2018 AUD) <sup>a</sup> Mean
POI–Sleep	Infants (intervention delivered antenatally to 2 years of age)	Intervention—163 Control—179	BMI at age 5 years	Low SEP: –0.220 (0.247) Middle SEP: –0.265 (0.208) High SEP: –0.183 (0.220)	184.34
POI–Combo	Infants (intervention delivered antenatally to 2 years of age)	Intervention—167 Control—179	BMI at age 5 years	Low SEP: 0.029 (0.244) Middle SEP: –0.182 (0.199) High SEP: –0.109 (0.217)	601.45
High Five for Kids	Children with overweight and obesity, mean age 5 years	Intervention—253 Control—192	Change in BMI at mean age 6 years	Low income: –1.02 (0.32) High Income: –0.01 (0.17)	231

SE standard error, AUD Australian Dollar, POI prevention of overweight in infancy, BMI body mass index, SEP socioeconomic position

<sup>a</sup>Present value age 0–1 years using a 5% discount rate

highest and lowest SEP quintiles was widest for POI–Combo and narrowest for H54K (Fig. 2). Compared with control, the POI–Sleep and H54K intervention cohorts had lower inequality, while POI–Combo had higher inequality in all outcomes.

### 3.4 Equity Impact and Net Health Benefit

The point estimate net health benefit for both POI–Sleep (0.003 QALYS) and H54K (0.007 QALYS) was positive (Fig. 3, Supplementary Appendix 8). The point estimate equity impact was also positive for both POI–Sleep (0.002 QALYS) and H54K (0.02 QALYS) (Fig. 3, Supplementary Appendix 8). Therefore, both interventions were in the ‘win–win’ quadrant of the equity–efficiency impact plane. The point estimate for POI–Combo was in the ‘lose–lose’ quadrant, demonstrating a net health loss (of 0.009 QALYS) and an increase in inequities (by 0.005 QALYS) when compared with control.

### 3.5 Uncertainty Analyses

When accounting for joint uncertainty in net health benefit and equity impact, H54K had a 100%, POI–Sleep had a 67% and POI–Combo had a 0% probability of having a positive net health benefit and equity impact (‘win–win’) compared with control. POI–Sleep had a 32% probability of having a positive net health benefit but negative equity impact (‘win–lose’) and POI–Combo had a 91% probability of having a net health loss and negative equity impact (‘lose–lose’) compared with control.

### 3.6 Scenario Analyses

The influence of key uncertain parameters on net health benefit and equity impact, investigated in the scenario analysis, are illustrated in Fig. 4 and quantified in Supplementary Appendix 8. In scenario analysis 1 (SA1), using the marginal productivity estimate of \$28,033 per QALY gained had the greatest impact on POI–Combo, worsening the net health loss by 0.009 QALYS (Supplementary Appendix 8). In scenario analysis 2 (SA2), assuming an uneven distribution of opportunity costs also had the greatest impact on POI–Combo, with all bootstrapped points moving into the ‘lose–lose’ quadrant but little effect on the other two interventions. In scenario analysis 3 (SA3), applying the same effect size in all SEP groups had the largest influence on H54K, where the probability of being in the ‘win–win’ quadrant went from 100 to 23%, and on POI–Combo in which the probability of being in the ‘lose–win’ quadrant went from 10 to 63%.

