Is obesity associated with depression in children? Systematic review and meta-analysis

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ABSTRACT

Objectives To compare the odds of depression in obese and overweight children with that in normal-weight children in the community.

Design Systematic review and random-effect meta-analysis of observational studies.

Data sources EMBASE, PubMed and PsychINFO electronic databases, published between January 2000 and January 2017.

Eligibility criteria for selecting studies Cross-sectional or longitudinal observational studies that recruited children (aged <18 years) drawn from the community who had their weight status classified by body mass index, using age-adjusted and sex-adjusted reference charts or the International Obesity Task Force age-sex specific cut-offs, and concurrent or prospective odds of depression were measured.

Results Twenty-two studies representing 143,603 children were included in the meta-analysis. Prevalence of depression among obese children was 10.4%. Compared with normal-weight children, odds of depression were 1.32 higher (95% CI 1.17 to 1.50) in obese children. Among obese female children, odds of depression were 1.44 (95% CI 1.20 to 1.72) higher compared with that of normal-weight female children. No association was found between overweight children and depression (OR 1.04, 95% CI 0.95 to 1.14) or among obese or overweight male subgroups and depression (OR 1.14, 95% CI 0.93 to 1.41% and 1.08, 95% CI 0.85 to 1.37, respectively). Subgroup analysis of cross-sectional and longitudinal studies separately revealed childhood obesity was associated with both concurrent (OR 1.26, 95% CI 1.09 to 1.45) and prospective odds (OR 1.51, 95% CI 1.21 to 1.88) of depression.

Conclusion We found strong evidence that obese female children have a significantly increased odds of concurrent and future depression compared with non-obese female children.

Background Childhood mental illness is poorly recognised by healthcare providers and parents, despite half of all lifetime cases of diagnosable mental illness beginning by the age of 14 years.1 Globally, depression is the leading cause of disease burden, as measured by disability-adjusted life years, in children aged 10–19 years.2 Untreated, it is associated with poor school performance and social functioning, substance misuse, recurring depression in adulthood and increased suicide risk, which is the second leading cause of preventable death among young people.3–6 The resulting cost to the National Health Service of treating depression is estimated at over £2 billion, and the wider social and economic impact of depression is likely to be considerable.7

What is already known about this topic?

- Childhood obesity is strongly associated with adverse physical health outcomes, and less is known about its association with mental health outcomes.
- The prevalence and future risk of depression in overweight and obese boys and girls in the community is unclear.

What this study adds?

- Obese female children have a significantly increased odds of concurrent and future depression compared with non-obese female children.
- Clinicians should consider screening obese female children for signs and symptoms of depression.

Overweight status and depression are closely related in children; both may develop simultaneously sharing a common aetiology and manifesting at different times or one may lead to the other.8–10 Cognitive and social factors are likely to be important mechanisms.11–13

Childhood obesity itself is a global public health crisis, threatening the health of future populations from physical health consequences,14 such as cardiovascular disease, type 2 diabetes and cancer.15–17 So far, research efforts have focused on establishing and tackling the physical consequences of childhood obesity. However, little is known about the impact of excess weight on mental health.18

Previous studies examining the excess risk of depression from being overweight as a child are equivocal. Estimates vary widely from 4% to 64%,6,19,20 due to differences in populations, study designs and measurement of weight and depression. Among overweight children drawn from specialist clinics, 23.4% are estimated to be depressed.21 However, overweight children drawn from specialist clinics are not representative of children in the community and may overestimate risk.22 Hence, the overall risk of depression in overweight children in the community remains unclear.
Understanding the risk and prevalence of depression in obese children may help guide clinicians in identifying high-risk children as well as guide policy planners to the mental health needs of obese children. We systematically identified cross-sectional and prospective studies reporting concurrent or future risk of depression and performed meta-analysis to report the overall risk of depression in overweight and obese children drawn from community settings, compared with normal-weight children.

**METHODS**

**Study selection**

**Types of studies**

We included observational studies with a prospective or retrospective cohort, or cross-sectional designs, where participants had been recruited from the general population, school or community setting. We excluded studies where participants were obtained from hospital or specialist settings, as they were unlikely to be representative of obese children in the population.22

**Types of participants**

We included studies if participants were aged 18 years or younger at the time weight was reported. In studies where only average age of participants was reported, we included if average age across all participants was 18 years or younger.

**Types of measures**

Weight status was defined by calculating body mass index (BMI) and using age-adjusted and sex-adjusted reference charts. Obesity was defined as ≥95th centile and overweight ≥85th centile, or using the International Obesity Task Force age-specific and sex-specific centile curves correlating to 25 and 30 kg/m² for adult overweight and obesity.23 We excluded studies that defined obesity using other methods such as waist circumference or body composition as these are rarely used in clinical practice.

