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Do surgical interventions to treat obesity in children and adolescents have long- versus short-term advantages and are they cost-effective?

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EVIDENCE FOR DECISION-MAKERS

Abstract

The prevalence of childhood and adolescent obesity in the WHO European Region has risen in recent decades. Obesity in this population is linked to increased risk factors for cardiovascular diseases, type 2 diabetes, sleep apnoea and psychological distress. While bariatric surgery is seen as an effective intervention under clear conditions for obese adults, the indications for medical and surgical treatment of overweight and obese children are still not well defined. Moreover, children and adolescents have distinctive metabolic, developmental and psychological needs, which must be carefully considered to avoid the inappropriate use of weight-loss surgery.

This review looks at the effectiveness and cost–effectiveness of surgical interventions for overweight and obese children and adolescents, and finds that the majority of relevant studies are methodologically limited and long-term data remain largely unavailable. Some evidence suggests that bariatric surgery in severely obese adolescents can result in significant weight loss, and improvement in co-morbidities and quality of life. A conservative approach to child and adolescent bariatric surgery is warranted until further long-term prospective studies on the subject are conducted, so there remains an urgent need to develop alternatives to surgery, such as lifestyle programmes that are even modestly effective.

Keywords

ADOLESCENT
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Contents

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Summary

The issue

During the last decades the prevalence of childhood and adolescent obesity in Europe has grown. Although it is possibly levelling off in some areas of Europe *(1–3)*, the scale of childhood obesity and its associated morbidities and costs remains considerable *(4,5)*. Obese children and adolescents are more likely than others to have risk factors for cardiovascular diseases, experience other health conditions associated with increased weight, such as type 2 diabetes and sleep apnoea, perform poorly at school and suffer psychological distress *(6,7)*. Clear evidence for successful and cost-effective non-surgical strategies for treating childhood obesity is lacking, leading the medical profession to turn increasingly to surgical treatment options. While bariatric surgery is established as a safe and effective alternative with well-defined risks for severely obese adults *(8–12)*, little of quality has been published on its use in children, with their unique metabolic, developmental and physiological needs *(13)*. Evidence is needed on the effectiveness and cost–effectiveness of surgical treatment in order to support policy-makers and guide future research.

Findings

In the context of a general lack of effective tools for primary prevention or behavioural treatment of obesity *(14)*, surgical treatment may be advocated as a preferred and cost-effective solution for certain children and adolescents *(15)*. However, the role of bariatric surgery in the treatment of obese children or adolescents is controversial. The concerns about surgery to treat obesity in young populations include:

- obtaining informed consent from minors;
- timing of intervention;
- whether or not surgery is cost-effective;
- how to ensure healthy growth through to adulthood; and
- what support services are needed after surgery: compliance with the postoperative nutrition regimen, and attendance at appointments for long-term follow-up and care.

These concerns underscore the importance of well-designed and well-evaluated research studies on the effectiveness of treatment options for obesity in child

populations *(6)*. As demonstrated in the current evidence review, the few studies that exist are primarily retrospective or observational, and underpowered *(16)*. The indications for medical and surgical treatment in overweight and obese children are still not well defined *(7)*. There is no clear indication of the cost–effectiveness of surgical interventions for paediatric obesity. There is very limited evidence available to adequately estimate long-term safety, effectiveness, cost–effectiveness or durability of bariatric surgery in growing children.

Policy considerations

- Although based on methodologically limited and underpowered studies, the existing evidence suggests that bariatric surgery in severely obese adolescents results in significant weight loss and improvements in comorbidities and quality of life.
- Postoperative complications, (both physical and psychological), compliance and follow-up may be more problematic in adolescents than adults, and long-term data on safety, effectiveness and cost remain largely unavailable.
- Simple adoption of adult bariatric surgery guidelines for use in younger age groups would overlook the contrasting metabolic, developmental and psychological needs of children and adolescents and could result in the inappropriate use and/or overuse of weight loss surgery. Conversely, delaying treatment and allowing comorbid conditions to progress could be equally or more disadvantageous.
- An academic approach to child and adolescent bariatric surgery is warranted until further long-term prospective studies on the subject are conducted.
- Controlled clinical trials to test the safety and efficiency of surgical approaches to address obesity in young people are required, as well as renewed efforts at developing effective approaches to preventing and treating excess weight gain in children in order to inhibit progression to greater degrees of obesity.

