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Healthcare utilisation in overweight and obese children: a systematic review and meta-analysis

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ABSTRACT

Objective This systematic review and meta-analysis aims to systematically analyse the association of overweight and obesity with health service utilisation during childhood.

Data sources PubMed, MEDLINE, CINAHL, EMBASE and Web of Science.

Methods Observational studies published up to May 2020 that assessed the impact of overweight and obesity on healthcare utilisation in children and adolescents were included. Studies were eligible for inclusion if the included participants were ≤19 years of age. Findings from all included studies were summarised narratively. In addition, rate ratios (RRs) and 95% CIs were calculated in a meta-analysis on a subgroup of eligible studies.

Outcome measures Included studies reported association of weight status with healthcare utilisation measures of outpatient visits, emergency department (ED) visits, general practitioner visits, hospital admissions and hospital length of stay.

Results Thirty-three studies were included in the review. When synthesising the findings from all studies narratively, obesity and overweight were found to be positively associated with increased healthcare utilisation in children for all the outcome measures. Six studies reported sufficient data to meta-analyse association of weight with outpatient visits. Five studies were included in a separate meta-analysis for the outcome measure of ED visits. In comparison with normal-weight children, rates of ED (RR 1.34, 95% CI 1.07 to 1.68) and outpatient visits (RR 1.11, 95% CI 1.02 to 1.20) were significantly higher in obese children. The rates of ED and outpatient visits by overweight children were only slightly higher and non-significant compared with normal-weight children.

Conclusions Obesity in children is associated with increased healthcare utilisation. Future research should assess the impact of ethnicity and obesity-associated health conditions on increased healthcare utilisation in children with overweight and obesity.

PROSPERO registration number CRD42018091752

Strengths and limitations of this study

- A systematic search of the published literature in English language in major databases up to May 2020 was conducted.
- Risk of bias was assessed in the included studies and the review is reported according to Preferred Reporting Items for Systematic reviews and Meta-Analysis guidelines.
- Search of grey literature, unpublished studies and studies published in a language other than English was not conducted.
- Meta-regression analysis could not be conducted.

INTRODUCTION

In recent years, childhood obesity has emerged as one of the greatest paediatric public health concerns worldwide. According to latest report by WHO, in 2016 over 41 million children under the age of 5, and over 340 million children and adolescents aged 5–19, were overweight or obese globally.[1] The situation is of serious concern in the UK, which is reported to be the most obese country in Western Europe by the Organisation of Economic Co-operation and Development.[2] Recent reports have shown that 1 in 5 children in the reception year (age 4–5) and 1 in 3 children in year 6 (age 12–13) are obese or overweight in the UK.[3]

The burden of obesity-related morbidity is well documented. Extensive research has shown that individuals who are obese or overweight in their childhood are more likely to stay overweight or obese in adult life,[4] leading to an increased risk of developing cardiometabolic conditions such as type 2 diabetes, ischaemic heart disease and stroke.[4–6] In addition, the increasing prevalence of overweight and obesity in childhood has led to an increase in the incidence of previously unusual metabolic imbalances at this age, and a rise in associated diseases such as type 2 diabetes and metabolic syndrome.[7–11]

Given the aforementioned associations, it could be inferred that individuals with overweight and obesity would experience greater morbidity compared with individuals of normal weight, leading to increased healthcare utilisation. Several studies have reported a strong association between overweight or obesity and increased healthcare use.[12–14] However, majority of these have quantified this association by assuming that individuals with obesity will start accruing the obesity-associated increased healthcare use at or after a certain age, with most ignoring the healthcare use during childhood.[12 15]

In order to address this issue, we conducted a systematic review and meta-analysis with the objective of evaluating the association of overweight or obesity with healthcare utilisation in children, pooling the available evidence from eligible studies. In this review, we also aim to identify the obesity-associated conditions that may explain the association of overweight or obesity with increased healthcare utilisation.

METHODS

This review is reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) recommendations.[16] The protocol for this review is registered with PROSPERO—International Prospective Register of Systematic Reviews. The PRISMA checklist is provided as online supplemental file 1.

Literature search

A systematic literature search was performed in five electronic databases (PubMed, Medline, EMBASE, Web of Science and CINAHL) from inception to July 2018. An update of database searches was conducted in May 2020. This search update covered the full data range from inception to May 2020, and records found in the previous search were removed based on the methods described by Bramer and Bain.[17] The search focused on studies reporting association between weight status and healthcare utilisation in children. Only studies published in English language were considered for inclusion. The searches were conducted by assembling terms that could relate to the three main components of the review: 'children or adolescents', 'obesity or overweight' and 'healthcare utilisation'. These terms comprised keywords, text terms or medical subject headings appropriate for each literature database. A copy of the searches conducted to identify studies is given in online supplemental file 2. We also searched the reference lists of screened publications to look for additional articles. A forward and backward reference search for all the studies meeting the inclusion criteria was carried out to identify any other relevant studies. Research reported in grey literature was not searched. Conference abstracts and review articles were not eligible for inclusion. However, reference lists of screened review articles were checked for potentially relevant studies.

Study eligibility

Observational studies assessing the impact of overweight or obesity on healthcare utilisation in children were included in the review. Studies were excluded based on the following criteria: studied the association for underweight children only; included participants over 19 years of age; included participants both less than and greater than 19 years of age but did not stratify the results by age groups; review articles. The decision for the inclusion of children/adolescents up to the age of 19 years was made based on WHO's definition of a child and adolescent.[18] In addition, instead of restricting the inclusion criteria to studies using predefined standard body mass index (BMI) cut-offs for childhood overweight (sex-specific and age-specific BMI ≥85th centile and <95th centile) and obesity (sex-specific and age-specific BMI ≥95th centile),[19 20] a decision was made to include the study-specific definitions with the aim of assessing the effect of varying BMI cut-offs on the association of overweight or obesity with healthcare utilisation.

Study selection

Titles and abstracts of records retrieved through literature search up to July 2018 were screened by a single reviewer (TH) with a random sample of 10% of these studies screened by a second reviewer (TSA). Studies were then full text screened by the first reviewer (TH) to assess their eligibility for inclusion in the review. A random sample of 10% of these full-text studies was also screened by the second reviewer (TSA). The level of agreement between the two reviewers at each stage was assessed by Cohen's kappa score. The score was classified as follows:<0.20 indicated a poor agreement; 0.21–0.40 a fair agreement; 0.41–0.60 a moderate agreement; 0.61–0.80 a good agreement; 0.81–1.00 a very good agreement.[21] All disagreements were resolved through discussion between the two reviewers and by consulting a third reviewer (LKF) if required.

Additional records retrieved from the search update in May 2020 were screened for title, abstract and full text by the first reviewer (TH).

Data extraction and risk of bias assessment

A customised data extraction form was designed to extract following information from each study: first author's surname, year of publication, study design, country, sample size, age range, time frame, definition of obesity/overweight, outcome measures and effect size for healthcare use. Data for each study were extracted by the first reviewer (TH) and reviewed by the second reviewer (TSA). Any discrepancies were discussed and resolved through consensus between the reviewers.

The Quality Assessment tool for Observational Cohort and Cross-sectional studies by the National Heart and Lung Institute (NHLBI) was used to assess the quality and risk of bias of each included study.[22] This assessment tool rates study quality along 14 criteria, with three possible outcomes for each question: 'Yes', 'No' and 'Cannot determine/Not reported/Not applicable'. For a response of 'Yes', a score of one was assigned against the criteria, whereas a score of zero was assigned for any answer other than 'Yes'. Each study was then rated Good, Fair or Poor based on a score ranging from 0 to 14; where a 'good' study was considered to have the least risk of bias, 'fair' was susceptible to some bias and 'poor' indicated a high risk of bias.

Narrative synthesis

Due to the diverse nature of healthcare utilisation outcomes, measures of effect and lack of appropriate or sufficient data in the majority of studies to statistically analyse these effect size measurements, a decision was made to summarise the findings of the included studies narratively. A narrative synthesis was developed to explain the impact of weight status on all the reported measures of health service use in different studies: emergency department visits, outpatient visits, general practitioner (GP) visits, hospital admissions and length of stay (LOS). In addition, potential sources of heterogeneity across studies were explored.