**Outcome measures**

Our primary outcome of interest was odds (future or concurrent) of depression in obese and overweight children compared with normal-weight children.

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**Figure 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram. BMI, body mass index.

**Figure 2** Funnel plot.
## Table 1 Systematic review table of 26 observational studies examining obese weight status and depression, ordered by study type and gender

| Study | Country of study/year of study/follow-up (years) | Study population | Method of diagnosis depression used (and name of tool) | Prevalence of depression in obese % (n/N) | OR (95%CI) obese vs normal weight | OR (95%CI) overweight vs normal weight | Variables used in adjustment |
|-------|-----------------------------------------------|------------------|-----------------------------------------------|-----------------|----------------------|----------------------------|-----------------------------------|
| **Prospective studies** | | | | | | | |
| Anderson et al 2007 | USA 2007 | 342 14.6 100 9 | Structured psychiatric interview (DISC) | 40 (4/10) | 1.3 (0.5 to 3.5)† | 0.9 (0.3 to 2.4)† | Socioeconomic status index (combination of family occupational status, family income, parental education), race/ethnicity, smoking, parental psychopathology |
| Herva et al 2006 | Finland 1980 | 3524 | Depression symptoms rating scale (HSCL) | 8.4 (3/155) | 1.55 (0.93 to 2.59) | 1.18 (0.78 to 1.78) | Father's social class, family type, smoking, alcohol use, chronic somatic disease at age 14 |
| **Girls** | | | | | | | |
| Anderson et al 2007 | USA 1980 | 332 14.7 0 3 | Structured psychiatric interview (DISC) | 15.6 (5/32) | 3.9 (1.3 to 11.8)† | 0.9 (0.5 to 1.8)† | Socioeconomic status index (combination of family occupational status, family income, parental education), race/ethnicity, smoking, parental psychopathology |
| Anderson et al 2011 | USA 2003 | 482 (white) 13.9 0 7.9 | Depression symptoms rating scale (CES-D) | 26.3 (10/38) | 2.50 (1.57 to 3.98) | 0.98 (0.16 to 5.97) | Age, free lunch, time spent home alone after school |
| Anderson et al 2011 | USA 2003 | 134 (black) | Depression symptoms rating scale (CES-D) | 10.3 (4/39) | 0.98 (0.16 to 5.97) | – | Age, free lunch, time spent home alone after school |
| Anderson et al 2011 | USA 2003 | 171 (Hispanic) | Depression symptoms rating scale (CES-D) | 16.7 (9/26) | 0.72 (0.26 to 1.95) | – | Age, free lunch, time spent home alone after school, BMI appropriate |
| Bouteille et al 2010 | USA 2010 | 495 | Structured psychiatric interview (K-SADS) | – | 1.62 (0.77 to 3.38) | 0.61 (0.24 to 1.57) | Age, early puberty, previous depression, BMI appropriate |
| Frisco et al 2013 | USA 1996 6 | 5243 13–19 | Depression symptoms rating scale (HSCL) | 11.5 (18/157) | 1.97 (1.19 to 3.26) | 0.97 (0.54 to 1.77) | Age, socioeconomic status index (combination of family occupational status, family income, parental education), family type, smoking, alcohol use, chronic somatic disease at age 14 |
| Herva et al 2006 | Finland 1980 | 3988 | Depression symptoms rating scale (HSCL) | 11.5 (18/157) | 1.97 (1.16 to 3.26) | 0.67 (0.33 to 1.34) | Father's social class, family type, smoking, alcohol use, chronic somatic disease at age 14 |
| **Boys and girls** | | | | | | | |
| Clark et al 2007 | England 2006 | 1513 | Depression symptoms rating scale (SMFQ) | – | 0.92 (0.57 to 1.48) | 1.2 (0.91 to 1.57) | Age, gender, ethnicity, free school meals, general health, long-standing illness, smoking, alcohol use, drug use |
| Marmorstein et al 2014 | USA 1988 | 308 | Structured psychiatric interview (DISC) | – | 0.70 (0.33 to 1.48) | – | Undiag |
| Roberts and Duong 2013 | USA 2000 | 3134 | Structured psychiatric interview (DISC) | – | 1.90 (0.85 to 4.25) | 0.93 (0.31 to 2.80) | Age, gender, family income, diet, physical activity |
| Sanderson et al 2011 | Australia 1985 | 2242 | Depression symptoms rating scale (HSCL) | – | 15.4 (6/219) | 0.91 (0.30 to 2.74) | Age, sex |
| Sveding et al 2005 | Scotland | 2146 | Structured psychiatric interview (DISC) | 1.8 (42/19) | 0.91 (0.30 to 2.74) | – | Undiag |
| **Cross-sectional studies:** | | | | | | | |
| Assor and Goldfeld 2015 | USA | 563 (black) | Structured psychiatric interview (CIDI) | – | 0.67 (0.54 to 2.68) | – | Age, family income |
| Flores et al 2011 | Norway 100 | 925 | Depression symptoms rating scale (HSCL) | 30 (6/08) | 0.8 (0.4 to 1.3)‡† | – | Age, school bullying, pubertal development, physical activity |
| Haare et al 2014 | Australia 2012 | 360 | Depression symptoms rating scale (SMFQ) | – | 1.83 (0.67 to 4.95)‡† | – | Age, school, parental level of education |
| Jari et al 2014 | Iran 2009 | 2715 | Single-item response in non-depression-specific questionnaire (GSRS) | 63.7 (170/263) | 0.99 (0.91 to 1.1)†† | 1.0 (0.76 to 1.32)†† | Unadjusted |
Table 1 Continued

