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

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Contributions

SS and SSax designed the study. SS conducted the searches and data extraction with help from DD and SSY. SS and SD conducted statistical analysis and all authors contributed to, data interpretation revising drafts produced by SS. All authors had full access to all the data collected in this systematic review, have checked for accuracy and have approved the final version of this manuscript.

What is already known about this topic?

Childhood obesity is strongly associated with adverse physical health outcomes, 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 females have a significantly increased odds of concurrent and future depression compared with non-obese females.

Clinicians should consider screening obese females for signs and symptoms of depression.

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 to 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

(BMI), using age and sex adjusted reference charts or the International Obesity Task Force (IOTF) age-sex specific cut offs and concurrent or prospective odds of depression was 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 1.17-1.50) in obese children. Among obese females, odds of depression were 1.44 (95% CI 1.20-1.72) higher compared to that of normal weight females. No association was found between overweight children and depression (OR 1.04 95% CI 0.95-1.14) or among obese or overweight male subgroups and depression (OR 1.14 95% CI 0.93-1.41 and 1.08 95% CI 0.85-1.37 respectively). Subgroup analysis of cross-sectional and longitudinal studies separately revealed childhood obesity was associated with both concurrent (OR 1.26 95% CI 1.09-1.45) and prospective odds (OR 1.51 95% CI 1.21-1.88) of depression.

Conclusion

We found strong evidence that obese female children have a significantly higher odds of depression compared to normal weight female children and this risk persists into adulthood. Clinicians should consider screening obese female children for symptoms of depression.

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 NHS of treating depression is estimated at over £2 billion and the wider social and economic impact of depression is likely to be considerable.(7)

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, 9)(10) Cognitive and social factors are likely to be important mechanisms. (11)(12, 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 an already rising 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%,(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 over estimate 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 identifying cross-sectional and

prospective studies reporting concurrent or future risk of depression and performing 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 and sex adjusted reference charts. Obesity was defined as ≥95th centile and overweight ≥ 85th centile; or using the International Obesity Task Force (IOTF) age-sex specific centiles curves correlating to 25 and 30 kg/m^2 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 to normal weight children.

We included any study where depression had been measured either by standardised psychiatric interview, physician reported diagnosis, single or multiple item questions in questionnaire or by use of rating scales based on the presence of depressive symptoms above a threshold value determine 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 (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 (Appendix 2). Prior to publication SS updated searches to identify any new studies.

Using Endnote (version 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 SSY) 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 number of individuals reported as depressed per weight category, adjusted and unadjusted odds of depression, 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 (appendix 3).(24) *A priori* we considered studies to be high quality if they scored greater than 4 stars in cohort studies or greater than 3 stars in cross-section studies.

Statistical analysis

For meta-analysis we used extracted odds ratios and calculated standard errors from confidence intervals reported. Where relative risks or hazard ratios were reported, odds ratio and 95% confidence intervals (CI) 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. Standard error was calculated from reported confidence intervals or *p*-value if confidence intervals were not reported using previously described methods.(25)

Where sufficient data were reported, meta-analysis was performed using a random effects model. Heterogeneity was examined using the I^2 statistic, with an I^2 of over 75% indicating considerable heterogeneity.(7) Small study effect was assessed visually using funnel plots (figure 6) 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 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.

All analysis was performed using Stata (version 14).

We reported our findings following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement for reporting systematic reviews and meta-analysis. (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 and not included.(27) Among included studies, average age was 14.2 years, 48% were male and overall prevalence of obesity was 15.5%. Overall, prevalence of depression among obese children was 10.4%.

Study characteristics (table 1)

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 United States. Twelve studies reported gender specific odds ratio and two studies reported gender and ethnicity specific odds ratio.

Quality assessment (table 2)

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

The majority of studies (20/22) selected participants from a community setting, representative of the wider population, two studies purposely selected a high proportion of ethnic minorities.(28, 29) Over half of studies (14/22) calculated body mass index using independently measured height and weight, 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 (3

studies) was the Centre for Epidemiological Studies Depression Scale (CESD). Other methods included structured psychiatric interview (7/22) and previous reported health professional diagnosis (2/22). The remaining 3 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 odds ratio of 1.32 (95% CI 1.17-1.50). There was substantial statistical heterogeneity (chi squared $p<0.001$), with an I^2 of 72.1% (Figure 2). Subgroup analysis by gender yielded an odds ratio of 1.44 (95% CI 1.20-1.72) of depression in obese females versus normal weight females. In males, the odds ratio was 1.14 (95% CI 0.93-1.41) (Figure 2). Both females (I^2=50.2%) and males (I^2=49%) sub-groups showed lower moderate heterogeneity.

Meta-analysis of 13 studies, comparing odds of depression in overweight children versus normal weight children yielded an odds ratio of 1.04 (95 CI 0.95-1.14) with an I^2 of 34.2% (Figure 3). Further subgroup analysis by gender yielded an odds ratio of 1.07 (95% CI 0.92 - 1.24) of depression in overweight females versus normal weight females. In males, the odds ratio was 1.08 (95% CI 0.85-1.37) (Figure 3).

Subgroup meta-analysis of 10 longitudinal studies comparing odds of depression in obese children versus normal weight children yielded an odds ratio of 1.51 (95% CI 1.21-1.88; I^2 30.6%) (Figure 4). Subgroup meta-analysis of cross-sectional studies comparing odds of depression in obese children versus normal weight children yielded an odds ratio 1.26 (95% CI 1.09-1.45; I^2 79.2%) (figure 5).

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 odds ratio of 1.27 (95% CI 0.94-1.70; I^2 =18.1%) of depression in obese children versus non-obese children. Further analysis by gender revealed no significant association between obesity and psychiatric interviewed diagnosed depression among males (OR 0.98 (95% CI 0.42-2.33)) or females (OR 1.53 (95% CI 0.88-2.65)).

Small study effects

Visual assessment of funnel plot (figure 6) suggested no evidence of small study effects. Eggers test for asymmetry p=0.286, suggesting no statistical evidence of asymmetry.

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 to normal weight children, obese children have a 32% (95% CI 1.17-1.50) increased odds of current or future depression, with greatest odds among obese females (OR 1.44 95% CI 1.20-1.72). 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 1.21-1.88) increased odds of developing depression in the future compared to normal weight children.

No association was found between being overweight and depressed in males or females. 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 1.01-1.57),(30) with a greater effect seen in adult females; however the magnitude of the association appears stronger in children than adults.

Interestingly, in sub group analysis we only found a significant association with depression among obese females. We found no such association exists among obese males or among overweight males or females. Plausibly, psychosocial factors such as weight perception and body dissatisfaction that mediate between weight and depression do not correlate well with BMI.(12, 31) 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 males, the relationship is more complicated, as there is no linear relationship between body dissatisfaction and increasing BMI, unlike in females.(32) Higher BMI in males may be associated with strength and athleticism, and males are more likely to underestimate their weight compared to females,(33) hence many overweight males 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 (NCMP) 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.(34) It is therefore important to recognise and treat depression in children. Yet current clinical guidelines on the management of childhood obesity focus entirely on screening and preventing the physical harms associated with obesity (35-38). This lack of attention to mental health and depression is concerning given our findings. Clinicians should consider screening for symptoms of depression in obese children as part of a more holistic approach in the management of obese children.