Statistical analysis

The 'meta' command in Stata V.16.1 [23] was used to generate meta-analysis for rate ratios (RRs) of healthcare utilisation in obese and overweight children, using normal-weight children as a reference. Studies that reported RRs with corresponding measures of precision (95% CIs or SEs) were included in the meta-analysis. In addition, studies with appropriate raw data to compute crude RRs were eligible for inclusion in the meta-analysis. Meta-analysis uses effect sizes in a metric that makes them closest to normally distributed; therefore, before undertaking the analysis in Stata, RRs were log transformed and corresponding SEs were computed from effect sizes and 95% CIs using the Comprehensive Meta-Analysis software V.3.[24] Afterwards, a random-effects meta-analysis with Hartung-Knapp-Sidik-Jonkman method was carried out.[25 26] The error rates for this method have consistently been shown to be more robust than the more commonly used DerSimonian and Laird method, particularly when there are small number of studies in the meta-analysis.[27]

Publication bias was assessed using funnel plots; however, due to the number of studies included in the analysis being less than 10, statistical tests for funnel plot asymmetry were not performed.[28] Heterogeneity among studies was assessed using the I^2 statistic. Based on the interpretation provided in the Cochrane Handbook for Systematic Reviews, heterogeneity in this review is considered substantial if $I^2 > 50\%$.[29]

Patient and public involvement

No patients or members of public were involved in the conduct and reporting of this review.

RESULTS

Study selection

A PRISMA flow diagram for study selection is shown in figure 1. The search of electronic databases up to July 2018 identified 36 077 records. After removal of duplicates, 18 966 studies were screened by titles and abstracts. A random sample of 1900 studies (10%) was also reviewed by the second reviewer. The level of agreement between reviewers at this stage was reflected by a Cohen's kappa

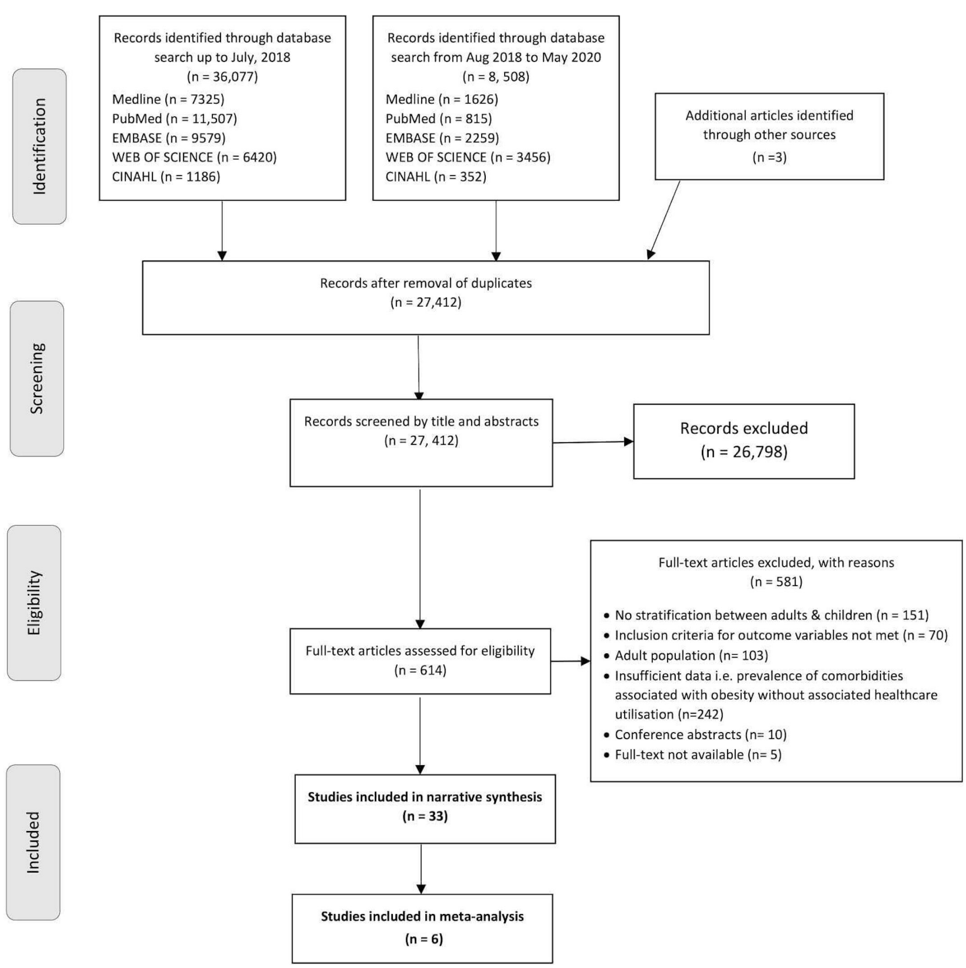

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study selection diagram.

score of 0.86. Full texts of 578 studies were screened by the first reviewer with a random sample of 60 studies (10%) also reviewed by the second reviewer. Cohen's kappa score for level of agreement at this stage was 0.67, which indicated a good agreement. Twenty-six articles were eligible for inclusion at this stage.

The search update in May 2020 identified 8504 additional articles, of which 4 were eligible for inclusion. Three additional articles were identified through searching the reference lists of screened systematic reviews. Overall, 33 studies were eligible for inclusion. All these studies were included in the narrative synthesis, but only six were included in the meta-analysis.

Study characteristics

The basic characteristics of included studies are summarised in table 1. The majority of these studies (n=20) were conducted in the USA. Twenty-three of the included studies were cohort studies. Nine of the remaining studies used cross-sectional methods, while one study was a case–control study (table 1). Multiple studies reported data from two surveys/cohorts. The Medical Expenditure Panel Survey (MEPS) is reported in five studies[30–34] and the German Interview and Examination Survey for Children and Adolescents (KiGGS) is reported in two studies.[35 36] As studies from the same survey/cohort reported data for different years or different outcome measures, decision was made to analyse the data for each individual study.

Table 1 summarises the measures of healthcare utilisation reported across the included studies. The most commonly reported outcome measures were emergency department (ED) visits (n=10)[32–34 37–43] and outpatient (n=11) visits (including primary care and specialty visits).[32–34 36–41 43 44] Seven studies reported on healthcare use associated with respiratory diseases,[41 44–49] two reported on musculoskeletal conditions[44 50] and two on conditions concerning mental health.[37 44] The rest of the studies analysed the overall healthcare use in children with no reporting on reasons for utilisation. The studies represented children between 1 and 19 years of age. Table 1 shows that seven studies calculated BMI from anthropometric measurements (height and weight) based on self-reported or parent-reported data.[30 32–34 51 52] In all other studies, heights and weights were either measured as part of the study or recorded from the health facility records. Two studies reported data on weight only and used weight:age ratio to define obesity or overweight.[53 54] In addition, different variables were adjusted for in the multivariate analysis in respective studies. These variables are listed in table 1.

Risk of bias

The response for each study against the criteria in NHLBI's quality assessment tool to critically appraise the internal validity is shown in table 2. Fourteen studies scored a 'good' rating, sixteen had a 'fair' rating, while three had a 'poor' rating. The studies included in the meta-analysis were either of 'good' or 'fair' quality; therefore, weighting based on quality assessment was not done in the meta-analysis. However, quality assessment was used to weigh the strength of evidence during narrative synthesis.

Narrative synthesis and meta-analysis

Findings from all included studies were synthesised narratively for each outcome measure of healthcare utilisation. A subgroup synthesis was done by dividing studies based on BMI cut-offs, ethnicity and method of anthropometric measurement.