| Study | Country of study/ year of study/ follow-up (years) | Study population | Method of diagnosis depression used (and name of tool) | Prevalence of depression in obese % (n/N) | OR (95%CI) obese vs normal weight | OR (95%CI) overweight vs normal weight | Variables used in adjustment |
|-------|---------------------------------------------------|------------------|-----------------------------------------------------|-----------------------------------------|----------------------------------|--------------------------------------|-------------------------------|
| Sutaria et al 2012 | USA 2003 | 67 | 50.7 | 11.9 | Depression symptoms rating scale (CES-D) | 22.6 (21/93) | 1.68 (0.93 to 3.02†) | 2.23 (1.3 to 3.82)† | Age, gender, parental education |
| Schiefelbein et al 2012 | USA 2003 | 3189 | 16.5 | 100 | 41§ | Single-item response in non-depression-specific questionnaire | 1.45 (0.88 to 2.38) | – | – | Age, race/ethnicity, urbanisation, border, SES, weight-loss attempts, physical activity, TV usage |
| Zakeri et al 2012 | Iran 2006 | 4524 | 13.8 | 100 | 7.5 | Single-item response in non-depression-specific questionnaire (GSHS) | 30.9 (166/538) | 1.00 (0.78 to 1.29) | 0.89 (0.71 to 1.2) | School grade |
| Assari and Caldwell 2015 | USA 2003 | 605 | 15 | 0 | 24.08 | Structured psychiatric interview (CIDI) | – | 0.85 (0.34 to 3.14) | – | Age, family income |
| Hoare et al 2014 | Australia 2012 | 440 | 13.1 | 0 | 26.3 | Depression symptoms rating scale (SMFQ) | – | 0.99 (0.64 to 1.52) | – | Age, school bullying, pubertal development, physical activity |
| Jari et al 2014 | Iran 2009 | 2691 | 14.7 | 0 | 7.5 | Single-item response in non-depression-specific questionnaire | 63.7 (128/201) | 1.12 (0.83 to 1.55) | 1.06 (0.77 to 1.48) | Unadjusted |
| Schiefelbein et al 2012 | USA 2003 | 473 | 13.5 | 0 | 38.4§ | Single-item response in non-depression-specific questionnaire | – | 1.70 (1.07 to 2.69) | – | Age, race/ethnicity, urbanisation, border, SES, weight-loss attempts, physical activity, TV usage |
| Seyedamini 2012 | Iran 2008 | 200 | 9.0 | 0 | – | Depression symptoms rating scale (CBCL) | – | 1.12 (0.94 to 1.31) | – | Israel, gender, age, country of origin |
| BeLue et al 2009 | USA 2003 | 35 18 | 12–17 | 50 | 13.2 | Reported health professional diagnosis | 11.1 (486/4379) | 1.6 (1.2 to 2.0)** | – | Gender, age, poverty level, family educational level, family composition |
| Halfan et al 2013 | USA 2007 | 43 21 | 13.8 | 52.2 | 16 | Reported health professional diagnosis | 4 (27/614) | 1.41 (1.04 to 1.93) | 1.33 (0.98 to 1.82) | Age, gender, race/ethnicity, parental education, household income, family structure |
| Jansen et al 2008 | Netherlands 2000 | 1900 | 9.5 | 51 | 7 | Depression symptoms rating scale (CDI) | 26.6 (381/14) | 0.96 (0.64 to 1.44) | 0.86 (0.66 to 1.11) | Gender and country of origin |
| Ting et al 2012 | Taiwan 2010 | 859 | 15.7§§ | 53.7 | 11.9 | Depression symptoms rating Scale (CES-D) | 22.6 (21/93) | 1.68 (0.93 to 3.02) | 2.23 (1.3 to 3.82) | Age, gender, parental education |
| Ting et al 2012 | Taiwan 2010 | 859 | 15.7§§ | 53.7 | 11.9 | Depression symptoms rating Scale (CES-D) | 22.6 (21/93) | 1.68 (0.93 to 3.02) | 2.23 (1.3 to 3.82) | Age, gender, parental education |

