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Utility values for childhood obesity interventions: a systematic review and meta-analysis of the evidence for use in economic evaluation

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Summary

Rigorous estimates of preference-based utilities are important inputs into economic evaluations of childhood obesity interventions, yet no published review currently exists examining utility by weight status in paediatric populations. A comprehensive systematic literature review and meta-analysis was therefore undertaken, pooling data on preference-based health state utilities by weight status in children using a random-effects model. Tests for heterogeneity were performed, and publication bias was assessed. Of 3,434 potentially relevant studies identified, 11 met our eligibility criteria. Estimates of Cohen's *d* statistic suggested a small effect of weight status on preference-based utilities. Mean utility values were estimated as 0.85 (95% uncertainty interval [UI] 0.84–0.87), 0.83 (95% UI 0.81–0.85), 0.82 (95% UI 0.79–0.84) and 0.83 (95% UI 0.80–0.86) for healthy weight, overweight, obese and overweight/obese states, respectively. Meta-analysis of studies reporting utility values for both healthy weight and overweight/obese participants found a statistically significant weighted mean difference (0.015, 95% UI 0.003–0.026). A small but statistically significant difference was also estimated between healthy weight and overweight participants (0.011, 95% UI 0.004–0.018). Study findings suggest that paediatric-specific benefits of obesity interventions may not be well reflected by available utility measures, potentially underestimating cost-effectiveness if weight loss in childhood/adolescence improves health or well-being.

Keywords: Health-related quality of life, paediatric obesity, systematic review, utility.

Abbreviations: 95% UI, 95% uncertainty interval; BMI, body mass index; CEA, cost-effectiveness analysis; CHU-9D, Child Health Utility 9D; CUA, cost–utility analysis; EQ-5D-Y, EuroQol 5D Youth; HRQoL, health-related quality of life; HUI, Health Utilities Index; MAUIs, multi-attribute utility instruments; QALY, quality-adjusted life year; WMD, weighted mean difference.

Introduction

Childhood overweight and obesity is a serious global public health challenge (1). Given society's scarce resources, rigorous economic evaluation of childhood obesity prevention and treatment interventions is a useful tool for priority setting. Cost–utility analysis (CUA) is a form of economic evaluation that compares the costs of an intervention with the benefits gained, incorporating intervention impact on both the quality and quantity of life. CUA allows for comparison of cost-effectiveness across healthcare programmes and is used as a tool for allocating health resources by governments, including in Australia and the UK (2,3).

The quality-adjusted life year (QALY) is the most widely used utility-based unit of measurement for CUA (4). The use of QALYs allows for comparison between different health states or health outcomes within diverse populations (e.g. both adult and child populations), with an underlying assumption that QALYs are of equal social value irrespective of who accrues them (5). Preference-based health-related quality of life (HRQoL) is incorporated using health utilities that are indexed on a cardinal scale where 0 represents death and 1 represents perfect health (6). Utilities are preference weights, with preference equated with value or desirability (7). Utilities can be measured directly (using techniques such as standard gamble or time trade-off) or indirectly (using multi-attribute utility instruments [MAUIs]) (8). The choice of utility method and measure can have an effect on estimated utility values, and in turn on cost-effectiveness results (9).

Catalogues of utility values can help to inform the appropriate selection of values for use in economic modelling. Health economists are often not equipped with the time or resources to elicit utility values either directly or indirectly themselves. Reviews of utility values for use in adult populations across health states such as diabetes, cancer and mental disorders exist (9–13). Evidence from such reviews improves the robustness, transparency and rigour of modelled economic evaluations, allowing for a more systematic approach to the selection of appropriate model parameters. For instance, the study by Davies *et al.* (14) incorporated utility values from the review by Beaudet *et al.* (9) to investigate the cost-effectiveness of different therapies for patients with type 2 diabetes mellitus.

Limited reviews have examined utility values by weight status in adults (13,15). Measuring utilities for children and adolescents is however only an emerging field of research, given the complexities of valuation in these age groups (16). In particular, whilst MAUIs have gained popularity as a straightforward and easy way to elicit values, most MAUIs have historically been applied in adult populations (17). Limited catalogues or reviews of utility values in child or adolescent populations currently exist (18–21). Additionally, no published reviews or catalogues of utility values for use in CUAs of childhood and adolescent obesity interventions have been identified. To date and to the best of our knowledge, studies undertaking meta-analysis of obesity-related HRQoL in paediatric populations have focused on non-preference-based measures (22,23).