Sub group analysis of longitudinal studies found a stronger association of obesity and depression than among cross sectional studies. The longitudinal relationship between obesity and depression adds evidence to the potential causal effect of obesity on depression.(8-10) 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. Firstly, in common with all systematic reviews, potentially eligible studies may have been missed. However, searches of citations in included studies and reviews made it unlikely that larger studies were missed.

Secondly, 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.

Thirdly, 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 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,(39) and underestimating of weight due to the use of self reported weight might have reduced the effect size seen.(40) Meta-analysis of 7 studies where the comparison group did not include underweight children (OR 1.22 95%CI 1.03-1.45) and meta-analysis of 14 studies were BMI was objectively measured (OR 1.25 95%CI 1.09-1.44) 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 0.94-1.70). It is plausible that obese children exhibit symptoms of depressions 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.(41)

Conclusions

Compared to normal weight female children, we found obese female children have a 44% (95% CI 1.20-1.72) 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.

References:

1. Kessler RC, Amminger GP, Aguilar-Gaxiola S, Alonso J, Lee S, Ustun TB. Age of onset of mental disorders: A review of recent literature. Current opinion in psychiatry. 2007;20(4):359-64.
2. Gore FM, Bloem PJN, Patton GC, Ferguson J, Joseph V, Coffey C, et al. Global burden of disease in young people aged 10–24 years: a systematic analysis. The Lancet.377(9783):2093-102.
3. Cook MN, Peterson J, Sheldon C. Adolescent Depression: An Update and Guide to Clinical Decision Making. Psychiatry (Edgmont). 2009;6(9):17-31.
4. Merry SN, McDowell H, Hetrick S, Bir J, Muller N. Psychological and educational interventions for preventing depression in children and adolescents. Cochrane Database Syst, Rev. (1469-493X (Electronic)).
5. Preventing suicide: a global imperative. Geneva: World Health Organisation; 2014.
6. Global Accelerated Action for the Health of Adolescents (AA-HA!): guidance to support country implementation. Geneva: World Health Organization; 2017. Contract No.: Licence: CC BY-NC-SA 3.0 IGO.
7. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. The Lancet.387(10026):1377-96.
8. Mühlig Y, Antel J, Föcker M, Hebebrand J. Are bidirectional associations of obesity and depression already apparent in childhood and adolescence as based on high-quality studies? A systematic review. Obesity Reviews. 2016;17(3):235-49.
9. Reeves GM, Postolache TT, Snitker S. Childhood Obesity and Depression: Connection between these Growing Problems in Growing Children. International journal of child health and human development : IJCHD. 2008;1(2):103-14.
10. Preiss K, Brennan L, Clarke D. A systematic review of variables associated with the relationship between obesity and depression. Obesity Reviews. 2013;14(11):906-18.
11. Atlantis E, Ball K. Association between weight perception and psychological distress. International journal of obesity (2005). 2008;32(4):715-21.
12. Roberts RE, Duong HT. Perceived weight, not obesity, increases risk for major depression among adolescents. Journal of psychiatric research. 2013;47(8):1110-7.
13. Frisco ML, Houle JN, Martin MA. The image in the mirror and the number on the scale: Weight, weight perceptions, and adolescent depressive symptoms. Journal of Health and Social Behavior. 2010;51(2):215-28.
14. Musher-Eizenman DR, Holub SC, Miller AB, Goldstein SE, Edwards-Leeper L.
15. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. International journal of obesity (2005). 2011;35(7):891-8.
16. Park MH, Sovio U, Viner RM, Hardy RJ, Kinra S. Overweight in childhood, adolescence and adulthood and cardiovascular risk in later life: pooled analysis of three british birth cohorts. PloS one. 2013;8(7):e70684.
17. Friedemann C, Heneghan C, Mahtani K, Thompson M, Perera R, Ward AM. Cardiovascular disease risk in healthy children and its association with body mass index: systematic review and meta-analysis. BMJ (Clinical research ed). 2012;345:e4759.
18. WHO. Childhood overvweight and obesity: WHO; [Available from: http://www.who.int/dietphyiscalactivity/childhood/en.
19. Jari M, Qorbani M, Motlagh ME, Heshmat R, Ardalan G, Kelishadi R. Association of Overweight and Obesity with Mental Distress in Iranian Adolescents: The CASPIAN-III Study. Int J Prev Med. 2014;5(3):256-61.
20. Halfon N, Larson K, Slusser W. Associations between obesity and comorbid mental health, developmental, and physical health conditions in a nationally representative sample of US children aged 10 to 17. Academic pediatrics. 2013;13(1):6-13.

21. Britz B, Siegfried W, Ziegler A, Lamertz C, Herpertz-Dahlmann BM, Remschmidt H, et al. Rates of psychiatric disorders in a clinical study group of adolescents with extreme obesity and in obese adolescents ascertained via a population based study. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity. 2000;24(12):1707-14.
22. Fitzgibbon ML, Stolley MR, Kirschenbaum DS. Obese people who seek treatment have different characteristics than those who do not seek treatment. Health psychology : official journal of the Division of Health Psychology, American Psychological Association. 1993;12(5):342-5.
23. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ (Clinical research ed). 2000;320(7244):1240.
24. Wells G SB, O'Connell J, Robertson J, et al. . The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analysis. 2011. [Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
25. Higgins J GS. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from http://www.handbook.cochrane.org.
26. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine. 2009;151(4):264-9, w64.
27. Geoffroy MC, Li L, Power C. Depressive symptoms and body mass index: co-morbidity and direction of association in a British birth cohort followed over 50 years. Psychological medicine. 2014;44(12):2641-52.
28. Assari S, Caldwell CH. Gender and Ethnic Differences in the Association Between Obesity and Depression Among Black Adolescents. Journal of racial and ethnic health disparities. 2015;2(4):481-93.
29. Anderson SE, Murray DM, Johnson CC, Elder JP, Lytle LA, Jobe JB, et al. Obesity and depressed mood associations differ by race/ethnicity in adolescent girls. International Journal of Pediatric Obesity. 2011;6(1):69-78.
30. de Wit L, Luppino F, van Straten A, Penninx B, Zitman F, Cuijpers P. Depression and obesity: a meta-analysis of community-based studies. Psychiatry research. 2010;178(2):230-5.
31. Frisco ML, Houle JN, Martin MA. The Image in the Mirror and the Number on the Scale. Journal of Health and Social Behavior. 2010;51(2):215-28.
32. Austin SB, Haines J, Veugelers PJ. Body satisfaction and body weight: gender differences and sociodemographic determinants. BMC public health. 2009;9(1):313.
33. Martin MA, Frisco ML, May AL. Gender and Race/Ethnic Differences in Inaccurate Weight Perceptions Among U.S. Adolescents. Women's Health Issues. 2009;19(5):292-9.
34. Obesity and ethnicity 2011 [Available from: https://www.noo.org.uk/uploads/doc/vid_9444_Obesity_and_ethnicity_270111.pdf.
35. Recommendations for growth monitoring, and prevention and management of overweight and obesity in children and youth in primary care. Canadian Task Force on Preventive Health Care; 2015 20150408 DCOM- 20150611. Contract No.: 1488-2329 (Electronic).
36. Management of obesity: a national clinical guideline. Guidelines. Scottish Intercollegiate Guidelines Network (SIGN); 2010.
37. Kirby JB, Liang L, Chen Hj, Wang Y. Race, place, and obesity: the complex relationships among community racial/ethnic composition, individual race/ethnicity, and obesity in the United States. Am J Public Health. 2012;102(8)(1541-0048 (Electronic)).
38. Vine M, Hargreaves MB, Briefel RR, Orfield C. Expanding the role of primary care in the prevention and treatment of childhood obesity: a review of clinic- and community-based recommendations and interventions. Journal of obesity. 2013;2013:172035.
39. de Wit LM, van Straten A, van Herten M, Penninx BW, Cuijpers P. Depression and body mass index, a u-shaped association. BMC Public Health. 2009;9:14.

