**Health care utilization in overweight and obese children: a systematic review and meta-analysis**

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**Short title:** Health care use in overweight and obese children

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**Abbreviations:** WHO: World Health Organization, UK: United Kingdom, PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analysis, BMI: Body Mass Index, GP: General Practitioner, LOS: Length Of Stay, RRs: Rate Ratios, MEPS: Medical Expenditure Panel Survey, KiGGS: German Interview and Examination Survey for Children and Adolescents, ED: Emergency Department, CI: Confidence Interval, AROW: At Risk Of Overweight

**Word count:** 4,943

**ABSTRACT:**

**Objective:** This systematic review and meta-analysis aims to systematically analyse the association of overweight and obesity with health service utilization 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 health care utilization 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. Additionally, rate ratios (RR) and 95% confident intervals were calculated in a meta-analysis on a subgroup of eligible studies.

**Outcome measures:** Included studies reported association of weight status with healthcare utilization measures of outpatient visits, emergency department (ED) visits, GP visits, hospital admissions and hospital length of stay.

**Results:** Thirty-three studies were included in the review. When synthesizing the findings from all studies narratively, obesity and overweight was found to be positively associated with increased healthcare utilization 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 – 1.68) and outpatient visits (RR 1.11, 95% CI: 1.02 – 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 to normal weight children.

**Conclusions:** Obesity in children is associated with increased healthcare utilization. Future research should assess the impact of ethnicity and obesity-associated health conditions on increased healthcare utilization 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 PRISMA 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 the World Health Organization (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 United Kingdom (UK), which is reported to be the most obese country in Western Europe by the Organization of Economic Co-operation & 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 cardio-metabolic conditions such as type- 2 diabetes, ischemic heart disease, and stroke (4-6). Additionally, 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 above-mentioned associations, it could be inferred that individuals with overweight and obesity would experience greater morbidity compared to individuals of normal weight, leading to increased healthcare utilization. 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 utilization 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 utilization.

**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 (ID: CRD42018091752). The PRISMA checklist is provided as a supplementary 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 utilization 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 utilization”. These terms comprised of keywords, text terms or medical subject headings appropriate for each literature database. A copy of the searches conducted to identify studies is given in the supplementary 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 utilization 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 upon WHO’s definition of a child and adolescent (18). Additionally, instead of restricting the inclusion criteria to studies using predefined standard Body Mass Index (BMI) cut-offs for childhood overweight (sex- and age-specific BMI ≥ 85th centile and < 95th centile) and obesity (sex-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 utilization .

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 (TA). 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 (TA). 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 (LF) 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 customized 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 (TA). 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 diverse nature of healthcare utilization 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). Additionally, potential sources of heterogeneity across studies were explored.

Statistical Analysis:

The ‘meta’ command in Stata version 16.1 (23) was used to generate meta-analysis for rate ratios (RRs) of healthcare utilization in obese and overweight children, using normal weight children as a reference. Studies that reported RRs with corresponding measures of precision [(95% Confidence Intervals (CIs) or Standard Errors (SEs)] were included in the meta-analysis. Additionally, 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, rate ratios were log transformed and corresponding standard errors were computed from effect sizes and 95% CIs using the Comprehensive Meta-Analysis software version 3 (24). Afterwards, a random-effects meta-analysis with Hartung-Knapp-Sidik-Jonkman (HKSJ) 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 I2 statistic. Based on the interpretation provided in the Cochrane’s Handbook for Systematic Reviews, heterogeneity in this review is considered substantial if I2 > 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 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. The 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 8, 504 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,