Six studies were included in the meta-analysis.[37 38 40 41 43 55] All of these studies were cohort studies (table 1). All six studies reported an association between weight status and outpatient visits and were included in the meta-analysis for outcome measure of outpatient visits. Five of these six studies also reported on association of weight status with ED visits, and were therefore included in a separate meta-analysis for outcome measure of ED visits.[37 38 40 41 43] In addition, five of these[37 38 41 43 55] used a similar definition to define obesity (age-specific and sex-specific BMI ≥95th percentile) while one study[40] defined it as age-specific and sex-specific BMI z-score ≥2, which also corresponds to BMI ≥95th percentile.[19] Moreover, five studies included in the meta-analysis for ED visits were conducted in the USA. The sixth study, which was part of analysis for outpatient visits, was conducted in Canada. For one study,[38] the appropriate effect sizes with corresponding SEs were calculated using the available raw data. One study assessed healthcare use over 1-year and 3-year periods. A decision was made to include data for 1-year period due to larger sample size as many participants were lost to follow-up by the end of the 3-year period.[37] Figures 2 and 3 show the forest plots for meta-analysis with outcome measures of ED visits and outpatients visits, respectively. Online supplemental figures 1 and 2 show forest plots for ED and outpatient visits in obese children compared with normal-weight children calculated using the pre-specified adjusted RRs reported by individual studies. Due to a small number of studies eligible for inclusion in the meta-analysis and limited to no data available on key covariates, it was not possible to perform a subgroup analysis.

ED visits

Ten studies reported ED visits as an outcome measure for healthcare utilisation.[32–34 37–41 43 53] In both obese and overweight children compared with normal-weight children, the general direction of association was an increase in visits; however, variability in the strength and direction of association was reported. For obese children compared with normal-weight children, five studies reported a significant increase in ED visits.[32 33 40 41 43] Three studies reported a non-significant increase in ED visits.[37–39] In addition, one study reported a non-significant decrease of ED visits in obese children 6–11 years old, while for obese children aged 12–17 years, a significant increase in visits was reported.[34] For overweight children, four studies reported a significant increase in ED visits compared with normal-weight children.[32 33 41 43] Two studies reported a

Table 1 Basic characteristics of included studies

First author, year	Country	Number of participants	Study design	Age in years (cohort/survey)	Anthropometric measurement	BMI cut-offs	Measures of healthcare utilisation	Covariates
Adams, 2008† [83]	USA	4263	Cross-sectional	14–19	Physical assessment measurement	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Primary care referrals Dental referrals	Not reported
Bechere Fernandes,[54] 2014	Brazil	91	Retrospective cohort	1–10	Hospital-based measurements	Weight/age ratio (W/A) for 1–3 years: excess weight W/A ≥2 z-scores, normal weight as interval from −2 to +2 z-scores. Age 3–10: excess weight BMI ≥1 z-score, normal weight BMI −2 to +1 z-score	Length of stay in the hospital	Age and sex
Bertoldi, 2010[84]	Brazil	4452	Prospective cohort	11–12	Measurement by researchers	Not given	Medicine uptake in 15 days prior to interview	Skin colour, sex, socioeconomic status, pregnancy complication, ICU admission, nutrition status, sedentary lifestyle and use of sedatives by mothers
Bettenhausen,[57] 2015†	USA	518	Cross-sectional	5–17	Hospital-based measurement	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Inpatient length of stay Readmission rates	Age, sex, race and insurance
Bianchi-Hayes,[56] 2015†	USA	17 444	Retrospective cohort study	2–18 (NHANES)	Measured by trained health technicians	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Total healthcare visits Total number of hospitalisations Mental health visits	Age, sex, ethnicity, health insurance status, household income, presence of asthma or diabetes, and the educational status of the head of household
Breitfelder,[51] 2011	Germany	3508	Cross-sectional	9–12 (GINI and LISA)	Measured or self-reported	Overweight: BMI >90th to 97th percentile. Obese >97th percentile	Expenditure associated with physician, therapist and inpatient rehabilitation visits	Sex, region, parental education and income

Continued

Table 1 Continued

First author, year	Country	Number of participants	Study design	Age in years (cohort/survey)	Anthropometric measurement	BMI cut-offs	Measures of healthcare utilisation	Covariates
Buescher,[45] 2008†	USA	30 528	Cross-sectional	12–18	Clinical measurements	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Well-child visits Respiratory-related health visits Total expenditure	Sex and ethnicity
Carroll,[47] 2006†	USA	219	Retrospective cohort	2–18	Not given	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Duration of total ICU and hospital length of stay	Age, severe persistent asthma, admission modified pulmonary index score
Dilley,[59] 2007†	USA	1216	Retrospective cohort	≥2 years	Medical record	Overweight ≥95th percentile. At risk for overweight: BMI of 85th to 94th percentile	Number of visits to private practice or public health clinics	Age, race, BMI percentile, insurance status, parental education and household tobacco use
Doherty,[58] 2017	Ireland	5924	Prospective cohort	13 (GUI)	Measurement by health professionals	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	GP visits Inpatient stay	Child characteristics: gender, birth weight, gestation age and citizenship. Mother's characteristics: age, health status, education status, marital status and depression score. Household characteristics: income, location and health insurance status
Estabrooks and Shetterly,[37] 2007*†	USA	8282	Prospective cohort	3–17	Hospital medical record	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Primary care (outpatient) visits ED visits Number of hospitalisations	Sex, age and disease status
Fleming-Dutra,[53] 2013†	USA	32 966	Retrospective cohort	2–18	Hospital medical record	Overweight >95th percentile sex-specific weight for age. Normal weight ≤95% sex-specific weight for age	Billed charges for child's visit Hospitalisation rate ED length of stay in hours	Race, age, sex, insurance, and acuity

Continued

Table 1 Continued

First author, year	Country	Number of participants	Study design	Age in years (cohort/survey)	Anthropometric measurement	BMI cut-offs	Measures of healthcare utilisation	Covariates
Griffiths,[49] 2018	UK	3269	Prospective cohort	5–14	Measured by trained interviewers	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Hospital admission	Sex, mode of delivery, preterm, long-standing illness, disability, maternal BMI
Hampl,[38] 2007*†	USA	8404	Retrospective cohort	5–18	Measured by clinical nursing staff	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Primary care visits ED visits Laboratory use	Age, sex, race and insurance status
Hering,[39] 2009	Israel	Cases: 363 Controls: 382	Retrospective case–control	4–18	Clinical measurement	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	ED visits Primary care clinic visits Hospital admissions	Control group matched for age and gender
Janicke,[40] 2010*†	USA	200	Retrospective cohort	7–15	Measured by a trained researcher	Overweight: BMI z-score ≥1 and <2. Obese: BMI z-score ≥2	ED visits Acute care claims Outpatient and medical claims	Age, sex, ethnicity, insurance status
Kelly,[48] 2019	UK	9443	Prospective cohort	4–5	Measured by trained school nurses	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	GP appointments GP prescriptions	Sex, maternal age, gestational age, means tested benefits, Index of Multiple Deprivation (2010)
Kovalerchik,[43] 2020*†	USA	30 352	Retrospective cohort	3–17	Hospital-based measurements	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Emergency department visits Outpatient visits	Age, age^2, sex, race/ethnicity, and insurance status
Kuhle,[55] 2011†	Canada	4380	Prospective cohort	10–11	Measured by research assistants	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	GP visits Specialist referrals Total healthcare costs	Sex, income, education status and geographical region
Lynch,[41] 2015*†	USA	19 528	Retrospective cohort	2–18	Hospital medical record	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Outpatient visits ED visits Number of hospitalisations	Sex, age and socioeconomic status
Monheit,[30] 2009†	USA	6738	Retrospective cohort	12–19 (MEPS)	Parent-directed and self-directed	At risk for overweight BMI ≥85th and <95th percentile. Overweight BMI ≥95th percentile	Overall health expenditure	Age, race, region, parental education attainment and parental smoking