BMI, body mass index; CBCL, Child Behaviour Checklist; CES-D, Centre for Epidemiological Studies Depression Scale; CDI, Composite International Diagnostic Interview; DRS, Diagnostic Interview Schedule for Children; DSRS, Diagnostic Self-Rating Scale; GSHS, Global School-based Health Survey; HSL, Hopkins Symptom Check List; I-ADS, Schedule for Affective Disorders and Schizophrenia for School-age Children; SB, Short Depression Inventory for Children; SDI, self-efficacy status; SMFQ, Short Moods and Feeling Questionnaire; TV video usage.
Table 2 Quality assessment of 22 included studies

| Study (cohort studies) | Selection (maximum three stars) | Comparability (maximum two stars) | Outcome (maximum two stars) | Total/maximum |
|------------------------|-------------------------------|----------------------------------|----------------------------|---------------|
| Anderson et al49 2007  | ★                             | 2★                               | 1★                         | 5/7           |
| Anderson et al39 2011  | ★                             | 2★                               | 1★                         | 6/7           |
| Boutilier et al45 2010 | 3★                            | 2★                               | 1★                         | 6/7           |
| Clark et al39 2007     | 3★                            | 2★                               | 1★                         | 6/7           |
| Frisco et al49 2013    | 3★                            | 2★                               | 1★                         | 6/7           |
| Herva et al13 2006     | 1★                            | 2★                               | 1★                         | 4/7           |
| Marmostein et al12 2014| 3★                             | 0★                               | 2★                         | 5/7           |
| Roberts and Duong15 2013| 2★                             | 2★                               | 1★                         | 5/7           |
| Sanderson et al18 2011 | 2★                             | 1★                               | 1★                         | 4/7           |
| Sweeting et al9 2005   | 2★                             | 0★                               | 2★                         | 4/7           |

Study (cross-sectional studies)

| Assari and Caldwell16 2015 | 0★                             | 2★                               | 1★                         | 3/5           |
| BeLue et al9 2009          | 1★                             | 2★                               | 1★                         | 4/5           |
| Flottes et al12 2011       | 2★                             | 2★                               | 1★                         | 5/5           |
| Halton 2013                | 1★                             | 2★                               | 0★                         | 3/5           |
| Hoare et al9 2014          | 2★                             | 2★                               | 1★                         | 5/5           |
| Jansen et al9 2008         | 2★                             | 1★                               | 1★                         | 4/5           |
| Jain et al9 2014           | 2★                             | 0★                               | 1★                         | 3/5           |
| Schiefeleben et al15 2012  | 2★                             | 2★                               | 0★                         | 4/5           |
| Seyyedamini 2012           | 2★                             | 1★                               | 1★                         | 4/5           |
| Sjoberg et al6 2005        | 1★                             | 0★                               | 1★                         | 2/5           |
| Ting et al12 2012          | 1★                             | 2★                               | 1★                         | 4/5           |
| Zakeni et al5 2012         | 2★                             | 0★                               | 0★                         | 2/5           |

A maximum of seven stars for cohort studies and five for cross-sectional studies could be obtained.

We included any study where depression had been measured either by standardised psychiatric interview, physician-reported diagnosis, single-item or multiple-item questions in questionnaire or by use of rating scales based on the presence of depressive symptoms above a threshold value determined by the study. We excluded studies that reported depression scores only due to lack of patient-level data to allow calculation of depression prevalence.

We also examined subgroups and odds of depression, including boys and girls and odds of concurrent and future risk of depression separately.

Search method for identification of studies

We searched the following databases: EMBASE, MEDLINE via PubMed and PsychINFO. We combined search terms relating to children under 18 years and obesity with those for depression and related MeSH headings, truncated with wildcard characters if necessary (online supplementary appendix 2). Results were limited to human subjects. Search terms not covered under the MeSH tree were searched as keywords. Finally, we hand-searched reference lists of the identified articles for further studies and authoritative reviews. To obtain estimates relevant for current practice, searches were limited to being published from 2000 (online supplementary appendix 2). Prior to publication, SS updated searches to identify any new studies.

Using Endnote (V.7), duplicates were removed, SS reviewed titles for eligibility and studies that clearly did not meet the inclusion criteria were excluded. Two reviewers (SS and SY) independently reviewed the abstracts of the remaining studies and removed any that did not meet the inclusion criteria. Potentially eligible or unclear abstracts were obtained as full articles. SS and DD screened all full articles for inclusion; two reviewers (SS and DD) read the full texts of the papers and extracted the data from the studies that met the inclusion criteria (figure 1). This process was then repeated with the same reviewers to update searches. We resolved any disagreements regarding the inclusion or exclusion of papers through discussion with a third reviewer (SSax).