| First author, Year | Country | No. of participants | Study Design | Age in years (Cohort/survey) | Anthropometric measurement | BMI cut-offs | Measures of Healthcare utilization | Covariates |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Adams, 2008a | USA | 4263 | Cross-sectional | 14-19 years | Physical assessment measurement | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Primary care referralsDental referrals | Not reported |
| Bechere Fernandes et al, 2014 | Brazil | 91 | Retrospective cohort | 1-10 years | 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 | Brazil | 4452 | Prospective cohort | 11-12 years | Measurement by researchers | Not given | Medicine uptake in 15 days prior to interview | Skin color, sex, socioeconomic status, pregnancy complication, ICU admission, nutrition status, sedentary lifestyle, and use of sedatives by mothers |
| Bettenhausen, 2015a | USA | 518 | Cross-sectional | 5-17 years | Hospital based measurement | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Inpatient length of stayReadmission rates | Age, sex, race, and insurance |
| Bianchi-Hayes, 2015a | USA | 17 444 | Retrospective cohort study | 2-18 years (NHANES) | Measured by trained health technicians | Overweight BMI ≥ 85th and < 95th percentile. Obese BMI ≥ 95th percentile | Total healthcare visitsTotal no. of hospitalizationsMental 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 et al., 2011 | Germany | 3 508 | Cross-sectional | 9-12 years (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 |
| Buescher et al., 2008a | USA | 30528 | Cross-sectional | 12-18 years | Clinical measurements | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Well-child visitsRespiratory related health visitsTotal expenditure | Sex and ethnicity |
| Carroll et al., 2006a | USA | 219 | Retrospective cohort | 2-18 years | 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 et al., 2007a | USA | 1 216 | Retrospective cohort | ≥ 2 years | Medical record | Overweight ≥ 95th percentile. At risk for overweight: BMI of 85th to 94th percentile | No. of visits to private practice or public health clinics | Age, race, BMI percentile, insurance status, parental education, and household tobacco use. |
| Doherty et al., 2017 | Ireland | 5 924 | Prospective cohort | 13 years (GUI) | Measurement by health professionals | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | GP visitsInpatient stay | Child characteristics: gender birthweight, 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, 2007\*a | USA | 8 282 | Prospective cohort | 3-17 years | Hospital medical record | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Primary care (outpatient) visitsED visitsNo. of hospitalizations | Sex, age and disease status |
| Fleming-Dutra et al., 2013a | USA | 32 966 | Retrospective cohort | 2-18 years | Hospital Medical record | Overweight > 95th percentile sex=specific weight for age. Normal weight ≤ 95% sex-specific weight for age. | Billed charges for child’s visitHospitalization rateED length of stay in hours | Race, age, sex, insurance, and acuity |
| Griffiths et al., 2018 | United Kingdom | 3269 | Prospective cohort  | 5-14 years | 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 et al., 2007\*a | USA | 8 404 | Retrospective cohort | 5-18 years | Measured by clinical nursing staff | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Primary care visitsED visitsLaboratory use | Age, sex, race and insurance status |
| Hering et al., 2009 | Israel | Cases: 363Controls: 382 | Retrospective case control | 4-18 years | Clinical measurement | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | ED visitsPrimary care clinic visitsHospital admissions | Control group matched for age and gender |
| Janicke et al., 2010\*a | USA | 200 | Retrospective cohort | 7-15 years | Measured by a trained researcher | Overweight: BMI z-score ≥1 and < 2. Obese: BMI z-score ≥ 2 | ED visitsAcute care claimsOutpatient and medical claims | Age, sex, ethnicity, insurance status |
| Kelly et al., 2019 | United Kingdom | 9443 | Prospective cohort | 4-5 years | Measured by trained school nurses | Overweight BMI ≥85th and <95th percentile. Obese BMI ≥ 95th percentile | GP appointmentsGP prescriptions | Sex, maternal age, gestational age, means tested benefits, Index of Multiple deprivation (2010) |