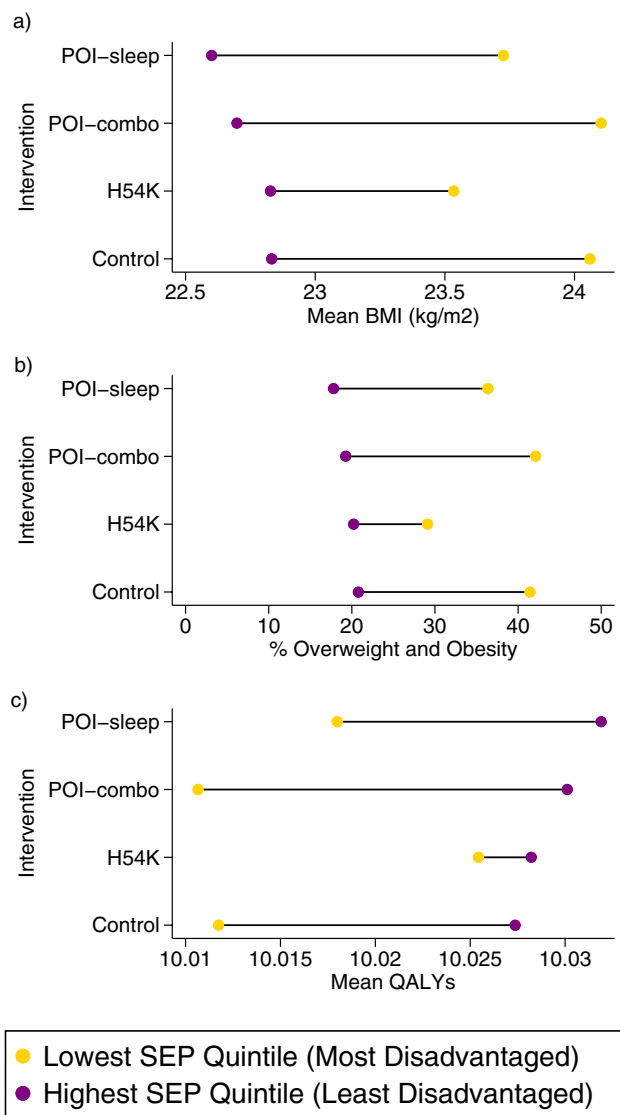
## 4 Discussion

In this study, we demonstrated how a modelled DCEA could be conducted for both preventative and treatment interventions addressing childhood overweight and obesity. These analyses showed that one prevention intervention (POI–Sleep) and one treatment (H54K) produced positive net health benefits and reduced inequities in BMI and QALYS, while another prevention intervention, POI–Combo, produced a net health loss and wider inequities.

The scenario analyses showed that using unstratified effect sizes instead of SEP-specific values had a large effect on the modelled equity impact, and to a lesser extent, the net health benefit, of H54K and POI–Combo. This reveals the importance of ensuring reliable, SEP-specific estimates of effect are identified for candidate interventions. Where possible, SEP-specific effects should be derived from well-designed and well-powered randomised controlled trials or systematic reviews with meta-analyses. The scenario analyses also showed that assumptions about the marginal productivity of the Australian healthcare system and the distribution of opportunity costs had the greatest effect on POI–Combo. This is because it had the largest incremental costs and therefore the largest opportunity costs per child of the three interventions (Supplementary Appendix 8).

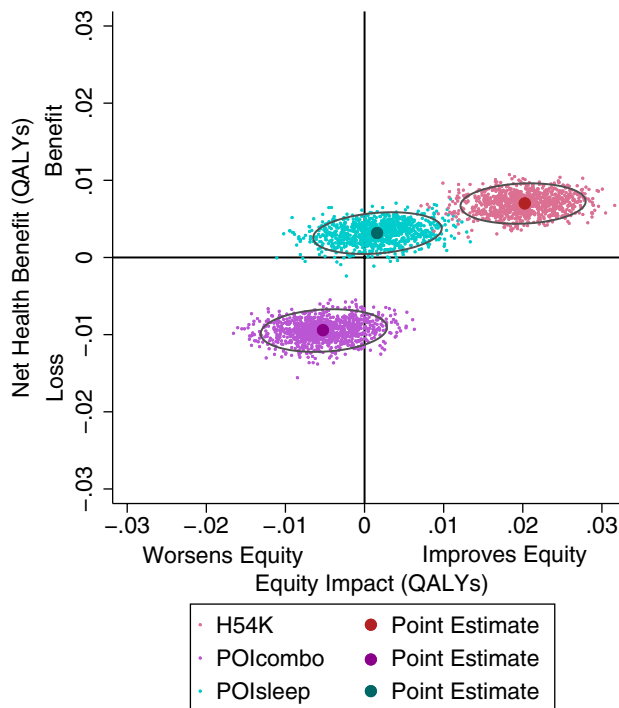
Relatively little existing literature is available for comparison. Two previous equity-informative economic evaluations of obesity interventions [7, 48], also used SEP-specific effect sizes but did not derive these from randomised controlled trials. In contrast to these studies which used cohort-based modelling, in our study, heterogeneity in BMI across SEP was inherently accounted for by performing individual-level simulation of data from a nationally representative child cohort. We additionally modelled SEP specific BMI trajectories, unlike the aforementioned studies. The equity-relevant results presented also differ across the studies. Both studies [7, 48] presented SEP-specific ICERs, and one [48] calculated equity impact by taking the difference in QALYS between the lowest and highest SEP tertile groups. This differs from our study in which equity impact is calculated by taking the difference in SIIs, a more robust measure of inequality, and accounting for opportunity costs. The two school-based prevention interventions when evaluated from a healthcare perspective in Oosterhoff et al. [48], were found to be ‘lose–win’ when compared with a regular curriculum control; however, uncertainty in the equity impact was not presented.