Continued

Table 1 Continued

First author, year	Country	Number of participants	Study design	Age in years (cohort/survey)	Anthropometric measurement	BMI cut-offs	Measures of healthcare utilisation	Covariates
Ortiz Pinto,[44] 2019	Spain	1857	Prospective cohort	4–6	Measured by paediatricians	Overweight: BMI z-score ≥1 and ≤2. Obese: BMI z-score >+2	Primary care visits Drug prescriptions Hospital admissions	Sex, age in months, mother's education, breastfeeding duration, family purchasing power
Skinner,[31] 2008†	USA	Not given	Cross-sectional	6–17 (MEPS)	Physical examination in NHANES. Parent-reported in MEPS	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Healthcare expenditure	Year, sex, race, poverty and insurance status
Trasande and Chatterjee,[32] 2009*	USA	19 613	Prospective cohort	6–19 (MEPS)	Parent-reported and self-reported	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Outpatient visits ED visits Healthcare expenditure	Race, gender, insurance status and family income
Trasande,[32] 2009*	USA	Not given	Prospective cohort	2–19	Parent-reported and self-reported	Based on ICD-9 diagnostic codes	Obesity-associated hospitalisations	Age, sex, ethnicity, expected primary payer, hospital location, hospital teaching status and median household income
Turer,[33] 2013*	USA	17 224	Cross-sectional	10–17 (MEPS)	Parent-reported and self-reported	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Hospital-based outpatient, or clinic visit Specialist visits ED visits Outpatient prescriptions	Gender, age, race, insurance status, and poverty status
van Leeuwen,[50] 2018	Netherlands	617	Prospective cohort	2–18 (DOERAK)	Measured by GP or research assistant	Overweight: BMI z-score ≥1 and <2. Obese: BMI z-score ≥2	Number and type of musculoskeletal consultation Total number of consultations	Age, gender, socioeconomic status and marital status
Wake, 2010[85]	Australia	923	Prospective cohort	5–19	Measured by trained field workers	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Healthcare visits	Sex, age and Socio-Economic Indexes for Areas (SEIFA) disadvantage index

Continued

Table 1 Continued

First author, year	Country	Number of participants	Study design	Age in years (cohort/survey)	Anthropometric measurement	BMI cut-offs	Measures of healthcare utilisation	Covariates
Wenig,[35] 2011	Germany	14 592	Retrospective cohort	3–17 (KiGGS)	Measured through physical examination	Overweight: BMI >90th to 97th percentile. Obese >97th percentile	Number of pharmaceuticals taken in the last 7 days	Age, sex, socioeconomic status and migrant status
Wenig,[36] 2012	Germany	14 277	Cross-sectional	3–17 (KiGGS)	Measured through physical examination	Overweight: BMI >90th to 97th percentile. Obese >97th percentile	Physician visits	Sex, age, BMI group, socioeconomic stats, town size, and east or west Germany variable
Woolford,[46] 2007†	USA	777 274	Cross-sectional	2–18	Hospital-based measurements	Obesity was defined based on ICD-9-CM codes Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Length of stay Total charges	Sex, race, region and hospital type
Wright and Prosser,[34] 2014†	USA	23 727	Cross-sectional	6–17 (MEPS)	Parent-reported and self- reported	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	ED visits Outpatient visits Prescription of drugs	Age, BMI class, sex, ethnicity, census region, poverty status, insurance status and survey year
Wyrick,[42] 2013†	USA	1746	Prospective cohort	2–18	Hospital-based measurements	Overweight BMI ≥85th and <95th percentile. Obese BMI ≥95th percentile	Admissions from ED	Age and sex

*Studies included in the meta-analysis.
†Studies using Centers for Disease Control (CDC) criterion to define obesity and not at the level of the survey/cohort. None of the six studies included in the meta-analysis use data from the same source.
BMI, body mass index; ED, emergency department; GP, general practitioner.

Table 2 Risk of bias assessment of included studies

Study	Criteria: Research question or objective clearly stated	Study population clearly defined	Participation rate of eligible persons at least 50%	Groups recruited from the same population with uniform eligibility criteria	Sample size justification	Exposure assessed prior to the outcome	Sufficient timeframe to see an effect	Different levels of exposure of interest (categorical/ continuous)	Exposure variables clearly defined or not. were the tools used for measurement were accurate	Repeated exposure assessment	Outcome measures clearly defined and measured	Blinding of the outcome assessors	Loss to follow-up 20% or less	Statistical analysis (measurement and adjustment of confounding variables)	Rating
Adams, 2008[83]	1	0	0	1	0	0	0	1	0	0	1	0	0	0	Poor
Bechere Fernandes *et al*[54]	1	1	0	1	1	1	1	1	1	0	1	0	0	1	Good
Bertoldi, 2010[84]	1	0	0	1	0	1	1	0	1	0	0	0	0	1	Poor
Bettenhausen[57]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Fair
Bianchi-Hayes[56]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Fair
Breitfelder 2011	1	1	0	1	0	0	0	1	1	0	0	0	0	1	Fair
Buescher *et al*[45]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Fair
Carroll *et al*[47]	1	1	0	1	0	1	1	1	0	0	1	0	0	1	Fair
Dilley *et al*[59]	1	0	0	1	0	1	1	1	0	0	0	0	0	1	Poor
Doherty *et al*[58]	1	1	0	1	0	1	1	1	1	1	1	0	0	1	Good
Estabrooks and Shetterly*[37]	1	1	0	1	0	1	1	1	1	1	1	0	0	1	Good
Fleming-Dutra *et al*[53]	1	1	0	0	1	1	1	1	0	0	1	0	0	1	Fair
Griffiths *et al*[49]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Good
Hampl *et al**[38]	1	1	0	1	0	1	1	1	1	0	1	0	1	1	Good
Hering *et al*[39]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Fair
Janicke *et al**[40]	1	1	0	1	0	0	0	1	1	0	1	0	0	1	Fair
Kelly *et al*[48]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Good
Kovalerchik *et al**[43]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Good
Kuhle *et al**[55]	1	1	1	1	0	1	1	1	1	0	1	0	1	1	Good
Lynch *et al**[41]	1	1	0	1	0	1	1	1	1	1	1	0	1	1	Good
Monheit *et al*[30]	1	1	0	1	0	0	1	1	1	0	0	0	0	1	Fair
Ortiz-Pinto *et al*[44]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Good
Skinner *et al*[31]	1	1	0	1	0	1	1	1	0	0	1	0	0	1	Fair
Trasande and Chatterjee[32]	1	1	0	1	0	0	1	1	0	1	0	0	0	1	Fair
Trasande *et al*[52]	1	1	0	1	0	1	1	0	0	0	1	0	0	1	Fair
Turer *et al*[33]	1	1	0	1	0	1	1	1	0	1	0	0	0	1	Fair
van Leeuwen *et al*[50]	1	1	1	1	0	1	1	1	1	1	1	0	1	1	Good
Wake *et al*[85]	1	1	0	1	0	0	1	1	1	1	1	0	1	1	Good
Wenig *et al*[35]	1	1	0	1	0	1	1	1	1	0	1	0	0	1	Fair
Wenig, 2012[36]	1	1	0	1	0	1	1	1	1	0	0	0	0	1	Fair

Continued

Table 2 Continued

Study	Criteria: Research question or objective clearly stated	Study population clearly defined	Participation rate of eligible persons at least 50%	Groups recruited from the same population with uniform eligibility criteria	Sample size justification	Exposure assessed prior to the outcome	Sufficient timeframe to see an effect	Different levels of exposure of interest (categorical/ continuous)	Exposure variables clearly defined or not. were the tools used for measurement were accurate	Repeated exposure assessment	Outcome measures clearly defined and measured	Blinding of the outcome assessors	Loss to follow-up 20% or less	Statistical analysis (measurement and adjustment of confounding variables)	Rating
Woolford *et al*, 2007[46]	1	1	0	1	0	0	1	1	0	0	1	0	0	1	Fair
Wright and Prosser, 2014[34]	1	1	0	1	0	1	1	1	1	1	1	0	0	1	Good
Wyrick *et al*, 2013[42]	1	1	0	1	0	1	1	1	1	0	1	0	1	1	Good

'1'=Yes, '0'=No/cannot determine/not recorded. Rating: Poor, score ≤6; Fair, score 7–9; Good, score ≥10.
*Studies included in the meta-analysis

non-significant increase[34 38] and two studies reported a non-significant decrease.[37 40]

In the five studies included in the meta-analysis for ED visits, obese children were significantly more likely to visit EDs compared with normal-weight children (figure 2A). The associated effect size (RR) was 1.34 (95% CI 1.07 to 1.68). The effect size for overweight versus healthy weight was RR 1.11 (95% CI 0.92 to 1.33) (figure 2B). The I^2 statistic showed substantial between-study heterogeneity for obese versus normal weight (I^2=94.3%, p<0.01) and overweight versus normal weight (I^2=92.5%, p<0.01).

On visual inspection of funnel plot asymmetry, there is a possibility of publication bias, with a small sized study reporting high RRs for obese children (online supplemental figure 3). A statistical test for publication bias was not performed due to small number of studies (n<10).