| Kovalerchik et al., 2020\*a | USA | 30,352 | Retrospective cohort | 3-17 years | Hospital based measurements | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Emergency Department visitsOutpatient visits | age, age2, sex, race/ethnicity, and insurance status. |
| Kuhle et al., 2011\* | Canada | 4 380 | Prospective cohort | 10-11 years | Measured by research assistants | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | GP visitsSpecialist referralsTotal Healthcare costs | Sex, income, education status and geographic region |
| Lynch et al., 2015\*a | USA | 19 528 | Retrospective cohort | 2-18 years | Hospital medical record | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Outpatient visitsED visitsNo. of hospitalizations | Sex, age and socioeconomic status |
| Monheit et al., 2009a | USA | 6 738 | Retrospective cohort | 12-19 years (MEPS) | Parent- 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. |
| Ortiz Pinto et al., 2019 | Spain | 1857 | Prospective cohort | 4-6 years | Measured by pediatricians | Overweight: BMI z-score ≥1 and ≤ 2. Obese: BMI z-score >+2 | Primary care visitsDrug PrescriptionsHospital admissions | Sex, age in months, mother’s education, breast feeding duration, family purchasing power.  |
| Skinner et al., 2008a | USA | Not given | Cross-sectional | 6-17 years (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, 2009a | USA | 19 613 | Prospective cohort | 6-19 years (MEPS) | Parent- and self-reported | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Outpatient visitsED visitsHealthcare expenditure | Race, gender, insurance status and family income. |
| Trasande et al., 2009a | USA | Not given | Prospective cohort | 2-19 years | Parent- and self-reported | Based on ICD-9 diagnostic codes | Obesity associated hospitalizations | Age, sex, ethnicity, expected primary payer, hospital location, hospital teaching status, and median household income. |
| Turer et al., 2013a | USA | 17 224 | Cross-sectional | 10-17 years (MEPS) | Parent- and self-reported | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Hospital based outpatient, or clinic visitSpecialist visitsED visitsOutpatient prescriptions | Gender, age, race, insurance status, and poverty status |
| van Leeuwen et al., 2018 | Netherlands | 617 | Prospective cohort | 2-18 years (DOERAK) | Measured by GP or research assistant | Overweight: BMI z-score ≥1 and < 2. Obese: BMI z-score ≥ 2 | No. and type of musculoskeletal consultationTotal no. of consultations | Age, gender, socioeconomic status and marital status. |
| Wake et al., 2010 | Australia | 923 | Prospective cohort | 5-19 years | Measured by trained field workers | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Healthcare visits | Sex, age and SEIFA disadvantage index |
| Wenig et al., 2011 | Germany | 14 592 | Retrospective cohort | 3-17 years (KiGGS) | Measured through physical examination | Overweight: BMI > 90th to 97th percentile. Obese > 97th percentile | No. of pharmaceuticals taken in the last 7 days | Age, sex, socioeconomic status and migrant status |
| Wenig, 2012 | Germany | 14 277 | Cross-sectional | 3-17 years (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 et al., 2007a | USA | 777 274 | Cross-sectional | 2-18 years | Hospital based measurements | Obesity was defined based on ICD-9-CM codes. (Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile) | Length of stayTotal charges | Sex, race, region and hospital type |
| Wright and Prosser, 2014a | USA | 23 727 | Cross-sectional | 6-17 years (MEPS) | Parent- and self- reported | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | ED visitsOutpatient visitsPrescription of drugs | Age, BMI class, sex, ethnicity, census region, poverty status, insurance status and survey year, |
| Wyrick et al., 2013a | USA | 1 746 | Prospective cohort | 2-18 years | Hospital based measurements | Overweight BMI ≥85th and < 95th percentile. Obese BMI ≥ 95th percentile | Admissions from ED | Age and sex |
| \*Studies included in the meta-analysisa Studies using Centre for Disease control (CDC) criterion to define obesity  |