This study aims to systematically review studies reporting utility values by weight status in children and adolescents aged ≤18 years. A meta-analysis was undertaken, providing a catalogue of utility values useful for informing CUAs of obesity interventions in paediatric populations. In addition, this study reviews published economic evaluations of obesity interventions in paediatric populations that have measured or referenced utility-based HRQoL. Health state utility values are often reported in economic evaluations, rather than solely in health benefit measurement studies (24). This ensures an extensive scope for the search for utility values by weight status, and also provides an overview of the current state of practice and context for how published utility values are used in the economic modelling of paediatric obesity interventions.

Methods

The systematic review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (25) and registered with International Prospective Register of Systematic Reviews (#CRD42017067226). A search of the literature was conducted using key search strategies agreed in conjunction with a subject specialist librarian (Supporting Information).

To be considered for inclusion, studies had to meet the following criteria:

- studies published in peer-reviewed journals reporting primary data collection of utility values, with results reported by weight status;
- conducted in paediatric populations (mean or median target age ≤ 18 years);
- written in the English language; and
- published anytime until May 2017.

Reviews or commentaries were excluded. A search was also conducted for economic evaluations of obesity interventions published in peer-reviewed journals including an analysis of HRQoL that used or referenced a preference-based utility instrument. Economic evaluations needed to include paediatric populations within their study population but did not have to be limited to paediatric populations. Utility values needed to specifically relate to weight status, rather than the potential health sequelae of obesity that can also appear in economic models that adopt long-term time horizons. The Paediatric Economic Database Evaluation (26) was also searched, using the search terms 'obes*', 'body mass index' and 'BMI' as keyword/title/abstract search terms. Screening of potential study inclusions was conducted by two authors (V. B. and E. T.), with conflicts resolved in consultation with a third author (M. M.). Reference lists of all included studies were checked for further inclusions (i.e. backward citation searching).

Data were extracted by one reviewer (V. B.) using Covidence (27) and Microsoft Excel and checked by a second reviewer (E. T.). Key characteristics of interest for studies eliciting utility values included study aim, methods, study population, sample size, intervention evaluated (where applicable), utility measure, tariff (where applicable) and QALY weights. Data on weight classification of the study population were extracted as per the body mass index (BMI) cut-off values used in each selected study. Meta-analysis was undertaken with the Microsoft Excel add-in MetaXL version 5.3 (28) using a random-effects model. Mean utility values for healthy weight, overweight, obese and overweight/obese (i.e. studies combining overweight and obese into a single category) states were estimated, ignoring potential within-study correlation in estimates because of the small numbers of studies included (29). Utility values from relevant studies were included as separate observations in the meta-analyses. Forest plots were presented, and tests for heterogeneity were performed using I^2 and Cochran's Q test. Heterogeneity was regarded as substantial when I^2 exceeded 40% or the Q statistic was significant at $p < 0.10$ (30). Formal quality assessment of primary studies eliciting utility values was not undertaken, given a lack of standard systems or checklists for grading the quality of health state utility values (24,31). We examined potential publication and small study bias visually using funnel and Doi plots, where a symmetrical plot suggests no or little bias (32). The Luis Furuya-Kanamori index of asymmetry is also presented from the Doi plot, with an assessment of 'no', 'minor' or 'major' asymmetry (32).

Studies reporting mean utility values for both healthy weight and overweight/obese participants were also pooled to estimate the weighted mean difference (WMD) in utility values and 95% uncertainty interval (95% UI). Sub-analyses were undertaken for studies reporting mean utility values for both healthy weight and either overweight or obese participants. Cohen's d effect sizes were estimated, where approximately 0.2, 0.5 and 0.8 are respectively considered small, moderate and large (33).

A number of sensitivity analyses were undertaken to test the robustness of meta-analysis results. Firstly, individual studies were sequentially excluded from all meta-analyses to gauge the effect on overall results (34) (Supporting Information). Variability in meta-analysis estimates may result from differences in the descriptive systems, valuation protocols and utility ranges of the utility measures. Therefore, sensitivity analyses were also undertaken, restricting study inclusion in the mean utility and WMD healthy weight and overweight/obese meta-analyses to (i) studies using the EuroQol 5D Youth (EQ-5D-Y) (35,36) and (ii) studies using the Child Health Utility 9D (CHU-9D) (36–38). Sensitivity analyses for WMD between healthy weight and either overweight or obese states were only estimated for studies using the CHU-9D instrument (36–38), owing to the small number of included studies using other instruments. Variability in meta-analysis results may also result from the use of