Outpatient visits

Eleven studies reported outpatient visits as a measure of healthcare utilisation.[32–34 36–41 43 44] In obese children compared with normal-weight children, the general direction of association was an increase in visits; however, variability in the strength of association was reported. Seven studies reported a significant increase in outpatient visits for obese children,[32 33 37 39–41 43] while four studies reported a non-significant increase.[34 36 38 44] For overweight children compared with normal-weight children, three studies reported a significant increase in outpatient visits.[37 41 43] Five studies reported a non-significant increase[32–34 36 38] while two studies reported a non-significant decrease in outpatient visits.[40 44]

Pooled unadjusted RRs for obese versus normal weight and overweight versus normal weight were 1.11 (95% CI 1.02 to 1.20) and 1.02 (95% CI 0.98 to 1.08), respectively (figure 3A,B). Significant between-study heterogeneity was observed for both obese versus normal-weight children (I^2=87.6%, p<0.01) and overweight versus normal-weight children (I^2=73%, p<0.01).

Visual inspection of funnel plot asymmetry for outpatient visits in obese children suggests publication bias (online supplemental figure 4). Statistical tests to assess publication bias were not performed due to the small number of studies (n<10).

Hospital admissions and LOS

Seven studies reported hospital admissions as a measure of healthcare use.[37 39 41 42 44 49 56] One study reported a significant increase[39] while two studies reported a non-significant increase[37 49] in hospital admissions for obese children compared with normal weight. Two studies reported a non-significant decrease in admissions.[44 56] In addition, one study reported that 14.5% of obese or overweight children were admitted, compared with 16.5% normal-weight children.[42] For overweight children, one study reported a significant decrease[56] while one reported a non-significant decrease[37] in admissions compared with normal-weight children.

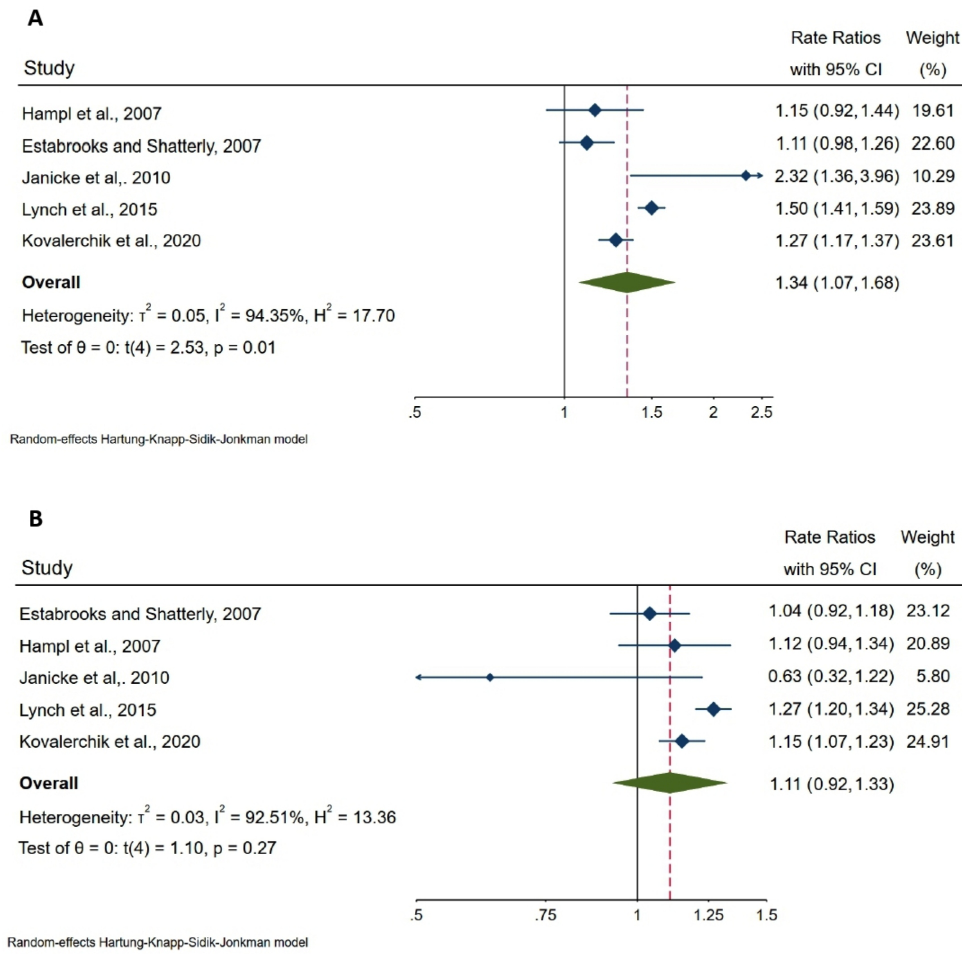

Figure 2 Forest plots showing the unadjusted effect sizes (rate ratios (RRs) with 95% CIs) for emergency department visits in (A) obese children, (B) overweight children. RRs are computed with normal-weight children as the reference category.

Hospital LOS was reported as a measure of healthcare utilisation by six studies.[46 47 52–54 57] Four studies found a significant increase in LOS for obese children compared with normal weight.[46 47 52 54] One study reported a slight significant decrease in LOS for obese children,[57] while one study reported no association between obese and normal-weight children.[53]

GP visits

Three studies reported GP visits as a measure for healthcare utilisation.[48 55 58] All three studies reported a significant increase in GP visits for overweight and obese children, compared with their normal-weight peers.

Associated medical conditions

Five studies reported on the effect of asthma or acute respiratory disorders on healthcare utilisation in obese children.[41 45–48] Of these studies, four reported that obese children significantly incurred increased healthcare use for asthma compared with normal-weight children.[45–48] In addition, two studies found that other acute respiratory conditions are also significantly associated with increased healthcare use in obese children.[41 45] Furthermore, two studies reported a non-significant increase for respiratory conditions in obese children.[44 46]

Two studies reported that obese children are at a significantly greater risk of seeking healthcare for mental health problems compared with normal-weight children.[37 44] The risk for overweight children was also reported to be higher but non-significant. Two studies reported a non-significant increase in visits for musculoskeletal problems in obese children compared with normal-weight children.[44 50]

BMI cut-offs

Table 1 shows that 20 of the included studies used the Centers for Disease Control or the International Obesity task force cut-off points to classify children into weight categories. However, some studies used the term 'overweight' in place of obese for ≥95% percentile, while using the term 'at-risk of overweight (AROW)' in place of overweight for children with BMI percentiles ≥85% and ≤95%. During the analysis, we adjusted for this difference in terminologies.

Two studies used the weight for age BMI z-score classification.[40 54] The effect size reported by these two studies for obese children was significant and much stronger than the studies not using this criterion. Three studies using data from German survey KiGGs and GINI and