Data collection and analysis

We analysed data from included studies descriptively and combined by meta-analysis. A data extraction form was prepared a priori to extract information on study design, year of study publication, year participants were enrolled, follow-up duration and country of study. We extracted information on the study population including number of participants in analysis, average age, sex and the numbers of obese, overweight and normal-weight individuals. For outcomes, we extracted the number of individuals reported as depressed per weight category, adjusted and unadjusted odds of depression, and variables used in adjustment.

Quality assessment

We assessed study quality by modifying the Newcastle-Ottawa Scale for assessing the quality of non-randomised studies in meta-analysis examining three potential areas of bias in participant selection, comparability and ascertainment of exposure and outcome (online supplementary appendix 3). A priori, we considered studies to be high quality if they scored greater than four stars in cohort studies or greater than three stars in cross-sectional studies.

Statistical analysis

For meta-analysis, we used extracted ORs and calculated SEs from CIs reported. Where relative risks or HRs were reported, OR and 95% CIs were calculated from absolute numbers of depressed children in different weight categories. Where multiple odds or risk ratios were reported, we selected the most highly adjusted odds or risk ratio. When in the same study or using the same study population, we selected prospective data with the longest follow-up period. SE was calculated from reported CIs or p value if CIs were not reported using previously described methods.

Where sufficient data were reported, meta-analysis was performed using a random-effects model. Heterogeneity was examined using the I² statistic, with an I² of over 75% indicating considerable heterogeneity. Small study effect was assessed visually using funnel plots (figure 2) and statistically by performing Egger’s test. We conducted subgroup analysis by sex, weight status and study type (cross-sectional and longitudinal) enabling us to report the sex-specific and comorbid and prospective odds of depression.

Sensitivity analysis

Through the review process, we identified several factors that may have influenced our results. To examine the robustness of our findings, we performed sensitivity analyses to examine the impact of excluding studies that use child-reported or parent-reported weight, studies that include underweight children in their normal-weight comparator group, low-quality studies, studies where participants had their weight status measured before 2000 and studies that diagnosed depression based on standardised psychiatric interview.
Figure 3  Meta-analysis (22 unique studies) odds of current or future depression in obese children versus normal-weight children*. *Multiple ORs for same studies reflect ORs for different subgroups (eg, male, female, ethnic group).

All analysis was performed using Stata (V14).

We reported our findings following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement for reporting systematic reviews and meta-analysis (online supplementary appendix 1).26

RESULTS

Twenty-two studies, including 143,603 children, met our inclusion criteria (figure 1). One study met our inclusion criteria but was excluded after review due to the age of the study.27 Among included studies, average age was 14.2 years, 48% were male children and overall prevalence of obesity was 15.5%. Overall, prevalence of depression among obese children was 10.4%.

Study characteristics

Of the 22 studies included, 10 were prospective cohorts and 12 were cross-sectional. The length of follow-up ranged from 1 to 20 years in the cohort studies, with half of studies having a follow-up period of 2 years or fewer. The number of participants in studies ranged from 200 to 43,211. Ten studies were from populations based in the USA. Twelve studies reported gender-specific OR and two studies reported gender-specific and ethnicity-specific OR (table 1).

Quality assessment

Studies varied in quality with no study obtaining maximum star rating across the three domains of participant selection, comparability of groups and outcome (table 2).

The majority of studies (20/22) selected participants from a community setting, representative of the wider population, and two studies purposely selected a high proportion of ethnic minorities.28 29 Over half of studies (14/22) calculated BMI using independently measured height and weight, and the remaining eight studies used self-reported (parent or child) measures of weight and/or height to determine weight status. Some measure of socioeconomic status was adjusted for in 14/22 studies.

A variety of methods were used to identify depression. The most frequent method was the use of depression symptom rating scales (10/22) of which the most frequently used (three studies) was the Centre for Epidemiological Studies Depression Scale. Other methods included structured psychiatric interview (7/22) and previous reported health professional diagnosis (2/22). The remaining three studies inferred a diagnosis of depression based on single item answer in non-depression-specific questionnaires.