40. Schiefelbein EL, Mirchandani GG, George GC, Becker EA, Castrucci BC, Hoelscher DM. Association between depressed mood and perceived weight in middle and high school age students: Texas 2004-2005. Maternal and child health journal. 2012;16(1):169-76.
41. Fergusson DM, Horwood LJ, Ridder EM, Beautrais AL. Subthreshold depression in adolescence and mental health outcomes in adulthood. Arch Gen Psychiatry. 2005;62(1):66-72.
42. Anderson SE, Cohen P, Naumova EN, Jacques PF, Must A. Adolescent obesity and risk for subsequent major depressive disorder and anxiety disorder: Prospective evidence. Psychosomatic medicine. 2007;69(8):740-7.
43. Herva A, Laitinen J, Miettunen J, Veijola J, Karvonen JT, Laksy K, et al. Obesity and depression: Results from the longitudinal Northern Finland 1966 Birth Cohort Study. International Journal of Obesity. 2006;30(3):520-7.
44. Boutelle KN, Hannan P, Fulkerson JA, Crow SJ, Stice E. Obesity as a Prospective Predictor of Depression in Adolescent Females. Health Psychology. 2010;29(3):293-8.
45. Frisco ML, Houle JN, Lippert AM. Weight change and depression among US young women during the transition to adulthood. American journal of epidemiology. 2013;178(1):22-30.
46. Clark C, Haines MM, Head J, Klineberg E, Arephin M, Viner R, et al. Psychological symptoms and physical health and health behaviours in adolescents: A prospective 2-year study in East London. Addiction. 2007;102(1):126-35.
47. Marmorstein NR, Iacono WG, Legrand L. Obesity and depression in adolescence and beyond: Reciprocal risks. International Journal of Obesity. 2014;38(7):906-11.
48. Sanderson K, Patton GC, McKercher C, Dwyer T, Venn AJ. Overweight and obesity in childhood and risk of mental disorder: A 20-year cohort study. Australian and New Zealand Journal of Psychiatry. 2011;45(5):384-92.
49. Sweeting H, Wright C, Minnis H. Psychosocial correlates of adolescent obesity, 'slimming down' and 'becoming obese'. Journal of Adolescent Health. 2005;37(5):409.e9-.e17.
50. Flotnes IS, Nilsen TIL, Augestad LB. Norwegian adolescents, physical activity and mental health: The Young-HUNT study. Norsk Epidemiologi. 2011;20(2):153-61.
51. Hoare E, Millar L, Fuller-Tyszkiewicz M, Skouteris H, Nichols M, Jacka F, et al. Associations between obesogenic risk and depressive symptomatology in Australian adolescents: a cross-sectional study. Journal of epidemiology and community health. 2014;68(8):767-72.
52. Zakeri M, Sedaghat M, Motlagh ME, Ashtiani RT, Ardalan G. BMI correlation with psychiatric problems among 10-18 years Iranian students. Acta medica Iranica. 2012;50(3):177-84.
53. BeLue R, Francis LA, Colaco B. Mental health problems and overweight in a nationally representative sample of adolescents: effects of race and ethnicity. Pediatrics. 2009;123(2):697-702.
54. Jansen W, van de Looij-Jansen PM, de Wilde EJ, Brug J. Feeling Fat Rather than Being Fat May Be Associated with Psychological Well-Being in Young Dutch Adolescents. Journal of Adolescent Health. 2008;42(2):128-36.
55. Sjoberg RL, Nilsson KW, Leppert J. Obesity, shame, and depression in school-aged children: a population-based study. Pediatrics. 2005;116(3):e389-92.
56. Ting WH, Huang CY, Tu YK, Chien KL. Association between weight status and depressive symptoms in adolescents: Role of weight perception, weight concern, and dietary restraint. European journal of pediatrics. 2012;171(8):1247-55.

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
		Number	Average age	% Male	% Obese					
Prospective Studies:										
Males										
Anderson, 2007(42)	USA 1985 20	342	14.6	100	9	Structured Psychiatric interview (DISC)	40 (4/10)	1.3 (0.5-3.5)[fj]	0.9 (0.3-2.4)[fj]	Socioeconomic status index (combination of family occupational status, family income, parental education), race/ethnicity, smoking, parental psychopathology
Herva, 2006(43)	Finland 1980 17	3524	14	100	-	Depression symptoms rating Scale (HSCL)	8.4 (13/155)	1.55 (0.93-2.59)	1.18 (0.78-1.78)	Father's social class, family type, smoking, alcohol use, chronic somatic disease at age 14
Females										
Anderson, 2007(42)	USA 1985 20	332	14.7	0	3	Structured Psychiatric interview (DISC)	15.6 (5/32)	3.9 (1.3-11.8)[fj]	0.9 (0.5-1.8)[fj]	Socioeconomic status index (combination of family occupational status, family income, parental education), race/ethnicity, smoking, parental psychopathology
Anderson, 2011(29)	USA 2003 2	482 (White)	13.9	0	7.9	Depression symptoms rating Scale (CES-D)	26.3 (10/38)	2.50 (1.57-3.98)	-	Age, free lunch, time spent home alone after school,
Anderson, 2011(29)	USA 2003 2	134 (Black)	14	0	29.1	Depression symptoms rating Scale (CES-D)	10.3 (4/39)	0.98 (0.16-5.97)	-	Age, free lunch, time spent home alone after school,
Anderson, 2011(29)	USA 2003 2	171 (Hispanic)	13.9	0	21.1	Depression symptoms rating Scale (CES-D)	16.7 (6/36)	0.72 (0.26-1.95)	-	Age, free lunch, time spent home alone after school,
Boutelle, 2010(44)	USA 2010[b] 1	495	13.5	0	10.7	Structured Psychiatric interview (K-SADS)	-	1.62 (0.77-3.38)	0.61 (0.24-1.57)	Age, early puberty, previous depression, BMI appropriate
Frisco, 2013(45)	USA 1996 6	5243	13-19	0	4.2	Depression symptoms rating Scale (CES-D)	10.2 (52/514)	1.97 (1.19-3.26)	0.97 (0.54-1.74)	Age, race/ethnicity, family income. Parental education, family structure, self reported health, physical activity, pregnancy
Herva, 2006(43)	Finland 1980 17	3988	14	0	-	Depression symptoms rating Scale (HSCL)	11.5 (18/157)	1.97 (1.06-3.68)	0.67 (0.33-1.34)	Father's social class, family type, smoking, alcohol use, chronic somatic disease at age 14
Males and females										