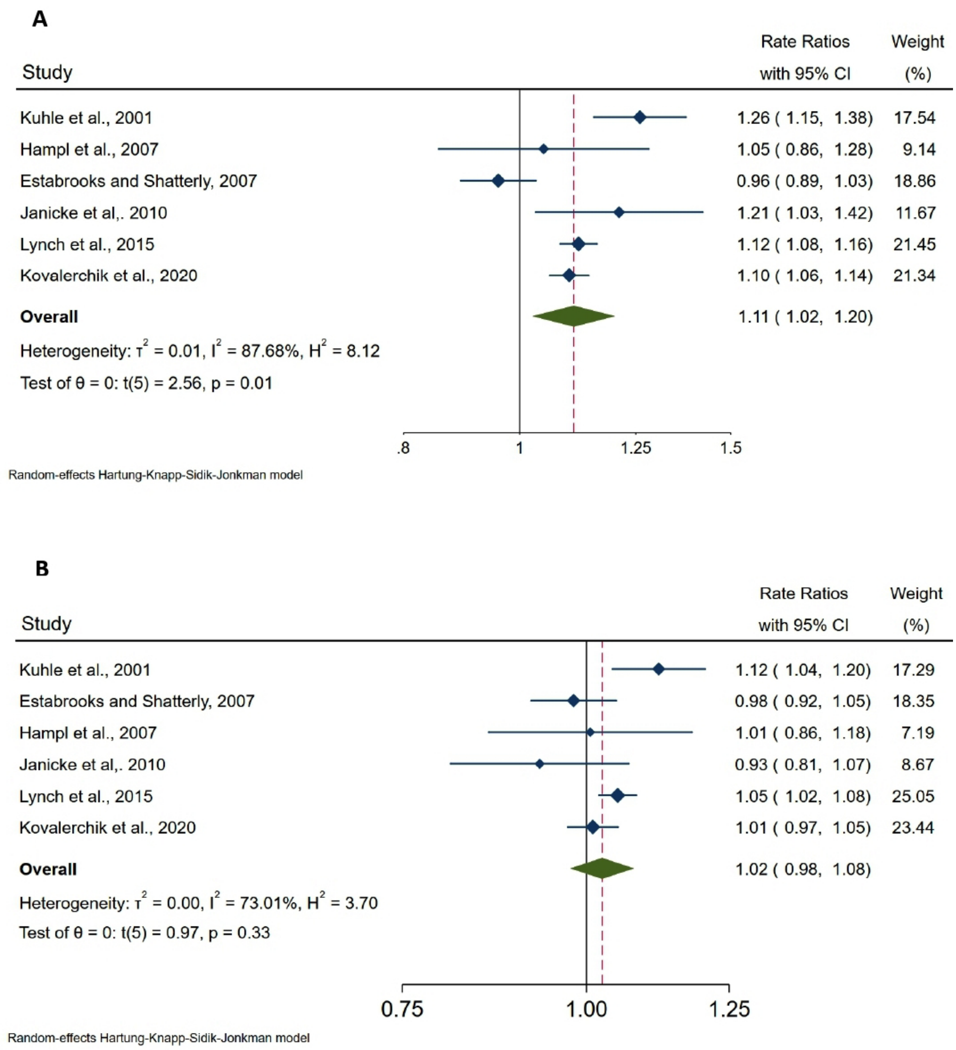

Figure 3 Forest plots showing the unadjusted effect sizes (rate ratios (RRs) with 95% CIs) for outpatient visits in (A) obese children, (B) overweight children. RRs are computed with normal-weight children as a reference category.

LISA cohorts used the country-specific BMI cut-off values with obesity defined as >97th percentile.[35 36 51] It was not possible to formally establish a comparison based on BMI cut-off criteria due to the small number of studies using respective BMI cut-offs and the use of different outcome measures across these studies.

Ethnicity

Two studies reported the effect of ethnicity on the association of weight status with healthcare utilisation.[30 59] Both these studies were from the USA. They reported a decrease in healthcare utilisation in black overweight or obese children compared with white overweight or obese children. In addition, one study also reported decreased healthcare use in obese Asian or Hispanic children compared with white obese children.[30]

Anthropometric measurements

Seven studies recorded the height and weight by self-reporting or parental reporting without validation.[30–34 51 52] Five of these studies used data from MEPS survey in the USA. Variability in the direction and strength of association between weight status and healthcare use was observed across these studies. This heterogeneity could be subject to reporting bias due to self-reporting or parent-reporting; however, not enough data were available to formally assess this.

DISCUSSION

This systematic review and meta-analysis has demonstrated an association between excess weight and increased healthcare use in children. Thirty-three studies were included in the review, of which six had appropriate data to be included in the meta-analysis. Attesting to the diverse nature of health services and the variability in their provision in different countries, the studies used multiple outcome measures to define healthcare utilisation. Commonly examined outcome measures were outpatient visit, ED visit, hospital admission and hospital LOS. Studies included in the meta-analysis reported an increased risk of healthcare utilisation in obese children compared with normal-weight children. A significant unadjusted positive association of obesity with increased outpatient and ED visits was observed in the meta-analysis. The results of the narrative synthesis supported these findings and indicated that obese children are much more likely to have higher healthcare utilisation for all the reported outcome measures. However, variability in the direction and strength of association was observed across studies, with a few studies reporting a negative or no association.

A vast body of research and associated systematic reviews exist which have analysed the burden of adult obesity on healthcare systems and also the incremental health burden of child obesity during adulthood.[60–62] Such studies have indicated repeatedly that obesity is significantly related to a greater risk of morbidity in adult life and associated increase in healthcare utilisation. Our review builds on this knowledge and suggests that much like adult life, obesity during childhood results in an increased burden of morbidity on healthcare services. These findings can be explained in the light of recent clinical research reporting an increasing prevalence of obesity-related conditions in childhood that were more commonly associated with adulthood in the past.[7 63]

This leads our discussion into one of the secondary objectives of the review: to analyse the most common obesity-associated health conditions that are contributing to an increased healthcare use in children with obesity. Most of the included studies did not attempt to ascertain the reason for increased healthcare utilisation. Two studies included in the review analysed the rate of mental health related visits in obese children, with both reporting an increased risk. These findings support the previous evidence that has shown obesity to be a strong risk factor for stigmatisation and development of low self-esteem and other mental health issues in children.[64 65] The role of obesity in increasing the risk of asthma in children is well founded.[66] Five studies in the review supported the previous evidence and reported that obesity leads to increased health service utilisation in asthmatic children and also in children with other respiratory diseases.

Regional variation in rates of healthcare utilisation is well reported in literature.[67–69] When studies conducted in different regions or countries with different population characteristics and healthcare systems are systematically reviewed and analysed together, regional variation in healthcare utilisation may result in between-study heterogeneity. Evidence suggests that this regional variation is in part driven by population-specific factors such as ethnicity, socioeconomic status, health status, cultural beliefs and preferences.[68] The prevalence of childhood obesity varies between different regions and countries. It is also well reported that within a population, the prevalence of obesity varies between children of different ethnic origins.[3 70 71] In addition, evidence shows an inverse relationship between the prevalence of obesity and low socioeconomic status.[3 72] The extent to which this variability in prevalence translates into variability in associated morbidity and healthcare use is not known. There is evidence that healthcare seeking behaviour and healthcare uptake varies across ethnic groups and socioeconomic classes.[73–76] Most of this evidence suggest that people belonging to black and other minority ethnic groups are at a disadvantage in accessing health services.[77 78] In addition, cultural beliefs and perceptions towards health status in general and weight status in particular may contribute to ethnic disparities in healthcare utilisation.[79 80] None of the studies included in the review analysed the impact of socioeconomic status while only two studies analysed the impact of ethnicity. They reported a significantly lower use of health services in obese children of black, Asian and other ethnic minority groups compared with white children. To what extent this lower use is a result of disadvantage in access to healthcare and what results from differences in prevalence and in levels of morbidity remains unclear. In addition, both of these studies were from the USA, which has specific health insurance programmes for children.[81 82] Therefore, care should be taken in generalising these findings to other countries with different healthcare systems. In the light of these two studies and previous research evidence, we can infer that ethnicity and socioeconomic status could be sources of between-study heterogeneity reported in this review; however, as the studies did not report the ethnic and socioeconomic characteristics of the populations studied, it was not possible to explore this further. Evidence also suggests that in addition to population-specific factors, regional variation in healthcare is in part due to differences in region-specific factors such as access to health services, healthcare resources, health policies and physician beliefs.[68 69] For example, some percentage of the between-study heterogeneity reported in our review may be attributable to regional variations in physician beliefs towards excess weight or barriers and facilitators to healthcare access. However, exploring the extent of heterogeneity due to region-specific variables was beyond the scope of this review.

Strengths and limitations

This review has a number of strengths. First, to our knowledge this is the first systematic review and meta-analysis of the utilisation of healthcare services in obese and overweight children. Second, we have used a comprehensive search strategy, with publications not restricted by region or year of publication which resulted in the inclusion of 33 studies reporting outcome measures from primary and secondary healthcare. In addition, a protocol was developed and registered a priori and methodological guidelines were followed on conducting and reporting a review.

A limitation of this review was the restriction of studies to English-language reports only. A limitation of the meta-analysis was the inclusion of only six studies which meant we were unable to include all the outcomes described in the review. In addition, there was uncertainty over the weighted effect sizes due to between-study heterogeneity in methods and outcomes.

There were some further limitations in terms of the characteristics of the included studies. First, the majority of the studies were from the USA, with the remainder being from eight first-world countries, therefore limiting the extent to which the findings may be generalised beyond certain national contexts due to differences in healthcare services and systems. Second, there was poor reporting of data for key study characteristics. For example, none of the studies included in the meta-analysis reported the use of healthcare services stratified by sex. Therefore, it was not possible to run a subset analysis and adjust for covariates in a meta-regression to formally analyse sources of between-study heterogeneity.