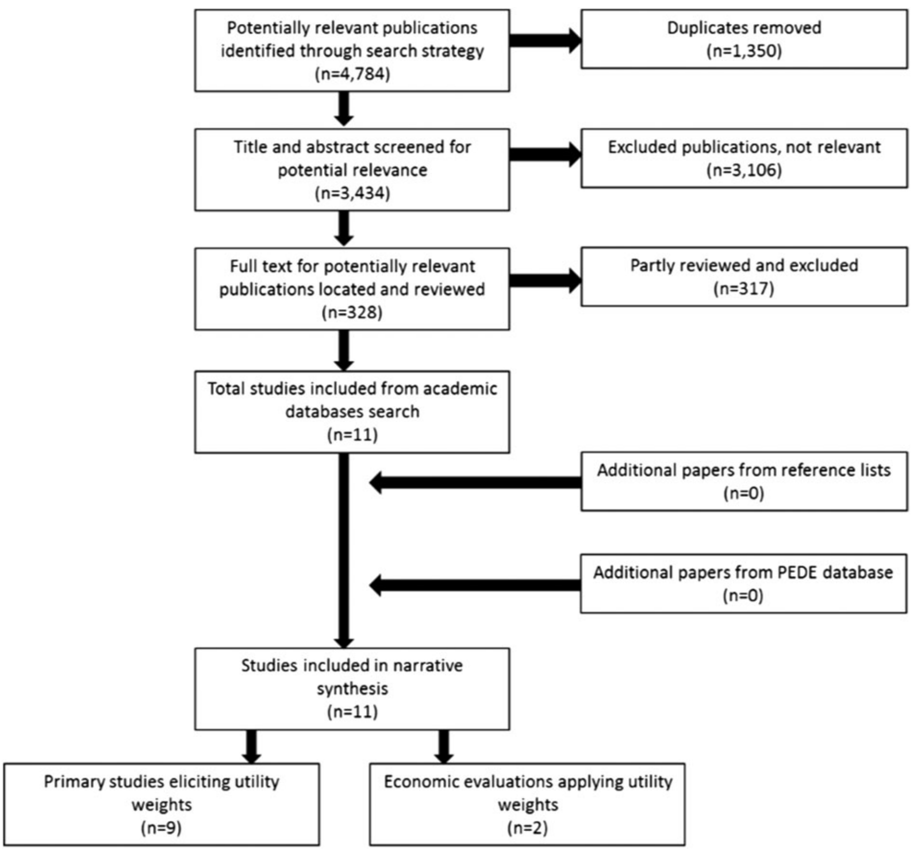

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of systematic review results.

different BMI cut-off reference values between studies (Supporting Information). Sensitivity analyses were therefore conducted, stratifying by BMI cut-off reference values. Sensitivity analyses were also conducted to stratify study inclusions by age, by pooling studies whose mean study participant age was <10 or ≥10 years.

Key study variables of interest for economic evaluations of paediatric obesity interventions included those reported in the Consolidated Health Economic Evaluation Reporting Standards checklist (39). Economic evaluation studies were summarized narratively, focusing on methodology and use of preference-based utility values within the analyses.

Results

Selection and inclusion of studies

After the removal of duplicates, the systematic search resulted in the identification of 3,434 potentially relevant publications (Fig. 1). Titles and abstracts were searched by two independent reviewers, following which 3,106 studies were excluded because they did not meet the inclusion criteria. Full texts for the remaining 328 potentially relevant studies were located and searched, with 317 of these studies excluded because they did not meet the inclusion criteria. No additional papers were identified from the reference lists of included studies or the Paediatric Economic Database Evaluation database. A total of 11 studies were included in our review, nine health state valuation studies eliciting primary utility values (35–38,40–44) and two economic evaluations (45,46).

Study characteristics – primary health state valuation studies eliciting utility values

Health state valuation studies eliciting utility values were undertaken in Australia (37,41,42), England (35,36,38), the USA (40,44) and the Netherlands (43). All studies were cross-sectional, with seven studies reporting data collected at single time points within larger intervention studies (36–38,41–44). Study settings included clinic or specialist care centres (40,43), primary or middle schools (36,38,44), secondary schools (35,41,42) or a mix of both primary and secondary schools as part of a community-based intervention (37). The mean age of study participants varied between 6.3 years (38) and 15.7 years (43) (Supporting Information). Only one study used parental proxy report for utility (with self-report also undertaken in participants aged ≥8 years) (40).

Utility instruments used are reported in Table 1. As might be expected, the most common utility instruments were those developed specifically for use in children and adolescents, with the CHU-9D used in three studies (36–38) and the EQ-5D-Y used in two studies (35,36). One study (35)