Clark, 2007(46)	England 2006[b] 2	1513	12.4	48.7	12.4	Depression symptoms rating Scale (SMFQ)	-	0.92 (0.57-1.48)	1.2 (0.91-1.57)	Age, gender, ethnicity, free school meals, general health, long-standing illness, smoking, alcohol use, drug use,
Marmorstein, 2014(47)	USA 1988 13	908	11.7	49.7	7.1	Structured Psychiatric interview (DISC)	-	0.70 (0.33-1.49)	-	Unclear
Roberts, 2013(12)	USA 2000 1	3134	13.9	51.4	19.7	Structured Psychiatric interview (DISC)	-	1.90 (0.85-4.25)	0.93 (0.31-2.80)	Age, gender, family income, diet, physical activity
Sanderson, 2011(48)	Australia 1985 20	2243	11.1	49.4	9.1[a]	Structured Psychiatric interview (CIDI)	13.2 (27/204)[a]	1.54 (1.06-2.23)[dj]	-	Age, sex
Sweeting, 2005(49)	Scotland 2005[b] 4	2196	11	51.0	10.0	Structured Psychiatric interview (DISC)	1.8 (4/219)	0.91 (0.30-2.74)	-	Unclear
Cross-sectional studies:										
Males										
Assari, 2015(28)	USA 2003	563 (Black)	15	100	25.31	Structured Psychiatric interview (CIDI)	-	0.67 (0.54-2.60)	-	Age, family income
Flotnes, 2011(50)	Norway 2000	925	13-19	100	7.1	Depression symptoms rating Scale (HSCL)	30 (6/20)	0.8 (0.4-1.3)[acdj]	-	Age, school bullying, pubertal development, physical activity
Hoare, 2014(51)	Australia 2012	360	13.1	100	27.0[a]	Depression symptoms rating Scale (SMFQ)	-	1.83 (0.67 – 4.97)[e]	-	Age, school, parental level of education
Jari, 2014(19)	Iran 2009	2715	14.7	100	9.8	Single item response in non depression specific questionnaire (GSHS)	63.7 (170/263)	0.99 (0.91-1.1)[e]	1.0 (0.76-1.32)[e]	Unadjusted
Schiefelbein, 2012(40)	USA 2003	4274	13.5	100	42.3[a]	Single item response in non depression specific questionnaire	-	2.05 (1.16-3.62)	-	Age, race/ethnicity, urbanisation, border, SES, weight loss attempts, physical activity, TV/video usage,
Schiefelbein, 2012(40)	USA 2003	3158	16.5	100	41[a]	Single item response in non depression specific questionnaire	-	0.72 (0.41-1.26)	-	Age, race/ethnicity, urbanisation, border, SES, weight loss attempts, physical activity, TV/video usage,
Zakeri, 2012(52)	Iran 2006	4524	13.8	100	7.5	Single item response in non depression specific questionnaire (GSHS)	30.9 (166/538)[i]	1.00 (0.78 – 1.29)	0.89 (0.71 – 1.12)	School grade
Females										
Assari, 2015(28)	USA 2003	605 (Black)	15	0	24.08	Structured Psychiatric interview (CIDI)	-	0.85 (0.34-3.14)	-	Age, family income
Flotnes, 2011(50)	Norway 2000	988	13-19	0	2.2	Depression symptoms rating Scale (HSCL)	9.1 (6/66)	1.2 (0.9-1.6)[acdj]	-	Age, school bullying, pubertal development, physical activity
Hoare, 2014(51)	Australia 2012	440	13.1	0	26.3[a]	Depression symptoms rating Scale (SMFQ)	-	0.99 (0.64 – 1.52)[e]	-	Age, school, parental level of education
Jari, 2014(19)	Iran 2009	2691	14.7	0	7.5	Single item response in non depression specific questionnaire	63.7 (128/201)	1.12 (0.83-1.51) [e]	1.06 (0.77-1.46)[e]	Unadjusted

						(GSHS)				
Schiefelbein, 2012(40)	USA 2003	4473	13.5	0	38.4[a]	Single item response in non depression specific questionnaire	-	1.70 (1.07-2.69)	-	Age, race/ethnicity, urbanisation, border, SES, weight loss attempts, physical activity, TV/video usage,
Schiefelbein, 2012(40)	USA 2003	3189	16.5	0	29.6[a]	Single item response in non depression specific questionnaire	-	1.45 (0.88-2.38)	-	Age, race/ethnicity, urbanisation, border, SES, weight loss attempts, physical activity, TV/video usage,
Seyedamini, 2012(40)	Iran 2008	200	9.0	0	-	Depression symptoms rating Scale (CBCL)	-	1.12 (1.04-1.21)	-	TV duration, crisis experience within last 6 months, maternal educational level, previous disease history, birth order, birth weight,
Zakeri, 2012(52)	Iran 2006	3936	14.0	0	5.3	Single item response in non depression specific questionnaire (GSHS)	30.9 (166/538)[i]	1.13 (0.84 – 1.52)	1.11 (0.90-1.38)	School grade
Males and females										
Belue, 2009(53)	USA 2003	35184	12-17	50	13.2	Reported health professional diagnosis	11.1 (486/4379)	1.6 (1.2-2.0)[cj]	-	Gender, age, poverty level, family educational level family, family composition.
Halfon, 2013(20)	USA 2007	43211	13.8	52.2	16	Reported health professional diagnosis	4 (277/6914)	1.41 (1.04-1.93)	1.33 (0.98-1.82)	Age, gender, race/ethnicity, parental education, household income, family structure
Jansen, 2008(54)	Netherlands 2000	1900	9.5	51	7	Depression symptoms rating Scale (SDI)	26.6 (35/134)	0.96 (0.64-1.43)	0.86 (0.66-1.11)	Gender and country of origin
Sjoberg, 2005(55)	Sweden 2004	4703	15.9	50.7	2.7	Depression symptoms rating Scale (DSRS)	26.7 (35/131)	1.67 (1.12-2.49)	0.96 (0.77-1.20)	Unclear
Ting, 2012(56)	Taiwan 2010	859	15.7[h]	53.7	11.9	Depression symptoms rating Scale (CES-D)	22.6 (21/93	1.68 (0.93-3.02)[j]	2.23 (1.3-3.82)[j]	Age, gender, parental education