META-ANALYSIS

Meta-analysis of 22 studies, comparing odds of depression in obese children versus normal-weight children, yielded an OR of 1.32 (95% CI 1.17 to 1.50). There was substantial statistical
Table 1: Meta-analysis of odds of depression in overweight and normal-weight children

| Study ID | Odds ratio (95% CI) | Weight |
|----------|---------------------|---------|
| ANDERSON (2007) | 1.06 (0.40, 2.82) | 0.85 |
| FLOTNES (2011) | 0.93 (0.44, 1.97) | 1.44 |
| HERVA (2008) | 1.18 (0.78, 1.78) | 4.43 |
| JARI (2014) | 1.00 (0.76, 1.32) | 8.87 |
| TING (2012) | 2.55 (1.28, 5.08) | 1.69 |
| ZAKERI (2012) | 0.89 (0.71, 1.12) | 11.96 |
| Subtotal (I-squared = 42.7%, p = 0.121) | 1.08 (0.85, 1.37) | 29.25 |

Figure 4: Meta-analysis (13 unique studies) odds of depression in overweight children versus normal-weight children*. *Multiple ORs for same studies reflect ORs for different subgroups (eg, male, female, ethnic group).

Table 2: Meta-analysis of odds of developing depression in obese and normal-weight children

| Study ID | Odds ratio (95% CI) | Weight |
|----------|---------------------|---------|
| ANDERSON (2007) | 0.95 (0.46, 1.98) | 1.49 |
| BOUTELLE (2010) | 0.61 (0.24, 1.56) | 0.93 |
| FLOTNES (2011) | 1.41 (0.93, 2.15) | 4.27 |
| FRISCO (2013) | 0.97 (0.54, 1.74) | 2.31 |
| HERVA (2006) | 0.67 (0.33, 1.35) | 1.64 |
| JARI (2014) | 1.08 (0.77, 1.49) | 6.94 |
| TING (2012) | 0.80 (0.28, 2.28) | 0.75 |
| ZAKERI (2012) | 1.11 (0.90, 1.37) | 13.15 |
| Subtotal (I-squared = 0.0%, p = 0.616) | 1.07 (0.92, 1.24) | 31.47 |

Figure 5: Meta-analysis of 10 longitudinal studies examining odds of developing depression in obese children versus normal-weight children, by gender*. *Multiple ORs for same studies reflect ORs for different subgroups (eg, male, female, ethnic group).

NOTE: Weights are from random effects analysis

Overall (I-squared = 11.7%, p = 0.312) 1.04 (0.95, 1.14) 100.00
heterogeneity ($\chi^2$ p<0.001), with an $I^2$ of 72.1% (figure 3). Subgroup analysis by gender yielded an OR of 1.44 (95% CI 1.20 to 1.72) of depression in obese female children versus normal-weight female children. In male children, the OR was 1.14 (95% CI 0.93 to 1.41) (figure 3). Both female ($I^2=50.2\%$) and male ($I^2=49\%$) children subgroups showed lower moderate heterogeneity.

Meta-analysis of 13 studies comparing odds of depression in overweight children versus normal-weight children yielded an OR of 1.04 (95 CI 0.95 to 1.14) with an $I^2$ of 34.2% (figure 4). Further subgroup analysis by gender yielded an OR of 1.07 (95% CI 0.92 to 1.24) of depression in overweight female versus normal-weight female children. In male children, the OR was 1.08 (95% CI 0.85 to 1.37) (figure 4).

Subgroup meta-analysis of 10 longitudinal studies comparing odds of depression in obese children versus normal-weight children yielded an OR of 1.51 (95% CI 1.21 to 1.88; $I^2$ 30.6%) (figure 5). Subgroup meta-analysis of cross-sectional studies comparing odds of depression in obese children versus normal-weight children yielded an OR of 1.26 (95% CI 1.09 to 1.45; $I^2$=79.2%) (figure 6).

**SENSITIVITY ANALYSIS**

Multiple sensitivity analyses were performed (table 3). All except one demonstrated a similar trend of results to the main analysis. Meta-analysis of studies restricted to those studies that diagnose depression using a standardised psychiatric interview yielded an OR of 1.27 (95% CI 1.01 to 1.50) increased odds of current or future depression, with greatest odds among obese female children (OR 1.44 95%CI 1.20 to 1.72). We found clear evidence that this risk persists over time, whereby in a subgroup meta-analysis of longitudinal studies, obese children had a 51% (95% CI 1.21 to 1.88) increased odds of developing depression in the future compared with normal-weight children.

No association was found between being overweight and depressed in male or female children.

The size of the study and wide inclusion criteria of all international literature make it unlikely that the effect sizes arose by chance.

**Findings in relation to previous studies**

Our findings are consistent with the association between obesity and depression reported in adults (OR 1.18 95%CI 1.01 to 0.98 (95% CI 0.42 to 2.33)) or female (OR 1.53 (95% CI 0.88 to 2.65)) children.

**DISCUSSION**

To date, this is the largest study examining weight status and depression in childhood with over 140 000 children drawn from the community and the first to include both concurrent and prospective odds of depression. We found, compared with normal-weight children, obese children have a 32% (95% CI 1.17 to 1.50) increased odds of current or future depression, with greatest odds among obese female children (OR 1.44 95%CI 1.20 to 1.72).
1.57), with a greater effect seen in adult women; however, the magnitude of the association appears stronger in children than adults.