CONCLUSIONS

In summary, this systematic review has shown that overweight and obesity in children is positively associated with increased utilisation of ED and outpatient healthcare services during childhood. This finding remained in the meta-analysis although with potential heterogeneity between studies. The reported evidence for inpatient health service use is mixed. The studies included in the review are limited to only a few developed countries; therefore, it is difficult to generalise these findings to other countries due to differences in healthcare systems and delivery of health services. The substantial between-study heterogeneity reported in the review might be due to these differences across countries; however, it was not possible to formally analyse this due to insufficient data. The review has identified areas of research where gaps exist. In particular, further research is required in understanding the dynamics of obesity-associated health conditions that may drive increased healthcare utilisation in children. In addition, the driving factors behind the varying effect of ethnicities and socioeconomic status on association of obesity with healthcare utilisation are yet to be explored. Such evidence is necessary for the development of policies for clinical practice and research, and for their implementation in a way that, while being cost-effective, can successfully target the therapeutic needs of obese and overweight children from different ethnic and socioeconomic backgrounds.

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Contributors TH conceptualised and designed the protocol, conducted the literature search and screening, assessed risk of bias, extracted data, conducted the narrative synthesis and meta-analysis, drafted the initial manuscript and revised the manuscript. TSA screened the studies, reviewed the extraction of data and quality assessment, and revised the initial and subsequent drafts. JW and LKF designed the protocol, revised the initial and subsequent manuscript drafts and approved the final version for publication. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of work.

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REFERENCES

1 Organization WH. *Taking action on childhood obesity*. World Health Organization, 2018.
2 OECD. *Health at a glance 2017*, 2017.
3 NHS Digital. *Statistics on Obesity, Physical Activity and Diet – England, 2018*, 2018.
4 Singh AS, Mulder C, Twisk JWR, *et al*. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev* 2008;9:474–88.
5 Bray GA, Kim KK, Wilding JPH, *et al*. Obesity: a chronic relapsing progressive disease process. A position statement of the World Obesity Federation. *Obes Rev* 2017;18:715–23.
6 Llewellyn A, Simmonds M, Owen CG, *et al*. Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis. *Obes Rev* 2016;17:56–67.
7 Abbasi A, Juszczyk D, van Jaarsveld CHM, *et al*. Body mass index and incident type 1 and type 2 diabetes in children and young adults: a retrospective cohort study. *J Endocr Soc* 2017;1:524–37.
8 Lang JE, Obesity LJE. Obesity, nutrition, and asthma in children. *Pediatr Allergy Immunol Pulmonol* 2012;25:64–75.
9 Chen F, Wang Y, Shan X, *et al*. Association between childhood obesity and metabolic syndrome: evidence from a large sample of Chinese children and adolescents. *PLoS One* 2012;7:e47380.
10 Vukovic R, Zdravkovic D, Mitrovic K, *et al*. Metabolic syndrome in obese children and adolescents in Serbia: prevalence and risk factors. *J Pediatr Endocrinol Metab* 2015;28:903–9.
11 Daniels SR, Arnett DK, Eckel RH, *et al*. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. *Circulation* 2005;111:1999–2012.
12 Finkelstein EA, Graham WCK, Malhotra R. Lifetime direct medical costs of childhood obesity. *Pediatrics* 2014;133:854–62.
13 Kent S, Green J, Reeves G, *et al*. Hospital costs in relation to body-mass index in 1.1 million women in England: a prospective cohort study. *Lancet Public Health* 2017;2:e214–22.
14 Dee A, Kearns K, O'Neill C, *et al*. The direct and indirect costs of both overweight and obesity: a systematic review. *BMC Res Notes* 2014;7:242.
15 Tucker DMD, Palmer AJ, Valentine WJ, *et al*. Counting the costs of overweight and obesity: modeling clinical and cost outcomes. *Curr Med Res Opin* 2006;22:575–86.
16 Moher D, Liberati A, Tetzlaff J, *et al*. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009;151:264–9.
17 Bramer W, Bain P, PJJotMLAJ B. Updating search strategies for systematic reviews using EndNote. *JMLA* 2017;105.
18 World Health Organization. Definition of key terms, 2013. Available: http://www.who.int/hiv/pub/guidelines/arv2013/intro/keyterms/en/
19 Dinsdale H, Ridler C, Ells L. *A simple guide to classifying body mass index in children*. Oxford, UK: National Obesity Observatory, 2011.
20 Centers for Disease Control and Prevention. Defining Childhood Obesity | Overweight & Obesity | CDC, 2019. Available: https://www.cdc.gov/obesity/childhood/defining.html
21 Altman DG. *Practical statistics for medical research*. CRC Press, 1990.
22 National Heart L, Institute B. *Quality assessment tool for observational cohort and cross-sectional studies*. Bethesda: National Institutes of Health, Department of Health and Human Services, 2014.
23 StataCorp. *StataCorp LJCS, Stata*. release 16.0. Texas: StataCorp LP, 2019.
24 Borenstein M, Hedges L, Higgins J, *et al*. *Comprehensive meta-analysis*. 2013. Version 3. NJ, 2013.
25 Hartung J, Knapp G. A refined method for the meta-analysis of controlled clinical trials with binary outcome. *Stat Med*