Table 1 Utility instruments from included studies

Instrument	Brief description	Studies using instrument	Tariff used
Assessment of Quality of Life 6D (AQoL-6D) (47)	A 20-item questionnaire, including six dimensions (independent living, mental health, coping, relationships, pain and senses).	Bolton *et al.* (41) Keating *et al.* (42)	Recalibrated for adolescents (48)
Child Health Utility 9D (CHU-9D) (49)	Developed exclusively with children by The University of Sheffield. Recommended age range is 7–17 years. Nine dimensions (worried, sad, pain, tired, annoyed, school work or homework, sleep, daily routine and ability to join in activities).	Canaway and Frew (36) Chen *et al.* (37) Frew *et al.* (38)	UK general population (50) Recalibrated for Australian adolescents (51) UK general population (50)
EuroQol 5D Youth (EQ-5D-Y) (52)	The EQ-5D-Y consists of a descriptive system and a VAS developed specifically for use in children and adolescents. Includes five dimensions (mobility, looking after myself, doing usual activities, having pain or discomfort and feeling worried, sad or unhappy).	Boyle *et al.* (35) Canaway and Frew (36)	UK general population (53) UK general population (50)
EuroQol 5D 3L (EQ-5D-3L) (54)	The EQ-5D-3L consists of a descriptive system and VAS scale, including five dimensions (mobility, self-care, usual activities, pain/discomfort and anxiety/depression).	Makkes *et al.* (43)	Dutch general population (55)
Health Utilities Index (HUI2, HUI3) (56)	The HUI2 includes seven attributes (sensation, mobility, emotion, cognitive, self-care, pain and fertility). The HUI3 includes eight attributes (vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain).	Belfort *et al.* (40) Treviño *et al.* (44)	Canadian adult population (57,58)

VAS, visual analogue scale.

Table 2 Published utility weights by weight status from the literature

Reference	Population	Published mean utility value (95% CI or s.d.*)					Utility instrument
		Healthy/normal weight	Overweight	Obese	Severely obese	Overweight or obese	
Belfort *et al.* (40)	Children aged 5–18 years, recruited from primary care and obesity clinic (*n* = 76)	0.81 (95% CI 0.76–0.86)	—	—	—	0.78 (95% CI 0.72–0.83)	HUI3
Bolton *et al.* (41)	Secondary-school students aged 11 to 19.6 years (*n* = 1,583)	0.89 (s.d. 0.14)	—	—	—	0.87 (s.d. 0.14)	AQoL-6D
Boyle *et al.* (35)	Secondary-school children aged 11 to 15 years (*n* = 1,771)	*Winter data collection:* 0.9 (s.d. 0.18) *Summer data collection:* 0.93 (0.14)	—	—	—	*Winter data collection:* 0.89 (s.d. 0.15) *Summer data collection:* 0.84 (0.3)	EQ-5D-Y VAS
Canaway and Frew (36)	Children aged 6–7 years (*n* = 160)	0.87 (95% CI 0.84–0.89)	0.86 (95% CI 0.81–0.9)	0.84 (95% CI 0.77–0.91)	—	0.85 (95% CI 0.8–0.89)	CHU-9D
		0.73 (95% CI 0.66–0.8)	0.66 (95% CI 0.43–0.83)	0.69 (95% CI 0.54–0.83)	—	0.67 (95% CI 0.56–0.78)	EQ-5D-Y
Chen *et al.* (37)	Primary-school children aged 7–13 years (*n* = 2,588) Secondary-school children aged 13–17 years (*n* = 765)	*Primary-school sample:* 0.87 (s.d. 0.11) *Secondary-school sample:* 0.82 (s.d. 0.12)	*Primary-school sample:* 0.86 (s.d. 0.12)	*Primary-school sample:* 0.83 (s.d. 0.16)	—	*Secondary-school sample:* 0.81 (s.d. 0.12)	CHU-9D
Frew *et al.* (38)	Children aged 5–6 years (*n* = 1,344)	0.825 (s.d. 0.14)	0.811 (s.d. 0.14)	0.827 (s.d. 0.13)	—	0.82 (s.d. 0.13)	CHU-9D
Keating *et al.* (42)	Secondary-school children aged 12–15 years (*n* = 2,890)	0.86 (s.d. 0.16)	0.842 (s.d. 0.17)	0.805 (s.d. 0.18)	—	—	AQoL-6D
Makkes *et al.* (43)	Children aged 8–13 years (*n* = 16) and 13–19 years (*n* = 64) with severe obesity	—	—	—	0.79 (s.d. 0.22)	—	EQ-5D-3L VAS
Treviño *et al.* (44)	Children aged under 13 years (average age for a sixth-grade student approximately 11 years) (*n* = 4,979)	0.8553 (s.d. 0.157)	0.848 (s.d. 0.157)	0.838 (s.d. 0.163)	0.814 (s.d. 0.175)	—	HUI2
		0.805 (s.d. 0.233)	0.795 (s.d. 0.236)	0.786 (s.d. 0.242)	0.759 (s.d. 0.245)	—	HUI3

*As per published paper.