Interestingly, in subgroup analysis, we only found a significant association with depression among obese female children. We found no such association exists among obese male or among overweight male or female children. Plausibly, psychosocial factors such as weight perception and body dissatisfaction that mediate between weight and depression do not correlate well with BMI.

Only those children who recognise themselves as being overweight, which tends to be those with the highest BMI, may then develop the negative body image leading to depression. Among male children, the relationship is more complicated, as there is no linear relationship between body dissatisfaction and increasing BMI, unlike in female children. Higher BMI in male children may be associated with strength and athleticism, and male children are more likely to underestimate their weight compared with female children, hence many overweight male children may not perceive their weight negatively.

### Policy implications and future research

We found overall prevalence of depression among obese children at 10%. This is of concern as the UK National Child Measurement Programme estimates for obesity prevalence in year 6 (aged 10/11 years) is 20%; hence, of the estimated 6.5 million children aged 10–18 years in the UK, as many as 1.3 million are obese. Our findings suggest 130,000 of these obese children may be living with depression in the UK. Depression in childhood has serious consequences; it is a major risk factor for suicide, which is one of the leading causes of death in this age group as well as having an impact on educational and social attainment.

It is therefore important to recognise and treat depression in children. Yet, current clinical guidelines on the management of obesity on depression. It is also plausible that those children identified with higher weights continue to gain weight over their lives, and hence the psychological and social impact of the excess weight continues to increase. However, studies varied in their inclusion and measurement of known confounders, hence further research is needed to know to what degree obesity is an independent risk factor for depression.

### Limitations of study

We acknowledge several important limitations to our study. First, in common with all systematic reviews, potentially eligible studies where BMI has been independently measured. Only studies with >3 stars in cross-sectional studies or >3 stars in cohort/case-control studies included in this meta-analysis. The longitudinal relationship between obesity and depression adds evidence to the potential causal effect of obesity on depression. It is plausible that those children identified with higher weights continue to gain weight over their lives, and hence the psychological and social impact of the excess weight continues to increase. However, studies varied in their inclusion and measurement of known confounders, hence further research is needed to know to what degree obesity is an independent risk factor for depression.