(-) = Information not available/not calculable, a=obese and overweight, b=date of study publication, c=composite outcome depression and anxiety, d=relative risk, e=Odds ratio/confidence interval calculated from data reported, f=hazard ratio, h=median, i = males and females combined, j=transformed data or calculated sex-specific data used in meta-analysis

DISC = Diagnostic Interview Schedule for Children, CES-D = Centre for Epidemiologic Studies Depression Scale, K-SADS = Schedule for Affective Disorders and Schizophrenia for School-age Children, SMFQ = Short Moods and feeling questionnaire, CDI = Children's Depression Inventory, HSCL = Hopkins Symptom Check List, SDI = Short Depression Inventory for Children, GSHS = Global School-based Health Survey, DSRS = Diagnostic Self Rating Scale, CIDI = Composite International Diagnostic Interview, CBCL = Child Behaviour Checklists,

Table 2 – Quality assessment of 22 included studies

Study (Cohort Studies)	Selection (maximum 3 stars)	Comparability (maximum 2 stars)	Outcome (maximum 2 stars)	Total/maximum
Anderson, 2007	?	2	1	5/7
Anderson, 2011	1	2	1	4/7
Boutelle, 2010	3	2	1	6/7
Clark, 2007	3	2	1	6/7
Frisco, 2013	3	2	1	6/7
Herva, 2006	1	2	1	4/7
Marmorstein, 2014	3	0	2	5/7
Roberts, 2013	2	2	1	5/7
Sanderson, 2011	2	1	1	4/7
Sweeting, 2005	2	0	2	4/7

Study (Cross-sectional Studies)	Selection (maximum 2 stars)	Comparability (maximum 2 stars)	Outcome/Exposure (maximum 1 stars)	Total/maximum
Assari, 2015	0	2	1	3/5
Belue, 2009	1	2	1	4/5
Flotnes, 2011	2	2	1	5/5
Halfron, 2013	1	2	0	3/5
Hoare, 2014	2	2	1	5/5
Jansen, 2008	2	1	1	4/5
Jari, 2014	2	0	1	3/5
Schiefelbein, 2012	2	2	0	4/5
Seyedamini, 2012	2	1	1	4/5
Sjoberg, 2005	1	0	1	2/5
Ting, 2012	1	2	1	4/5
Zakeri, 2012	2	0	0	2/5

A maximum of 7 stars for cohort studies and 5 for cross-sectional studies could be obtained.

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)									Studies included
		Overall			Males			Females			
		OR	95% CI	I^2	OR	95% CI	I^2	OR	95% CI	I^2	
All studies – Odds of depression if obese vs normal weight	22/22	1.32	1.17-1.50	72.1%	1.14	0.93-1.41	49.0%	1.44	1.20-172	50.2%	All studies
Studies where BMI has been independently measured	14/22	1.25	1.09-1.44	44.5%	1.12	0.77 – 1.63	54.5%	1.42	1.15-1.75	52.7%	Anderson 2011, Boutelle 2009, Clark 2007, Flotnes 2011, Frisco 2013, Hoare 2014, Jansen 2008, Marmorstein 2014, Roberts 2013, Sanderson 2011, Schielfelbein 2012, Seyedamini 2012, Sweeting 2005, Zakeri 2012.
Studies where comparator group does not include underweight or overweight individuals	7/22	1.22	1.03-1.45	84.3%	1.05	0.85-1.30	45.5%	1.14	1.06-1.22	0.0	Belue 2009, Flotnes 2011, Hoare 2014, Jari 2014, Schiefelbein 2012, Seyedamini 2012, Zakeri 2012,
Studies where effect estimate was adjusted by some measure of socioeconomic deprivation	11/22	1.44	1.20-1.72	75.7%	1.33	0.88-2.02	58.1%	1.51	1.15-1.98	56.2%	Assari 2005, Belue 2009, Clark 2007, Frisco 2013, Halfron 2013, Herva 2006, Hoare 2014, Roberts 2013, Schielfelbein 2012, Seyedamini 2012, Ting 2012.
High quality studies (>4 stars in cohort/case-control studies or >3 stars in cross-section studies)	13/22	1.39	1.14-1.69	77.9	1.33	0.80-2.20	60.5%	1.51	1.16-1.95	50.7%	Anderson 2007, Belue 2009, Boutelle 2009, Clark 2007, Flotnes, Frisco 2013, Hoare 2014, Jansen, Marmorstein 2014, Roberts 2013, Schielfelbein 2012, Seyedamini 2012, Ting 2012.
Studies including populations where weight has been measured after the year 2000 onwards	17/22	1.28	1.12-1.46	75.4%	1.08	0.87-1.35	50.7%	1.34	1.12-1.60	44.7%	Anderson 2011, Assari 2005, Belue 2009, Boutelle 2009, Clark 2007, Flotnes, Halfron 2013, Hoare 2014, Jansen, Jari, Roberts 2013, Schielfelbein 2012, Seyedamini 2012, Sjoberg

											2005, Sweeting 2005, Ting 2012, Zakeri 2012.
Studies where depression is diagnosed using structured psychiatric interview	7/22	1.27	0.94-1.70	18.1%	0.98	0.42-2.33	45.5%	1.53	0.88-2.65	0.0%	Anderson 2007, Assari 2005, Boutelle 2009, Marmorstein 2014, Roberts 2013, Sanderson 2011, Sweeting 2005.
Only studies with population drawn from USA	10/22	1.47	1.23-1.77	46.3%	1.11	0.61-2.04	66.2%	1.72	1.37-2.15	6.1%	Anderson 2007, Anderson 2011, Assari 2005, Belue 2009, Boutelle 2009, Frisco 2013, Halfron 2013, Marmorstein, Roberts 2013, Schiefelbein 2012.