There are a number of strengths to our analyses. First, our fit-for-purpose EQ-EPOCH model is sufficiently flexible to allow simulation of interventions at different ages and targeted to specific sectors of the population, whilst



**Fig. 2** Simulated outcomes at age 17 years in the highest and lowest SEP quintile. **a** Mean BMI, **b** prevalence of overweight and obesity and **c** mean QALYs. *POI* prevention of Overweight in Infancy trial, *H54K* high five for kids, *BMI* body mass index, *QALYs* quality-adjusted life years, *SEP* socioeconomic position

comparing costs and benefits for the same cohort and over the same time horizon. Second, as per best-practice guidelines [49], the EQ-EPOCH model was validated and shown to closely predict aggregate and SEP-specific BMI trajectories and overweight and obesity prevalence. Furthermore, the large, nationally representative cohort of Australian children from which the model was derived and validated was used to simulate outcomes for each intervention, strengthening our confidence in the model predictions produced in this study. Another strength is that the model captures individual level heterogeneity allowing the assessment of uncertainty in net health benefit and

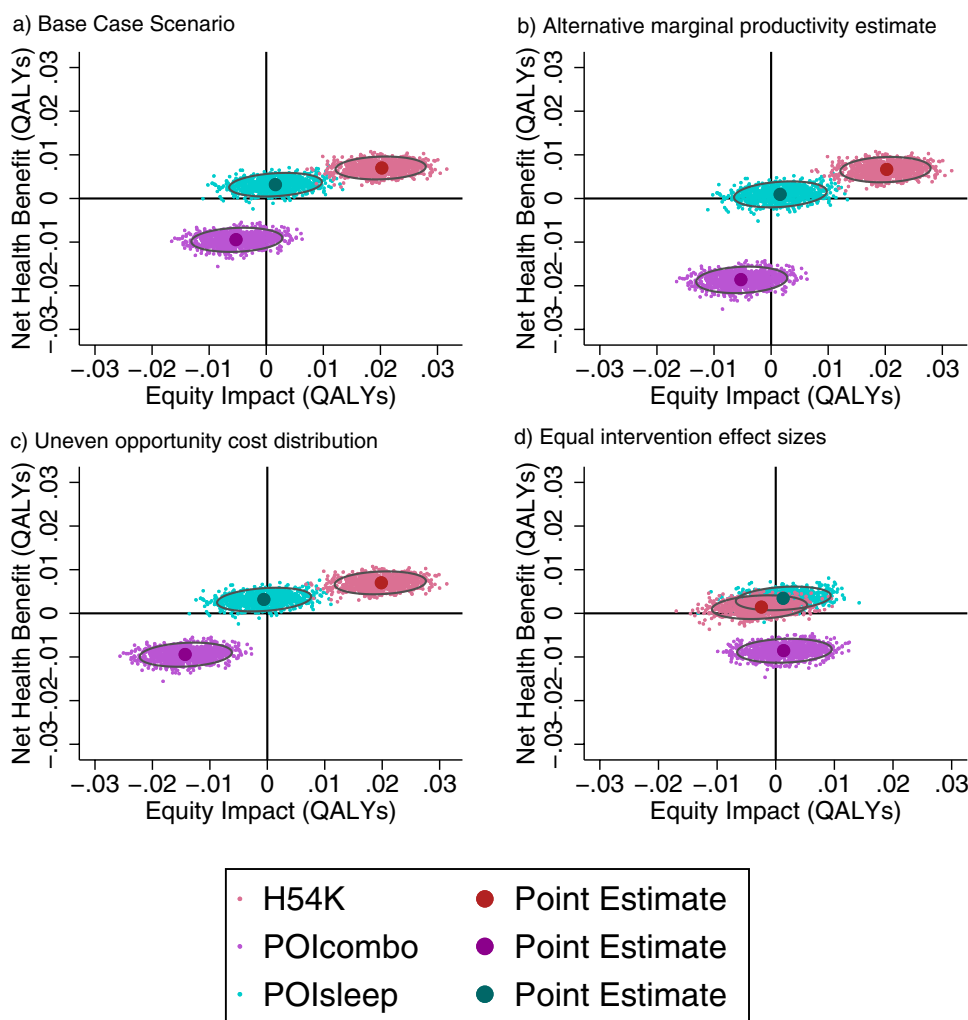


**Fig. 3** Equity–efficiency plane. Point estimates (large circle), bootstrapped estimates (small circles) and 95% confidence ellipses are presented on the equity efficiency plane for each intervention. *POI* prevention of overweight in Infancy trial, *H54K* high five for kids, *QALYs* quality-adjusted life years

equity impact and estimation of the probability that the intervention fell in each quadrant of the equity–efficiency plane. To the best of our knowledge, this is the first DCEA to account for individual-level heterogeneity in uncertainty analysis. Parameter uncertainty has been examined in one other study [50], but not individual-level heterogeneity. Finally, by illustrating the multi-faceted results on the equity-efficiency plane we have made them accessible to policy makers and other end users. In a single diagram, the end user can grasp information on the net health impact and equity impact of different intervention options including an understanding of uncertainty in the results.