95% CI, 95% confidence interval; AQoL-6D, Assessment of Quality of Life 6D; CHU-9D, Child Health Utility 9D; EQ-5D-Y, EuroQol 5D Youth; EQ-5D-3L, EuroQol 5D 3L; HUI2, Health Utilities Index 2; HUI3, Health Utilities Index 3; s.d., standard deviation; VAS, visual analogue scale.

collected height and weight outcomes by self-report, with all other studies using objectively measured data. Studies used different weight classification BMI cut-off values (Supporting Information), and weight classification categories varied between studies (healthy weight, overweight, obese, severe obesity and overweight/obese). Only three included studies reported that utility data were non-normally distributed (37,38,40), with two studies specifically reporting the data as negative/left skewed (38,40); only one study reported no underlying differences in the distribution of the utility data in different weight categories (38).

Table 2 lists the published mean utility values by weight status from studies included in our review. The study by Boyle *et al.* (35) invited participants to complete the study survey on two occasions (in winter and in summer) but analysed the data cross-sectionally. It is unclear how many of the children completed the survey at both time points. Three studies used more than one utility instrument (36,40,44); however, only the studies by Canaway and Frew (36) and Treviño *et al.* (44) reported complete results per instrument used.

Results of meta-analyses

Results from our systematic review demonstrate that there is a relatively wide range of utility values by weight status reported within the literature (range reported for healthy weight 0.73–0.93, overweight 0.66–0.86, obese 0.69–0.84 and overweight/obese 0.67–0.89) (Table 2). Figure 2 reports the forest plots for mean utility values by weight status. The mean utility values were 0.85 (95% UI 0.84–0.87, I^2 = 97, Q = 424, p = 0.00), 0.83 (95% UI 0.81–0.85, I^2 = 89, Q = 56.1, p = 0.00), 0.82 (95% UI 0.79–0.84, I^2 = 86, Q = 42.1, p = 0.00) and 0.83 (95% UI 0.8–0.86, I^2 = 87, Q = 55.5, p = 0.00) for healthy weight, overweight, obese and overweight/obese states, respectively. Given that only two studies reported utility values for the severe obesity weight category (40,41), a separate mean utility value for the severe obesity state was not estimated. All meta-analyses displayed a moderate level of heterogeneity.

After pooling relevant results, the WMD in utility value between healthy weight and overweight/obese participants was small but statistically significant (WMD 0.015, 95% UI 0.003–0.026, I^2 = 9.3, Q = 7.7, p = 0.36) (Table 2). An even smaller but still statistically significant WMD in utility value was found between healthy weight and overweight participants (WMD 0.011, 95% UI 0.004–0.018, I^2 = 0, Q = 1.6, p = 0.95). The WMD between healthy weight and obese participants was slightly larger; however, results suggest that heterogeneity exists (0.024, 95% UI 0.009–0.039, I^2 = 60.2, Q = 15.1, p = 0.02). Visual inspection of funnel and Doi plots also indicated the possibility of publication bias for all analyses. Luis Furuya-Kanamori indexes for all analyses reported major asymmetry (Table 3).

Sensitivity analyses were undertaken for all analyses, and full results are presented in Supporting Information. Omitting individual studies within the analyses of mean utility values for healthy weight, overweight, obese and overweight/obese states did not change results markedly. When considering all analyses, the mean utility value for healthy weight ranged from 0.82 (95% UI 0.78–0.87, when including only studies where the mean participant age was <10 years (36,38)) to 0.88 (95% UI 0.83–0.93, when including only studies using the EQ-5D-Y (35,36)). Mean