**Table 1**: Basic characteristics of included studies

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.

Table 1 summarises the measures of healthcare utilization 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 utilization. The studies represented children between 1 to 19 years of age. Table 1 shows that seven studies calculated BMI from anthropometric measurements (height and weight) based on self- 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 (W/A) ratio to define obesity or overweight (53, 54). Additionally, 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.

|  |  |  |
| --- | --- | --- |
| Study | Criteria | Rating |
| **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 time-frame 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)** |
| Adams, 2008 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | **Poor** |
| Bechere Fernandes et al, 2014 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | **Good** |
| Bertoldi, 2010 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | **Poor** |
| Bettenhausen, 2015 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Bianchi-Hayes, 2015 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Breitfelder et al., 2011 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | **Fair** |
| Buescher et al., 2008 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Carroll et al., 2006 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Dilley et al., 2007 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | **Poor** |
| Doherty et al., 2017 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | **Good** |
| Estabrooks and Shetterly, 2007\* | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | **Good** |
| Fleming-Dutra et al., 2013 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Griffiths et al., 2018 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **Good** |
| Hampl et al., 2007\* | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | **Good** |
| Hering et al., 2009 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Janicke et al., 2010\* | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | **Fair** |
| Kelly et al., 2019 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **Good** |
| Kovalerchik et al., 2020\* | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **Good** |
| Kuhle et al., 2011\* | **1** | **1** | **1** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **Good** |
| Lynch et al., 2015\* | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **1** | **1** | **0** | **1** | **1** | **Good** |
| Monheit et al., 2009 | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **1** | **1** | **0** | **0** | **0** | **0** | **1** | **Fair** |
| Ortiz-Pinto et al., 2019 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **Good** |
| Skinner et al., 2008 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **Fair** |
| Trasande and Chatterjee, 2009 | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **1** | **Fair** |
| Trasande et al., 2009 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **0** | **0** | **0** | **1** | **0** | **0** | **1** | **Fair** |
| Turer et al., 2013 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **1** | **Fair** |
| van Leeuwen et al., 2018 | **1** | **1** | **1** | **1** | **0** | **1** | **1** | **1** | **1** | **1** | **1** | **0** | **1** | **1** | **Good** |
| Wake et al., 2010 | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **1** | **1** | **1** | **1** | **0** | **1** | **1** | **Good** |
| Wenig et al., 2011 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **Fair** |
| Wenig, 2012 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **0** | **0** | **0** | **1** | **Fair** |
| Woolford et al., 2007 | **1** | **1** | **0** | **1** | **0** | **0** | **1** | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **Fair** |
| Wright and Prosser, 2014 | **1** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **1** | **1** | **0** | **0** | **1** | **Good** |
| Wyrick et al., 2013 | **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 |

**Table 2**: Risk of Bias assessment of included studies

Narrative synthesis and Meta-analysis:

Findings from all included studies were synthesized narratively for each outcome measure of healthcare utilization. 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). Additionally, five of these (37, 38, 41, 43, 55) used a similar definition to define obesity (age and sex specific BMI ≥ 95th percentile) while one study (40) defined it as age 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 standard errors were calculated using the available raw data. One study assessed healthcare use over one-year and three-year periods. A decision was made to include data for one-year period due to larger sample size as many participants were lost to follow-up by the end of three-year period (37). Figures 2 and 3 show the forest plots for meta-analysis with outcome measures of ED visits and outpatients visits, respectively. Supplementary figures 3 and 4 show forest plots for ED and outpatient visits in obese children compared to 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.

Emergency department visits:

Ten studies reported ED visits as an outcome measure for healthcare utilization (32-34, 37-41, 43, 53). In both obese and overweight children compared to 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 to 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). Additionally, one study reported a non-significant decrease of ED visits in 6-11-year-old obese children, 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 to normal weight children (32, 33, 41, 43). Two studies reported a 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 emergency departments compared to normal weight children (figure 2a). The associated effect size (RR) was 1.34 (95% CI: 1.07-1.68). The effect size for overweight versus healthy weight was RR= 1.11 (95% CI: 0.92-1.33) (figure 2b). The I2 statistic showed substantial between study heterogeneity for obese versus normal weight (I2 = 94.3 %, P < 0.01) and overweight versus normal weight (I2 = 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 (supplementary figure 1). 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 utilization (32-34, 36-41, 43, 44). In obese children compared to 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 to 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: 1.02-1.20) and 1.02 (95% CI: 0.98-1.08), respectively (Figure 3a and 3b). Significant between study heterogeneity was observed for both obese vs normal weight children (I2 = 87.6%, P < 0.01) and overweight vs normal weight children (I2 = 73 %, P < 0.01).

Visual inspection of funnel plot asymmetry for outpatient visits in obese children suggests publication bias (supplementary figure 2). Statistical tests to assess publication bias were not performed due to the small number of studies (n < 10).

Hospital admissions and length of stay:

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 to normal weight. Two studies reported a non-significant decrease in admissions (44, 56). Additionally, one study reported that 14.5% of obese or overweight children were admitted, compared to 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 to normal weight children.

Hospital LOS was reported as a measure of healthcare utilization by six studies (46, 47, 52-54, 57). Four studies found a significant increase in LOS for obese children compared to 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 utilization (48, 55, 58). All three studies reported a significant increase in GP visits for overweight and obese children, compared to their normal-weight peers.