### Table 3 Sensitivity analysis

| Study types included in meta-analysis | Number of included studies (n/N) | Meta-analysis (odds of depression in obese children vs normal-weight children) | Overall | Boys | Girls | Studies included |
|-------------------------------------|---------------------------------|-----------------------------------------------------------------|---------|------|-------|-----------------|
|                                      |                                 | OR | 95% CI | I²  | OR | 95% CI | I²  | OR | 95% CI | I²  | All studies |
| All studies—odds of depression if obese vs normal weight | 22/22                           | 1.32 | 1.17 to 1.50 | 72.1% | 1.14 | 0.93 to 1.41 | 49.0% | 1.44 | 1.20 to 1.72 | 50.2% | Anderson et al 2011, Boutelle et al 2009, Clark et al 2007, Flotnes et al 2011, frisco et al 2013, Hoare et al 2014, Jansen et al 2008, Marmorstein et al 2014, Roberts and Duong 2013, Sjoberg et al 2012, Sweeting et al 2005, Zakeri et al 2012 |
| Studies where BMI has been independently measured | 14/22                           | 1.25 | 1.09 to 1.44 | 44.5% | 1.12 | 0.77 to 1.63 | 54.5% | 1.42 | 1.15 to 1.75 | 52.7% | Anderson et al 2011, Boutelle et al 2009, Clark et al 2007, frisco et al 2013, Hoare et al 2014, Jansen et al 2008, Marmorstein et al 2014, Roberts and Duong 2013, Sjoberg et al 2012, Sweeting et al 2005, Zakeri et al 2012 |
| Studies where comparator group does not include underweight or overweight individuals | 7/22                            | 1.22 | 1.03 to 1.45 | 84.3% | 1.05 | 0.85 to 1.30 | 45.5% | 1.14 | 1.06 to 1.22 | 0.0 | BeLue et al 2009, Flotnes et al 2011, Hoare et al 2014, Jari et al 2014, Sjoberg et al 2012, Seydamini et al 2012, Sweeting et al 2005, Zakeri et al 2012 |
| Studies where effect estimate was adjusted by some measure of socioeconomic deprivation | 11/22                           | 1.44 | 1.20 to 1.72 | 75.7% | 1.33 | 0.88 to 2.02 | 58.1% | 1.51 | 1.15 to 1.98 | 56.2% | Anderson et al 2007, BeLue et al 2009, frisco et al 2009, Clark et al 2007, Flotnes et al 2011, frisco et al 2013, Hoare et al 2014, Jansen et al 2008, Marmorstein et al 2014, Roberts and Duong 2013, Sjoberg et al 2012, Seydamini et al 2012, Zakeri et al 2012 |
| High-quality studies (>3 stars in cohort/case-control studies or >3 stars in cross-section studies) | 13/22                           | 1.39 | 1.14 to 1.69 | 77.9% | 1.33 | 0.80 to 2.20 | 60.5% | 1.51 | 1.16 to 1.95 | 50.7% | Anderson et al 2007, BeLue et al 2009, frisco et al 2009, Clark et al 2007, Flotnes et al 2011, frisco et al 2013, Hoare et al 2014, Jansen et al 2008, Marmorstein et al 2014, Roberts and Duong 2013, Sjoberg et al 2012, Seydamini et al 2012, Zakeri et al 2012 |
| Studies including populations where weight has been measured after the year 2000 onwards | 17/22                           | 1.28 | 1.12 to 1.46 | 75.4% | 1.08 | 0.87 to 1.35 | 50.7% | 1.34 | 1.12 to 1.60 | 44.7% | Anderson et al 2011, Assari and Caldwell 2015, BeLue et al 2009, Boutelle et al 2009, friso et al 2013, Flotnes et al 2011, Hoare et al 2014, Jansen et al 2008, Marmorstein et al 2014, Roberts and Duong 2013, Schiefelbein et al 2012, Seydamini et al 2012, Zakeri et al 2012 |
| Studies where depression is diagnosed using structured psychiatric interview | 7/22                            | 1.27 | 0.94 to 1.70 | 18.1% | 0.98 | 0.42 to 2.33 | 45.5% | 1.53 | 0.88 to 2.65 | 0.0 | Anderson et al 2007, Assari and Caldwell 2015, BeLue et al 2009, Boutelle et al 2009, friso et al 2013, Flotnes 2011, Hoare et al 2014, Jansen et al 2008, Marmorstein et al 2014, Roberts and Duong 2013, Sjoberg et al 2005 |
| Only studies with population drawn from USA | 10/22                           | 1.47 | 1.23 to 1.77 | 46.3% | 1.11 | 0.61 to 2.04 | 66.2% | 1.72 | 1.37 to 2.15 | 6.1% | Anderson et al 2007, Anderson et al 2011, Assari and Caldwell 2015, BeLue et al 2009, Boutelle et al 2009, friso et al 2013, Flotnes et al 2011, Hoare et al 2014, Marmorstein et al 2014, Roberts and Duong 2013, Schiefelbein et al 2012 |

BMI, body mass index.
studies may have been missed. However, searches of citations in included studies and reviews made it unlikely that larger studies were missed.

Second, we found considerable heterogeneity between studies despite our defined inclusion criteria. Heterogeneity may have occurred due to differences in study designs or as a result of genuine differences in the odds of depression in obese children across different populations.

Third, most of our studies were from high-income countries, of which nearly half (10/22) were from the USA. Hence, our findings may not be generalisable to low-income and middle-income countries, where the perception of obesity may be different.

We considered whether other factors might have affected our results and performed multiple sensitivity analysis to examine the robustness of our findings. We considered whether misclassification of underweight individuals into normal weight categories as comparator group, and underestimating of weight due to the use of self-reported weight might have reduced the effect size seen. Meta-analysis of seven studies where the comparison group did not include underweight children (OR 1.22, 95% CI 1.03 to 1.45) and meta-analysis of 14 studies where BMI was objectively measured (OR 1.25, 95% CI 1.09 to 1.44) did not substantially alter the results.

Of the sensitivity analysis performed (table 3), only one would have substantially altered our findings. We found restricting meta-analysis to only those 7/22 studies that diagnosed depression using structured psychiatric interviews revealed no association between obesity and depression (OR 1.27, 95% CI 0.94 to 1.70). It is plausible that obese children exhibit symptoms of depression detected on depression rating scales; however, they do not cause significant functional impairment to meet stricter diagnostic criteria of major depression. The lack of functional impairment does not mean that obese children with significant depressed symptoms should be ignored, as children with depressive symptoms have elevated risk of later depression and suicidal behaviour and share similar future mental health risk as those experienced by children with a diagnosis of depression.

CONCLUSIONS

Compared with normal-weight female children, we found obese female children have a 44% (95% CI 1.20 to 1.72) increase odds of depression. Further research is needed to understand why they are vulnerable to the negative mental health effects of obesity, and clinicians should consider screening obese female children for symptoms of depression.

Correction notice This paper has been corrected since it was published Online First. In the last line of the conclusion of the abstract, there was some text missing and this has now been reinstated.

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