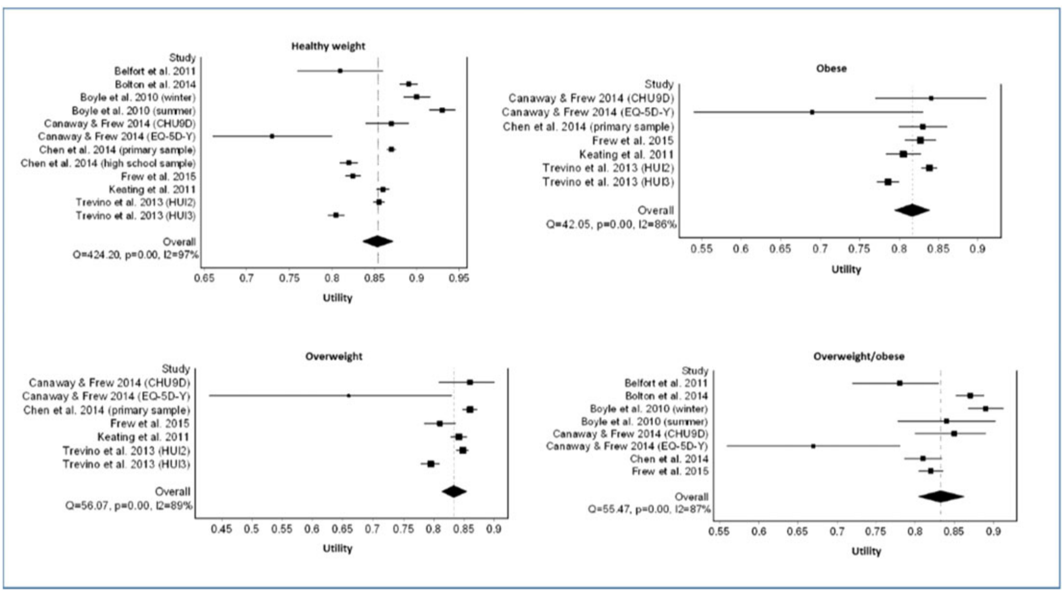

Figure 2 Forest plots of mean utility by weight status. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 3 Pooled estimates of WMD in HRQoL in children and adolescents, by weight status

Analysis	*n*	Pooled estimate WMD (95% CI)	Cochran's *Q* test (*p*)	I^2 (95% CI)	Risk of publication bias (LFK index)	Cohen's *d* (95% CI)
Healthy weight and overweight/obese	8	0.015* (0.003–0.026)	7.71 (0.36)	9% (0–71%)	Major (3.91)	0.14 (0.04–0.24)
Healthy weight and overweight	7	0.011* (0.004–0.018)	1.61 (0.95)	0% (0–0%)	Major (3.46)	0.07 (0.03–0.11)
Healthy weight and obese	7	0.024* (0.009–0.039)	15.06 (0.02)	60% (9–83%)	Major (6.42)	0.16 (0.06–0.26)

*$p < 0.05$.
95% CI, 95% confidence interval; HRQoL, health-related quality of life; LFK index, Luis Furuya-Kanamori index; *n*, number of included estimates; WMD, weighted mean difference.

utility values for the overweight/obese state ranged from 0.81 (95% UI 0.76–0.87, when only studies with a mean participant age < 10 years were included (36,38)) to 0.84 (95% UI 0.81–0.88, when only studies with a mean participant age ≥ 10 years were included (35,37,40,41) or when individual studies were excluded from the analyses (36,37,40)).

The sequential exclusion of the study by Bolton *et al.* (41) in the WMD analysis (healthy weight and overweight/obese) resulted in the WMD estimate no longer reaching statistical significance at the 5% level (WMD 0.014, 95% UI 0–0.029, I^2 = 17, Q = 7.3). Restriction of inclusions in the analysis of WMD between healthy weight and overweight/obese to studies using the UK BMI cut-off reference values (59) resulted in the WMD estimate no longer reaching statistical significance at the 5% level (WMD 0.019, 95% UI −0.004 to 0.043, I^2 = 43, Q = 7). Restrictions of inclusions into the analysis of WMD between healthy weight and overweight/obese to studies using either the EQ-5D-Y (35,36) or the CHU-9D (36–38) resulted in WMD in health utility no longer reaching statistical significance (Supporting Information), although it should be noted that these analyses were limited by the small number of study inclusions by instrument. Similar findings resulted from restricting inclusions into healthy weight and either overweight or obese analyses to those studies using the CHU-9D (healthy weight and overweight: WMD 0.011, 95% UI −0.001 to 0.022, I^2 = 0, Q = 0.07; healthy weight and obese: WMD 0.019, 95% UI −0.014 to 0.051, I^2 = 61, Q = 5.1) (Supporting Information).

Summary of economic evaluations

Only two economic evaluations of obesity interventions were identified as including an analysis of weight-related HRQoL using or referencing a utility-based instrument (Supporting Information). The study by McAuley *et al.* (45) evaluated a community-based obesity prevention intervention and utilized the Health Utilities Index (HUI) to collect parental proxy HRQoL data for a sample of New Zealand children aged 5 to 12 years. No statistically significant differences between the intervention and control groups were reported, and utility by weight status was therefore not reported. The economic evaluation consisted of a cost-effectiveness analysis (CEA), where results were presented as cost per kilogram of weight gain prevented from the intervention.

The study by Robertson *et al.* (46) evaluated the effectiveness and cost-effectiveness of a community-based programmatic intervention. Data on utility values were collected at baseline, 3 months and 12 months using the EQ-5D-Y based on both child self-report and parental proxy. Although utility values were not specifically reported, a statistically significant change in HRQoL was not found in study participants between intervention time points. Among children with complete cost and QALY data over the study period, the intervention was associated with a mean incremental QALY gain of only 0.0009.