Figure 1 –PRISMA Flow Diagram

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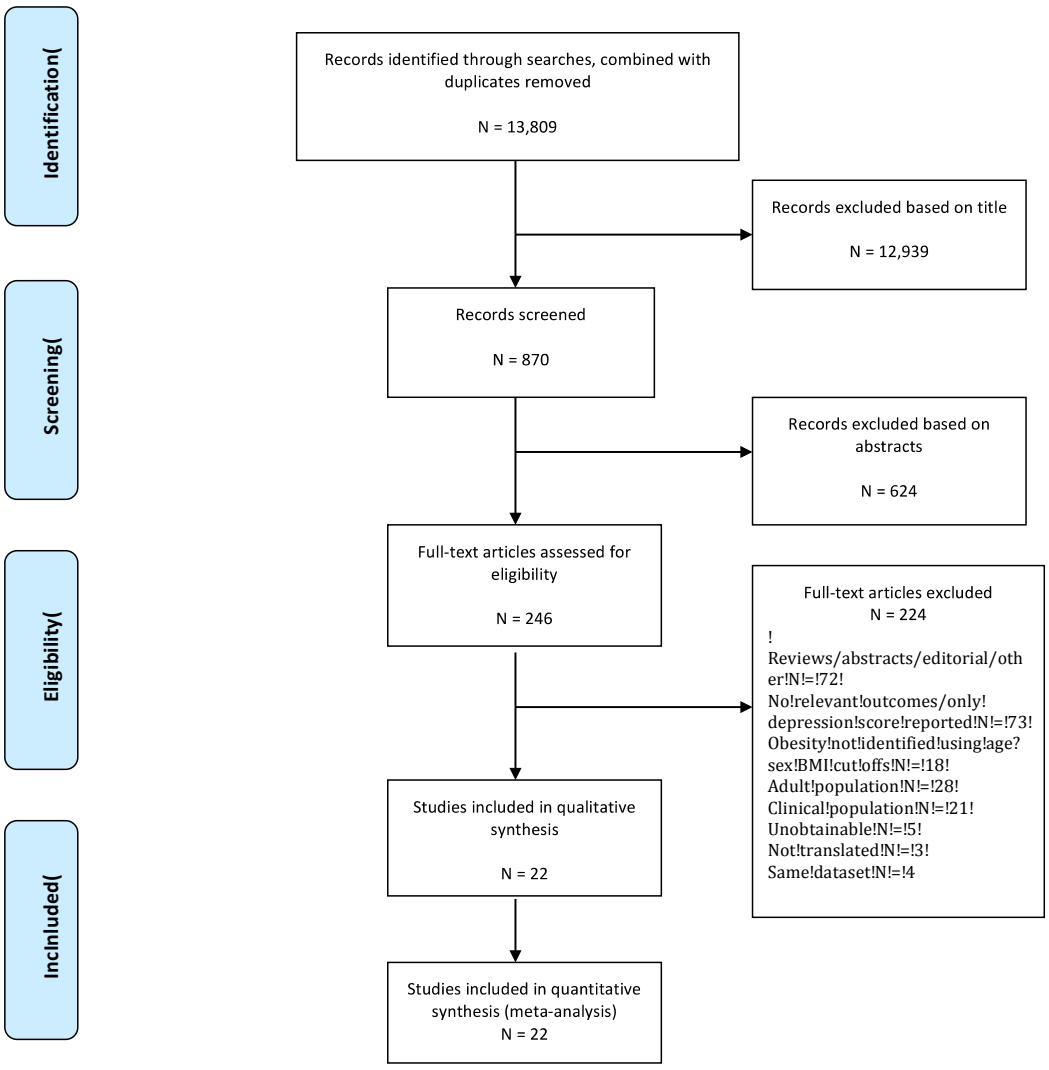
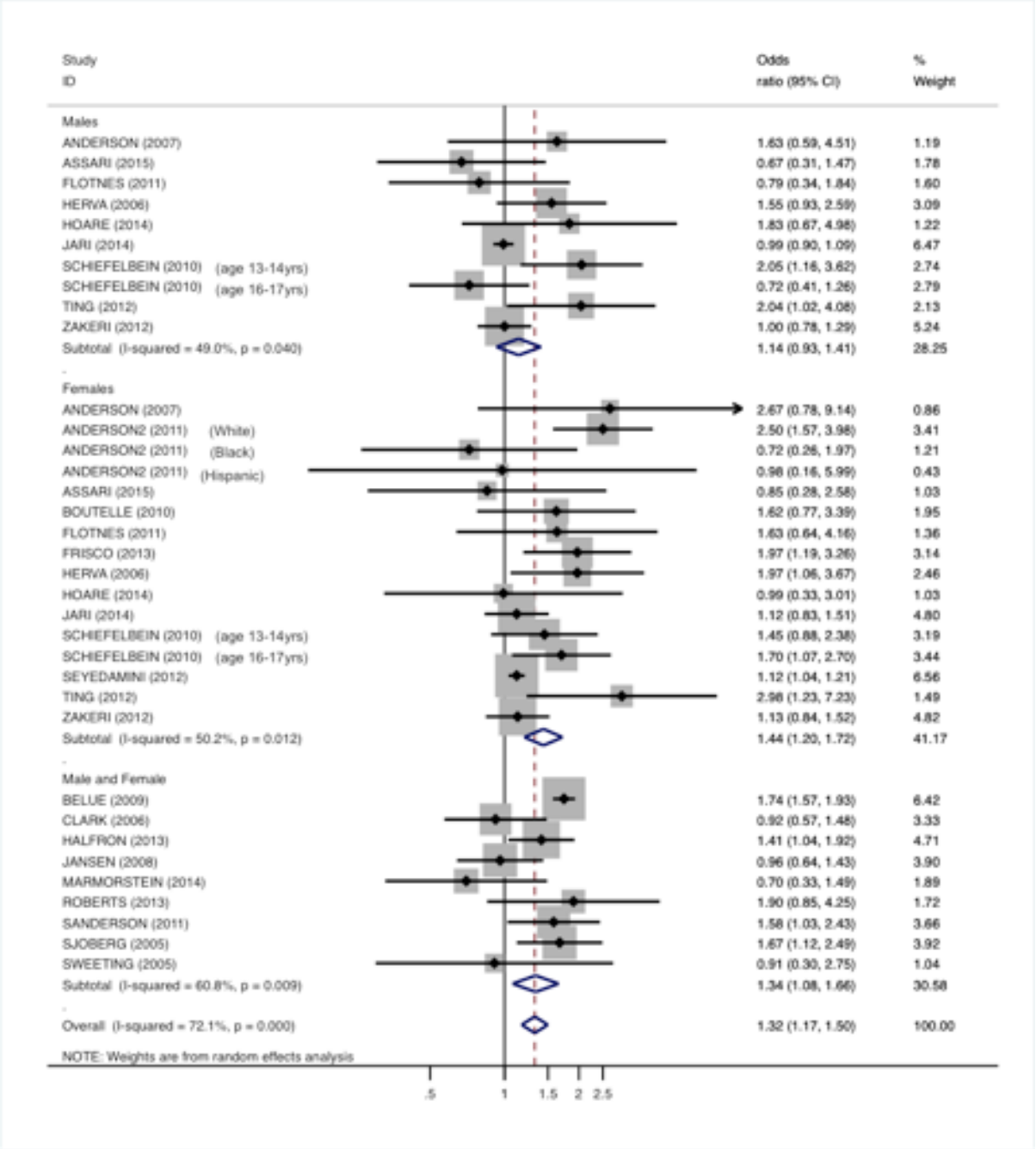
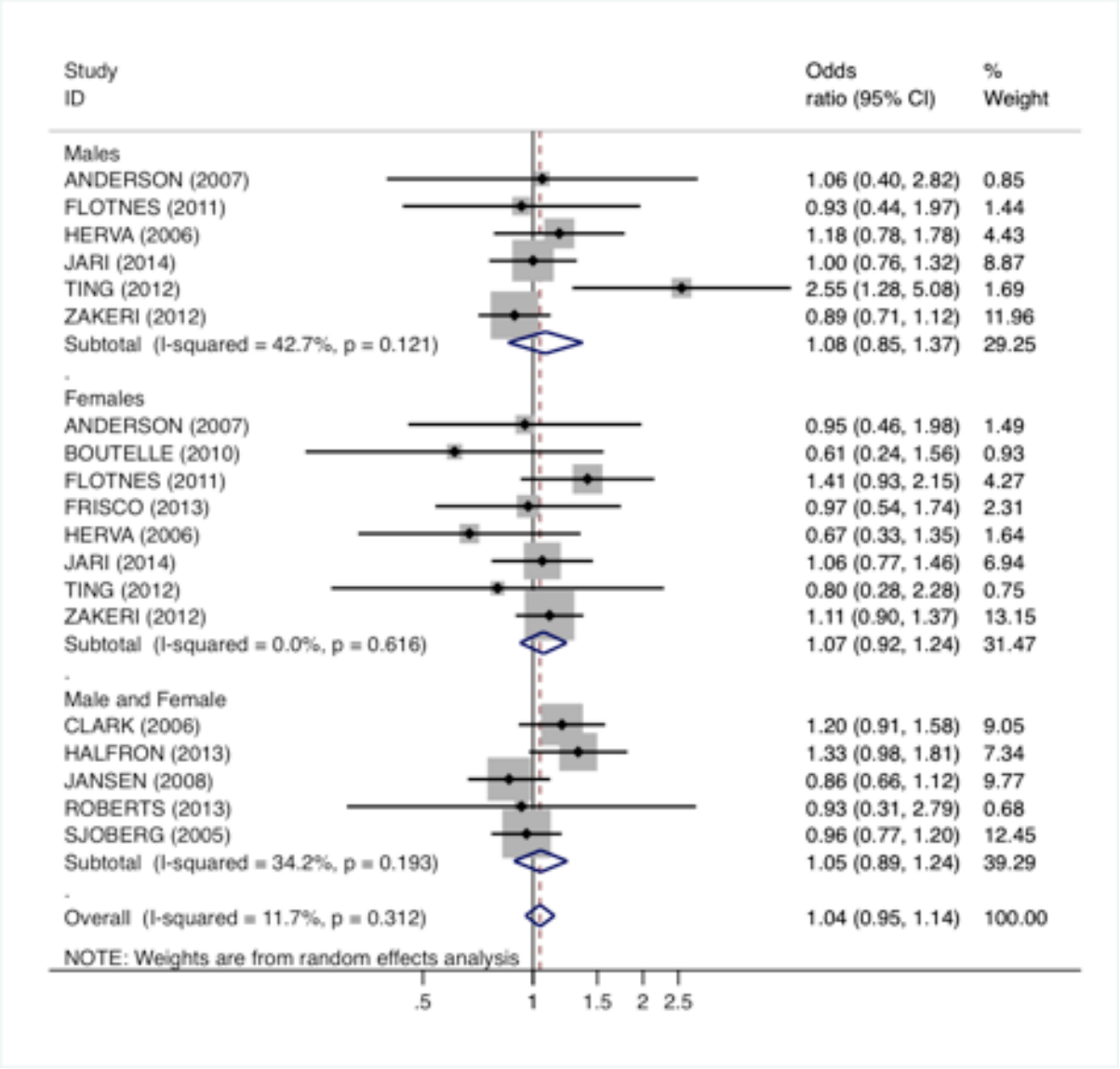