Associated medical conditions:

Five studies reported on the effect of asthma or acute respiratory disorders on healthcare utilization in obese children (41, 45-48). Of these studies, four reported that obese children significantly incurred increased healthcare use for asthma compared to normal weight children (45-48). Additionally, 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 to 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 to normal weight children (44, 50).

BMI cut-offs:

Table 1 shows that twenty of the included studies used the Centre 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 LISA cohorts used the country-specific BMI cut-off values with obesity defined as > 97th percentile (35, 36, 59) . 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 utilization (30, 60). Both these studies were from the USA. They reported a decrease in healthcare utilization in black overweight or obese children compared to white overweight or obese children. Additionally, one study also reported decreased healthcare use in obese Asian or Hispanic children compared to white obese children (30).

Anthropometric measurements:

Seven studies recorded the height and weight by self- 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- or parent-reporting, however, not enough data was 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 utilization. Commonly examined outcome measures were outpatient visit, ED visit, hospital admission, and hospital length of stay. Studies included in the meta-analysis reported an increased risk of healthcare utilization in obese children compared to 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 utilization 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 analyzed not only the burden of adult obesity on healthcare systems but also the incremental health burden of child obesity during adulthood (61-63). Such studies have indicated repeatedly that obesity is significantly related to a greater risk of morbidity in adult life and associated increase in healthcare utilization. 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, 64).

This leads our discussion into one of the secondary objectives of the review; to analyze 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 utilization. Two studies included in the review analyzed 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 stigmatization and development of low self-esteem and other mental health issues in children (65, 66). The role of obesity in increasing the risk of asthma in children is well-founded (67). Five studies in the review supported the previous evidence and reported that obesity leads to increased health service utilization in not only asthmatic children, but also in children with other respiratory diseases.

Regional variation in rates of healthcare utilization is well reported in literature (68-70). When studies conducted in different regions or countries with different population characteristics and healthcare systems are systematically reviewed and analyzed together, regional variation in healthcare utilization 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 (69). 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, 71, 72). Additionally, evidence shows an inverse relationship between the prevalence of obesity and low socioeconomic status (3, 73). 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 behavior and health care uptake varies across ethnic groups and socioeconomic classes (74-77). Most of this evidence suggest that people belonging to black and other minority ethnic groups are at a disadvantage in accessing health services (78, 79) . Additionally, cultural beliefs and perceptions towards health status in general and weight status in particular may contribute to ethnic disparities in healthcare utilization (80, 81). None of the studies included in the review analyzed the impact of socioeconomic status while only two studies analyzed 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 to 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. Additionally, both of these studies were from the USA, which has specific health insurance programs for children (82, 83). Therefore, care should be taken in generalizing 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 socio-economic 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 (69, 70). 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 utilization 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. Additionally, 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. Additionally, 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 generalized beyond certain national contexts due to differences in healthcare services and systems. Secondly, 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 analyze sources of between study heterogeneity.

**CONCLUSIONS**

In summary, this systematic review has shown that overweight and obesity in children is positively associated with increased utilization of ED and outpatient healthcare services during childhood. This finding remained in the meta-analysis albeit 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 generalize 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. Particularly, further research is required in understanding the dynamics of obesity-associated health conditions that may drive increased healthcare utilization in children. Additionally, the driving factors behind the varying effect of ethnicities and socio-economic status on association of obesity with healthcare utilization 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 socio-economic backgrounds.

**Author contributions:**

Taimoor Hasan conceptualized 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.

Tom Ainscough screened the studies, reviewed the extraction of data and quality assessment and revised the initial and subsequent drafts.

Jane West and Lorna Fraser 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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**Data Availability:** No additional data available

**Figure legends:**

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

Figure 2: Forest plots showing the unadjusted effect sizes (Rate Ratios with 95% CIs) for ED visits in A)Obese children B)Overweight children. RRs are computed with normal weight children as the reference category.

Figure 3: Forest plots showing the unadjusted effect sizes (Rate Ratios with 95% CIs) for outpatient visits in A)Obese children B)Overweight children. RRs are computed with normal weight children as a reference category.

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