Discussion

Many of the conditions for which obesity is a risk factor, such as stroke, heart disease and type 2 diabetes, generally occur later in life (60,61). HRQoL may therefore be the most measurable impact of overweight and obesity in the childhood years, and this is an important consideration when undertaking CUA of obesity interventions in paediatric populations. Given the potential influence on cost-effectiveness results, the selection of appropriate health state utility values is important. Therefore, estimates of utility associated with weight status arising from meta-analyses are useful in improving the rigour and reliability of CUA findings, as well as providing an overview of the current state of evidence for the impact of overweight and obesity on preference-based HRQoL in children and adolescents.

Studies in adult populations have estimated lower utility-based HRQoL between healthy weight and overweight or obese states (62). For instance, the study by Sach *et al.* (63) estimated a statistically significant mean difference of −0.099 between healthy weight and obese class I states using the EQ-5D instrument. A broad systematic review and meta-analysis of childhood health utilities by Kwon *et al.* has very recently been published (21). However, the breadth of that review did not allow the authors to focus on weight status in children in the granulated way that we do. For example, Kwon *et al.* (21) estimate weighted averages of mean utility or visual analogue scale scores for broad 10th revision of the *International Classification of Diseases*-delineated categories that grouped obese status and type II diabetes together. Moreover, Kwon *et al.* do not estimate utility score differences between children categorized as healthy weight, overweight, obese and overweight/obese (21). Our review therefore presents a more in-depth and granulated assessment of utility values by weight status in children and adolescents aged ≤18 years.

Our systematic review demonstrated that the current literature on utility values for children and adolescents by weight status is limited. There is also a relatively wide range of values estimated. The results of our meta-analyses displayed high degrees of heterogeneity; however, pooled analyses suggest that in children and adolescents, overweight and obesity states are associated with lower utility values than those for a healthy weight. This is important information for health economists and those interested in priority setting, with the catalogue of preference-based utility values presented here useful as inputs into economic evaluations of obesity interventions in paediatric populations. Whilst we do not recommend these values as definitive given the limited evidence base, our results highlight the potential for impact of interventions that are effective at changing weight status through the childhood years.

Utility measurement in childhood populations is clearly an underexplored area, with more research required to better understand the clinical importance and significance of HRQoL in children and adolescents. We found only 11 relevant studies for our review, although several other studies measured utility values, but were not included in our analyses because they did not report scored utility values (64–67) or ascribe them to weight categories (68). Reviews of non-preference-based studies assessing HRQoL in childhood populations suggest poorer HRQoL in obese youth (23,69–71), with recent studies finding that interventions that reduce BMI are associated with improvements in HRQoL (72,73). Our meta-analysis results broadly support these findings; however, given this is a relatively emerging field within the literature, it is clear that more research is required to better understand potential quantitative associations useful for economic modelling. Our meta-analysis results are also broadly consistent with the findings of other studies reporting an element of ill health or suboptimal HRQoL in the general population (74). Our estimated utility value for healthy weight children (mean 0.85 [95% UI 0.84–0.87]) is consistent with the findings from Kwon *et al.* (21), who reported a mean utility using the HUI3 of 0.876 (95% UI 0.788–0.965).

A hypothesis within the literature is that very young children do not experience any loss of HRQoL due to weight status, but that older children and adolescents may (36). We identified only two studies estimating utilities for children under 10 years (36,38), and so our sensitivity analyses estimating mean utilities in younger populations were limited by the lack of study inclusions. Results demonstrated overlapping of confidence intervals in utility values between younger children (i.e. <10 years) of healthy weight (0.82 [95% UI 0.78–0.87]) and those that were overweight/obese (0.81 [95% UI 0.76–0.87]). Whilst this may suggest either no or minimal effect of weight status on HRQoL in younger children, it is clear that more research is required for a better understanding of the potential differential effects across the childhood and adolescent years. This is important because if the HRQoL decrements between weight states are small, interventions aimed at reducing obesity in children are only likely to be cost-effective based on QALYs if they are either very low cost or if the intervention effects are able to be sustained through to adulthood, thereby reducing the incidence of chronic diseases in later life. Debate exists within the literature on the appropriateness of using QALY outcome measures in CUA for children, rather than CEA where benefits are expressed in terms of natural units (e.g. cost per BMI unit saved) (75).

Many studies conducted in paediatric populations use non-preference-based measures such as the Pediatric Quality of Life Inventory™ version 4.0 Generic Core Scales (76). Non-preference-based measures can be mapped or cross-walked onto generic preference-based measures of health; however, there are current limitations in doing so in paediatric populations (19,77). The current state of the literature allows for mapping from the Pediatric Quality of Life Inventory to the CHU-9D in adolescents (77) or to the EQ-5D-Y in children aged 11–15 years (78). More research is required to extend these and other mapping algorithms across different populations and age groups.