Figure 2 Meta-analysis (22 unique studies) odds of current or future depression in obese children versus normal weight children*



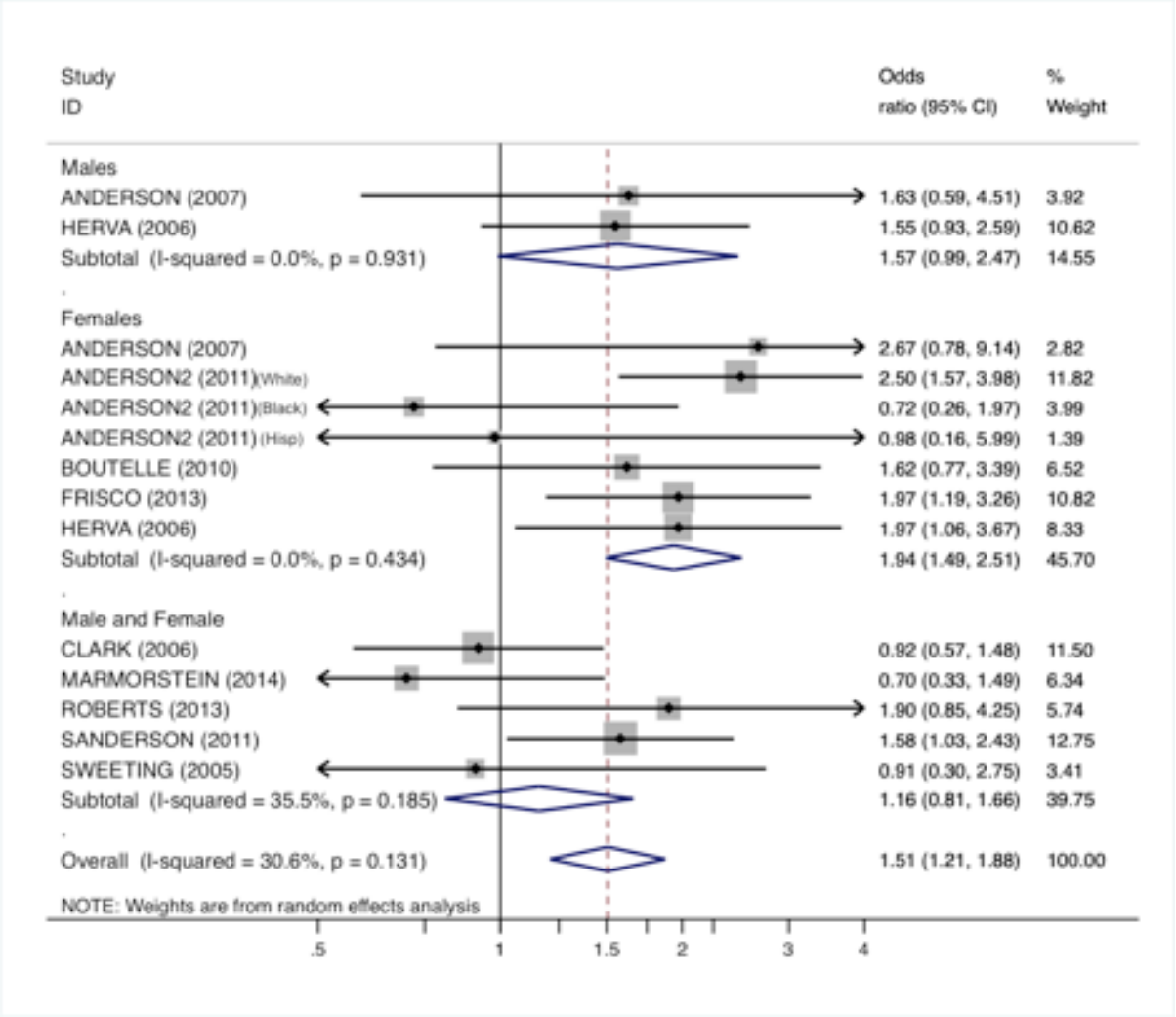
*Multiple odds ratios for same studies reflect odds ratios for different sub groups (e.g male, female, ethnic group)