26 Sidik K, Jonkman JN, Analysis D. Robust variance estimation for random effects meta-analysis. *Comput Stat Data Anal* 2006;50:3681–701.
27 IntHout J, Ioannidis JPA, Borm GF, GFJBmrm B. The Hartung-Knapp-Sidik-Jonkman method for random effects meta-analysis is straightforward and considerably outperforms the standard DerSimonian-Laird method. *BMC Med Res Methodol* 2014;14:25.
28 Sterne JAC, Sutton AJ, Ioannidis JPA, *et al*. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ* 2011;343:d4002.
29 Higgins J, Green S. *Cochrane handbook for systematic reviews of interventions*. version 5.1. 0. The Cochrane Collaboration, 2011.
30 Monheit AC, Vistnes JP, Rogowski JA. Overweight in adolescents: implications for health expenditures. *Econ Hum Biol* 2009;7:55–63.
31 Skinner AC, Mayer ML, Flower K, *et al*. Health status and health care expenditures in a nationally representative sample: how do overweight and healthy-weight children compare? *Pediatrics* 2008;121:e269–77.
32 Trasande L, Chatterjee S. The impact of obesity on health service utilization and costs in childhood. *Obesity* 2009;17:1749–54.
33 Turer CB, Lin H, Flores G. Health status, emotional/behavioral problems, health care use, and expenditures in overweight/obese us children/adolescents. *Acad Pediatr* 2013;13:251–8.
34 Wright DR, Prosser LA. The impact of overweight and obesity on pediatric medical expenditures. *Appl Health Econ Health Policy* 2014;12:139–50.
35 Wenig CM, Knopf H, Menn P. Juvenile obesity and its association with utilisation and costs of pharmaceuticals—results from the KiGGS study. *BMC Health Serv Res* 2011;11:340.
36 Wenig CM. The impact of BMI on direct costs in children and adolescents: empirical findings for the German healthcare system based on the KiGGS-study. *Eur J Health Econ* 2012;13:39–50.
37 Estabrooks PA, Shetterly S. The prevalence and health care use of overweight children in an integrated health care system. *Arch Pediatr Adolesc Med* 2007;161:222–7.
38 Hampl SE, Carroll CA, Simon SD, *et al*. Resource utilization and expenditures for overweight and obese children. *Arch Pediatr Adolesc Med* 2007;161:11–14.
39 Hering E, Pritsker I, Gonchar L, *et al*. Obesity in children is associated with increased health care use. *Clin Pediatr* 2009;48:812–8.
40 Janicke DM, Harman JS, Jamoom EW, *et al*. The relationship among child weight status, psychosocial functioning, and pediatric health care expenditures in a Medicaid population. *J Pediatr Psychol* 2010;35:883–91.
41 Lynch BA, Finney Rutten LJ, Jacobson RM, *et al*. Health care utilization by body mass index in a pediatric population. *Acad Pediatr* 2015;15:644–50.
42 Wyrick S, Hester C, Sparkman A, *et al*. What role does body mass index play in hospital admission rates from the pediatric emergency department? *Pediatr Emerg Care* 2013;29:974–8.
43 Kovalerchik O, Powers E, Holland ML, *et al*. Differences in frequency of visits to pediatric primary care practices and emergency departments by body mass index. *Acad Pediatr* 2020;20:532–9.
44 Ortiz-Pinto MA, Ortiz-Marrón H, Esteban-Vasallo MD, *et al*. Demand for health services and drug prescriptions among overweight or obese preschool children. *Arch Dis Child* 2020;105:292–7.
45 Buescher PA, Whitmire JT, Plescia M. Relationship between body mass index and medical care expenditures for North Carolina adolescents enrolled in Medicaid in 2004. *Prev Chronic Dis* 2008;5:A04.
46 Woolford SJ, Gebremariam A, Clark SJ, *et al*. Incremental hospital charges associated with obesity as a secondary diagnosis in children. *Obesity* 2007;15:1895–901.
47 Carroll CL, Bhandari A, Zucker AR, *et al*. Childhood obesity increases duration of therapy during severe asthma exacerbations. *Pediatr Crit Care Med* 2006;7:527–31.
48 Kelly B, West J, Yang TC, *et al*. The association between body mass index, primary healthcare use and morbidity in early childhood: findings from the Born In Bradford cohort study. *Public Health* 2019;167:21–7.
49 Griffiths LJ, Cortina-Borja M, Bandyopadhyay A, *et al*. Are children with clinical obesity at increased risk of inpatient hospital admissions? An analysis using linked electronic health records in the UK millennium cohort study. *Pediatr Obes* 2019;14:e12505.
50 van Leeuwen J, van Middelkoop M, Paulis WD, *et al*. Overweight and obese children do not consult their general practitioner more often than normal weight children for musculoskeletal complaints during a 2-year follow-up. *Arch Dis Child* 2018;103:149–54.
51 Breitfelder A, Wenig CM, Wolfenstetter SB, *et al*. Relative weight-related costs of healthcare use by children—results from the two German birth cohorts, GINI-plus and LISA-plus. *Econ Hum Biol* 2011;9:302–15.
52 Trasande L, Liu Y, Fryer G, *et al*. Effects of childhood obesity on hospital care and costs, 1999–2005. *Health Aff* 2009;28:w751–60.
53 Fleming-Dutra KE, Mao J, Leonard JC. Acute care costs in overweight children: a pediatric urban cohort study. *Child Obes* 2013;9:338–45.
54 Bechere Fernandes MT, Ferraro AA, Danti GV, *et al*. PP276-SUN: excess weight in children increases hospitalization days. *Clinical Nutrition* 2014;33:S122–3.
55 Kuhle S, Kirk S, Ohinmaa A, *et al*. Use and cost of health services among overweight and obese Canadian children. *Int J Pediatr Obes* 2011;6:142–8.
56 Bianchi-Hayes J, Calixte R, Huang J, *et al*. Healthcare utilization by obese and overweight children. *J Pediatr* 2015;166:626–31.
57 Bettenhausen J, Puls H, Queen MA, *et al*. Childhood obesity and in-hospital asthma resource utilization. *J Hosp Med* 2015;10:160–4.
58 Doherty E, Queally M, Cullinan J, *et al*. The impact of childhood overweight and obesity on healthcare utilisation. *Econ Hum Biol* 2017;27:84–92.
59 Dilley KJ, Martin LA, Sullivan C, *et al*. Identification of overweight status is associated with higher rates of screening for comorbidities of overweight in pediatric primary care practice. *Pediatrics* 2007;119:e148–55.
60 Reilly JJ, Kelly J, JJljoo K. Long-Term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *Int J Obes* 2011;35:891–8.
61 Wang F, McDonald T, Bender J, *et al*. Association of healthcare costs with per unit body mass index increase. *J Occup Environ Med* 2006;48:668–74.
62 Wang YC, McPherson K, Marsh T, *et al*. Health and economic burden of the projected obesity trends in the USA and the UK. *The Lancet* 2011;378:815–25.
63 Pulgarón ER. Childhood obesity: a review of increased risk for physical and psychological comorbidities. *Clin Ther* 2013;35:A18–32.
64 Franklin J, Denyer G, Steinbeck KS, *et al*. Obesity and risk of low self-esteem: a statewide survey of Australian children. *Pediatrics* 2006;118:2481–7.
65 Strauss RS, Pollack HA, HAJAop P. Social marginalization of overweight children. *Arch Pediatr Adolesc Med* 2003;157:746–52.
66 Visness CM, London SJ, Daniels JL, *et al*. Association of childhood obesity with atopic and nonatopic asthma: results from the National Health and Nutrition Examination Survey 1999–2006. *J Asthma* 2010;47:822–9.
67 Cheung CRLH, Gray JAM, JMJAodic G. Unwarranted variation in health care for children and young people. *Arch Dis Child* 2013;98:60–5.
68 Finkelstein A, Gentzkow M, Williams H, HJTqjoe W. Sources of geographic variation in health care: evidence from patient migration. *Q J Econ* 2016;131:1681–726.
69 Godøy A, Huitfeldt I, IJJoHE H. Regional variation in health care utilization and mortality. *J Health Econ* 2020;71:102254.
70 World Health Organization. *Report of the Commission on Ending Childhood Obesity: implementation plan: executive summary*, 2017.
71 Caprio S, Daniels SR, Drewnowski A, *et al*. Influence of race, ethnicity, and culture on childhood obesity: implications for prevention and treatment: a consensus statement of Shaping America's Health and the Obesity Society. *Diabetes Care* 2008;31:2211–21.
72 Shrewsbury V, Wardle J. Socioeconomic status and adiposity in childhood: a systematic review of cross-sectional studies 1990–2005. *Obesity*
73 Coker TR, Elliott MN, Kataoka S, *et al*. Racial/ethnic disparities in the mental health care utilization of fifth grade children. *Acad Pediatr* 2009;9:89–96.
74 Fischer AH, Shin DB, Margolis DJ, *et al*. Racial and ethnic differences in health care utilization for childhood eczema: an analysis of the 2001–2013 medical expenditure panel surveys. *J Am Acad Dermatol* 2017;77:1060–7.
75 Amre DK, Infante-Rivard C, Gautrin D, *et al*. Socioeconomic status and utilization of health care services among asthmatic children. *J Asthma* 2002;39:625–31.
76 Kangovi S, Barg FK, Carter T, *et al*. Understanding why patients of low socioeconomic status prefer hospitals over ambulatory care. *Health Aff* 2013;32:1196–203.
77 Szczepura A. Access to health care for ethnic minority populations. *Postgrad Med J* 2005;81:141–7.

78 Scheppers E, van Dongen E, Dekker J, *et al*. Potential barriers to the use of health services among ethnic minorities: a review. *Fam Pract* 2006;23:325–48.
79 Kocken PL, Schönbeck Y, Henneman L, *et al*. Ethnic differences and parental beliefs are important for overweight prevention and management in children: a cross-sectional study in the Netherlands. *BMC Public Health* 2012;12:867.
80 Peña M-M, Dixon B, Taveras EM. Are you talking to ME? The importance of ethnicity and culture in childhood obesity prevention and management. *Child Obes*
81 Racine AD, Long TF, Helm ME, *et al*. Children's Health Insurance Program (CHIP): accomplishments, challenges, and policy recommendations. *Pediatrics* 2014;133:e784–93.
82 Dubay L, Kenney G. The impact of CHIP on children's insurance coverage: an analysis using the National Survey of America's Families. *Health Serv Res* 2009;44:2040–59.
83 Adams MH, Carter TM, Lammon CAB, *et al*. Obesity and blood pressure trends in rural adolescents over a decade. *Pediatr Nurs* 2008;34:381.
84 Bertoldi AD, Tavares NUL, Hallal PC, *et al*. Medicine use among adolescents: the 11-year follow-up of the 1993 Pelotas (Brazil) birth cohort study. *Cad Saude Publica* 2010;26:1945–53.
85 Wake M, Canterford L, Patton GC, *et al*. Comorbidities of overweight/obesity experienced in adolescence: longitudinal study. *Arch Dis Child* 2010;95:162–8.