Measuring child and adolescent HRQoL is challenging, and there are well-recognized limitations to existing methods (16). Accurately capturing information on HRQoL in children requires instruments that are sensitive to detect differences and appropriate to deliver across different age groups. For instance, whilst younger children in particular may require parental proxy reporting, the accuracy of such reporting has recently been questioned with Ul-Haq *et al.* (23) finding that parents may overestimate the impact of obesity on the HRQoL of their children. In addition, the tariffs for scoring utility values for many instruments may not necessarily reflect the values of childhood or adolescent populations if elicited from general populations.

The findings of our systematic review and meta-analysis highlight that HRQoL is a significant source of uncertainty in the economic modelling of obesity interventions in childhood populations. The current paucity of published utility values by weight status is reflected in the lack of published CUAs of paediatric obesity interventions incorporating HRQoL in childhood. Many CEAs of paediatric obesity interventions focus on averting adult obesity, and only include utility values to estimate QALYs in adults (e.g. (79,80)).

This may not allow for the HRQoL benefits of an intervention during childhood to be considered (40) and may underestimate intervention cost-effectiveness if overweight or obese states themselves have a significant impact on HRQoL in childhood and adolescence. The recent study by Lal *et al*. (81) was published after our literature search was completed, but modelled the cost-effectiveness of a sugar-sweetened beverage tax across socioeconomic position using utility values for healthy weight and obesity in children and adolescents sourced from Chen *et al*. (37). This may reflect the growing interest in trying to capture the full range of costs and benefits of obesity interventions in childhood and adolescence, particularly when disease-specific consequences are largely experienced later in life.

The strengths of our study include the comprehensive and systematic search strategies, as well as the undertaking of a number of sensitivity analyses. This allowed for a range of summary estimates to be produced, for inclusion within economic evaluations at the discretion of study authors given the relative uncertainty within the body of literature.

Our study has some limitations, which should be borne in mind by readers. The small number of studies included in our meta-analyses means that less confidence may be placed in results, although we present all values here as a quantitative summary of the literature as it currently stands and recommend use with caution. The published evidence on which we have based our results has also only been undertaken in Western high-income countries, and therefore, the generalizability of these results to countries with differing cultural associations around body weight is unknown. Whilst our results build upon the currently limited evidence base on the impact of HRQoL by weight status in paediatric populations, it is clear that further investigation is required.

We also did not conduct quality assessments of studies included in our meta-analyses and, therefore, cannot comment on the rigour or reliability of study inclusions. The lack of standard systems or validated checklists for grading the quality of health state utility values for inclusion in meta-analysis is both a limitation and an area for future research (31,82). Owing to the small number of study inclusions and the lack of a validated quality assessment tool, we assumed that the quality across all included studies was of an equal standard, and this may in fact not have been the case. This in turn may influence results of the meta-analyses; however, we have tried to circumvent this through extensive sensitivity analyses omitting individual studies from the analyses in order to gauge overall effects on utility estimates. It is also possible that publication bias may influence these results, with studies finding no statistically significant difference in preference-based utility perhaps less likely to be published than studies that report a difference, and this should be considered.

Results have also been pooled across studies using different utility instruments, BMI cut-off values and tariffs for scoring, in different study populations. The use of meta-analytical methods to pool utility values from different instruments is an ongoing area for investigation, with more research required into the sources of variation in utility values that may be driven by differences in descriptive systems (83). We have again attempted to circumvent this by undertaking several sensitivity analyses, although the low number of studies using each respective instrument or by age group was a limitation. Finally, our systematic review and meta-analysis identified only cross-sectional studies examining HRQoL by weight status. It is possible that reverse causation may be a factor in any association, and given the current evidence base, we are unable to establish whether BMI might impact on the HRQoL of children and adolescents or vice versa. More rigorous investigation is therefore required, exploring causation and the complexity of possible associations through multiple pathways.

Conclusion

This study represents the first systematic review and meta-analysis of utility values by weight status for childhood populations, demonstrating the relative lack of published preference-based utility values by weight status in paediatric populations. To date, very few economic evaluations of obesity interventions incorporating HRQoL benefits to children and adolescents have been published. This potentially results in under-estimation of the cost-effectiveness of obesity interventions in children and adolescents. Meta-analysis results provide mean utility values by healthy weight, overweight, obese and overweight/obese states, although results should be interpreted with caution given high degrees of heterogeneity. Results demonstrate higher preference-based utility values in healthy weight as compared with overweight or obese children and adolescents, but more evidence is required to improve the rigour and reliability of these estimates.

Conflict of interest statement

There are no conflicts of interest to declare.

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Supporting information

Additional Supporting Information may be found online in the supporting information tab for this article. https://doi.org/10.1111/obr.12672

Data S1. Supporting info item

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