Figure 3 Meta-analysis (13 unique studies) odds of depression in overweight children versus normal weight children*



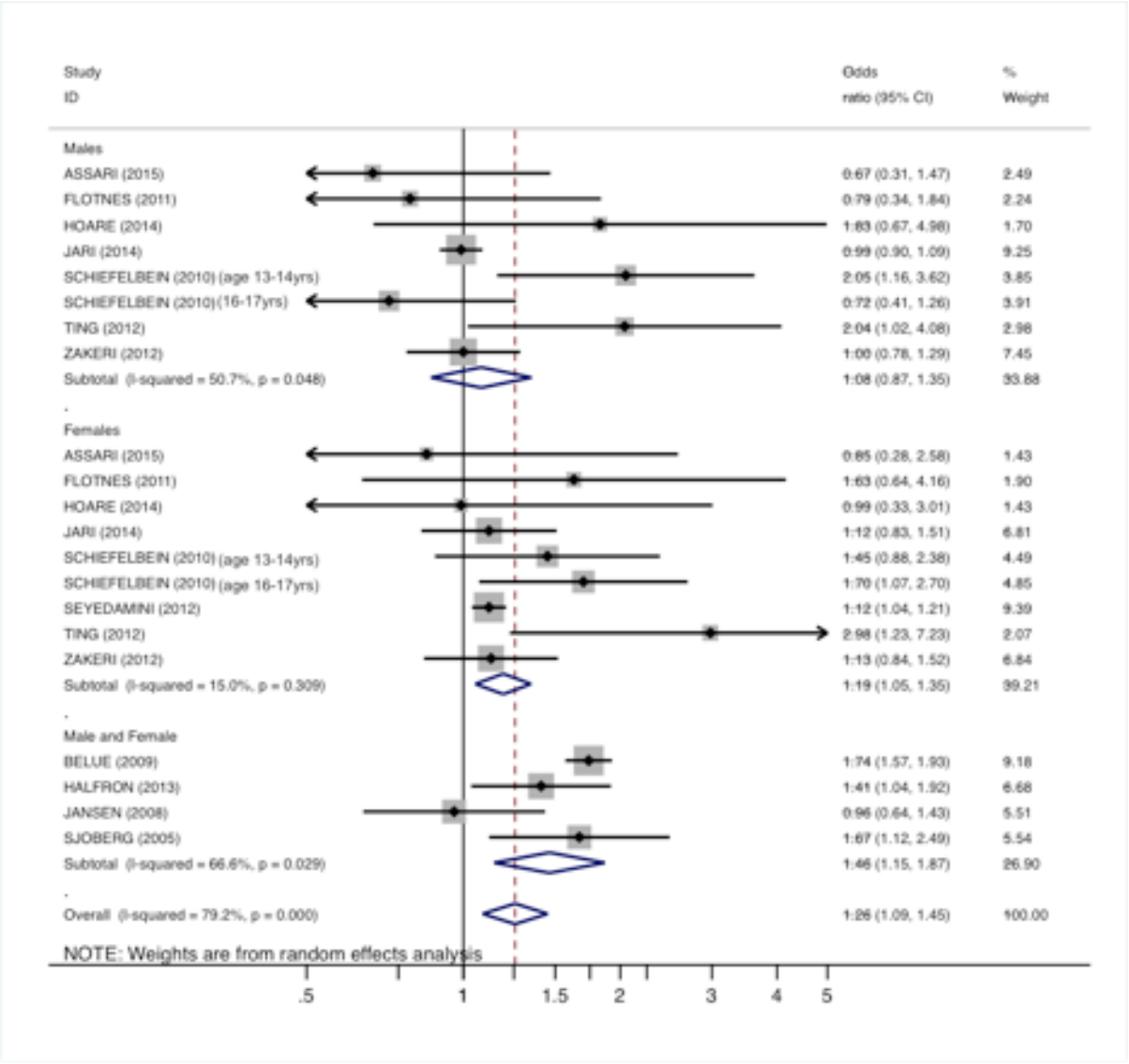
*Multiple odds ratios for same studies reflect odds ratios for different sub groups (e.g male, female, ethnic group)

Figure 4 Meta-analysis of 10 longitudinal studies examining odds of developing depression in obese children versus normal weight children, by gender*



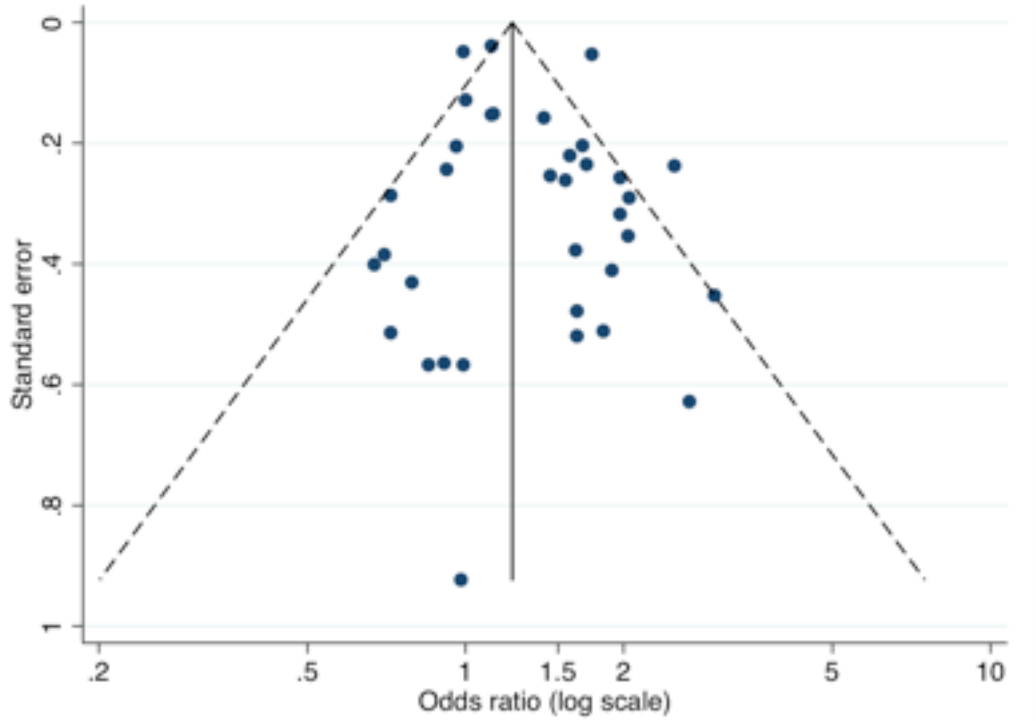
*Multiple odds ratios for same studies reflect odds ratios for different sub groups (e.g male, female, ethnic group)

Figure 5 Meta-analysis of 12 cross-sectional studies examining odds of depression in obese children versus normal weight children, by gender*



*Multiple odds ratios for same studies reflect odds ratios for different sub groups (e.g male, female, ethnic group)

Figure 6 Funnel plot



Appendix 1-3

(see separate attachment)