There are also some limitations. First, each trial and the model used measures of SEP that accounted for different socioeconomic attributes. While the attributes used are likely highly correlated, these measurement differences potentially influenced effect sizes, modelling and equity impact calculations. As has been recognised in the literature [51], further work is needed to achieve consensus on the most appropriate measure of SEP in the context of childhood obesity. Furthermore, as the EQ-EPOCH model is primarily deterministic in its current form, future BMI was determined by the current BMI, age, sex and SEP of each child. This meant that variation in BMI due to other factors and parameter uncertainty

**Figure 4** Equity–efficiency planes under base case and scenario analyses. **a** Base case and **b** alternative estimates for the marginal productivity of the Australian health system, **c** changed distribution of opportunity costs and **d** assumed equal intervention effect sizes. Point estimates (large circle), bootstrapped estimates (small circles) and 95% confidence ellipses. *POI* prevention of overweight in Infancy trial, *H54K* high five for kids, *QALYs* quality-adjusted life years



was not accounted for. Our methods did, however, account for uncertainty in effect sizes and population heterogeneity. Our model also only predicts outcomes until age 17 years which excludes health benefits in adulthood but is a relevant timeframe for decision makers working within policy funding cycles. Finally, variation in intervention uptake could not be assessed by the randomised controlled trials (RCTs) informing this study, but could affect the efficiency and equity impact of implementing the interventions. Future work, focussed on implementation, will investigate different uptake scenarios.

The methods demonstrated here can be used to conduct DCEA for interventions addressing childhood obesity in Australia. The EQ-EPOCH model allows for different types of interventions to be evaluated, and their distributional and efficiency attributes compared. Beyond childhood obesity, this study has implications for the evaluation of interventions, programmes and policies addressing other health issues. For example, the scenario analyses demonstrated the impact that using overall effect sizes rather than SEP-specific effects could have on a resource allocation decision;

with the latter, H54K would be considered the ‘best buy’ out of the three examples while with the former, POI–Sleep would be considered the best use of resources as it had the greatest probability of generating a net health benefit and positive equity impact. Any intervention whose effect relies on socioeconomically patterned mediators have the potential to have SEP-specific effects [52, 53] and this may influence the outcome of a DCEA in a similar way to this study’s example. Hence, it is important that DCEAs of such interventions apply reliable estimates of SEP-specific effects. The scenario analyses further highlighted that the larger the incremental costs, the more influential the assumptions around health system marginal productivity and distribution of opportunity cost become. This would be true for any DCEAs set in countries in which these indicators are unknown and this uncertainty needs to be made clear when findings are presented.

Beyond the methods demonstrated, this study offers direction for future research to support the application of DCEA findings to funding decisions for childhood obesity and other health interventions in the Australian context. For



example, further work is needed to examine, quantitatively, the distribution of opportunity costs and to reach consensus on the marginal productivity of the Australian health system to provide more certainty to the findings presented to end users. In prospective applications of the EQ-EPOCH model, where childhood obesity interventions may fall in ‘win–lose’ or ‘lose–win’ quadrants, further analyses may be needed to help decision makers’ determine the most favourable intervention. The DCEA literature proposes two approaches to these analyses [4]: (1) the use of direct equity weights to prioritise specific population groups (e.g. low SEP [54]) or (2) the use of indirect equity weights (such as the Atkinson and Kolm–Pollak indices), which prioritise groups based only on health level. Both approaches require further analysis decisions which reflect different normative perspectives on equity. There are legitimate reasons for choosing either approach and their downstream analytical options and, as such, further examination of the decision-making context may be warranted to support these choices.

## 5 Conclusions

The methods described here provide a process by which the equity and efficiency characteristics of interventions addressing childhood obesity can be comprehensively analysed, yet presented in an easily digestible format for an Australian context. While further research will be valuable, the use of these methods as is can inform funding decisions that explicitly consider equity and efficiency impacts side by side.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s40258-023-00813-9>.

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## Declarations

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**Conflict of interest** The funders did not have any input in the study design, conduct, analysis or reporting, and the authors have no further conflicts of interest to declare.

**Ethics approval** This study was approved by the University of Sydney Human Research Ethics Committee (project number 2018/726). The POI trial was approved by the University of Otago Ethics Committee.

**Consent to participate** POI trial participants consented to be part of the study.

**Consent for publication** POI trial participants consented to have aggregate analyses from their data published.

**Data availability** Deidentified participant data from the POI trial and the study protocol will be available upon reasonable request from Rachael W. Taylor for a period of 3 years.

**Code availability** STATA code for the analysis is available from the authors on request.

**Author contributions** AK conducted the analyses and wrote the initial draft of the manuscript. AK, AH, TL and RWT contributed to the study design, interpreted analyses and made revisions to the manuscript drafts.

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