Introduction

Since the early 1990s, the prevalence of childhood and adolescent obesity in Europe has grown rapidly. Despite reports of levelling off in some countries *(1–3)*, childhood obesity and its associated morbidities and costs are considerable and increasing in scale in many European countries *(4,5)*, particularly among socioeconomically disadvantaged population segments *(17)*. Obese children and adolescents are more likely than their normal weight peers to suffer endocrine, cardiovascular, pulmonary, orthopaedic, psychosocial and other complications associated with excessive weight, many of which persist into adulthood *(6,7,18)*. While prevention of obesity must continue to be a policy goal, the treatment of those that are already obese is an issue requiring urgent attention.

The treatment options for children and adolescents include changes in dietary and physical activity behaviour as well as pharmacotherapy and bariatric surgery *(19)*. A recent Cochrane review of childhood obesity treatments *(20)* concluded that combined behavioural lifestyle interventions, compared with standard care or self-help, can produce a significant and clinically meaningful reduction in overweight in children and adolescents. For severe paediatric obesity, however, there is evidence to suggest that non-surgical approaches are of limited effectiveness *(14)*. Moreover, strong evidence for successful and cost-effective strategies is still generally lacking, in large part because of methodological shortcomings in the majority of prevention trials *(18)*.

In this context, the medical profession is increasingly turning to surgical options (see below) to treat obesity in children and adolescents *(21)*. While established as a safe and effective alternative with well-defined risks for severely obese adults *(8–12)*, little has been published on bariatric surgery in children and their distinctive metabolic, developmental and physiological needs *(13)*. In the above-mentioned Cochrane review of childhood obesity treatments the maximum follow-up of studies was two years and no surgical intervention studies met the inclusion criteria *(20)*. To date there has only been one randomized controlled trial (published one year after the Cochrane review) comparing bariatric surgery with a lifestyle intervention in adolescents *(22)*.

The concerns about bariatric surgery for children and adolescents include questions about obtaining informed consent from minors, timing of intervention, whether or not

surgery is cost-effective, maintenance of weight loss, how to ensure healthy growth through to adulthood, what support services are needed after surgery, compliance with the postoperative nutrition regimen and ensuring participation in lifelong medical surveillance. Therefore, bariatric surgery for the treatment of child and adolescent obesity remains controversial. Many researchers are calling for caution and a critical appraisal of surgical interventions to treat obesity in children and adolescents *(7,23–25)*, as well as an economic analysis of these procedures to provide evidence in support of policy-making.

This report reports on the evidence of whether surgical interventions to treat children and adolescents have long- versus short-term advantages and whether they are cost-effective.

This report was challenging because of a number of limitations within the existing literature:

- Apart from one randomized controlled trial, the studies assessing the effectiveness of surgical options for obesity in children and adolescents were either retrospective or observational, and underpowered.
- Sample sizes were generally small, with the largest sample containing only 68 patients and the majority of studies reporting data on fewer than 40 patients.
- Results are not broadly comparable given a lack of consistency across surgeons, procedures and reported outcomes.
- Accurate information for low-frequency outcomes like mortality and complications is sparse.
- No studies on clinical effectiveness reported on costs, and only one publication addressed bariatric surgery cost in children.
- It is difficult to assess the degree of weight regain in adolescents from the literature, partially because of the bias introduced by patients lost to follow-up. In the current review, weight regain was reported in four studies for a minority of patients and ranged from 50 to over 100% of weight lost *(26–29)*. Common reasons for weight regain include postoperative complications, such as pouch dilation and staple disruption, and poor postoperative dietary habits, underscoring the need for continued focused research on effective behavioural lifestyle interventions.

Indications and patient assessment

A review of 15 guidelines for bariatric surgery in adolescents *(30)* reported on inclusion and exclusion criteria for surgery as detailed below.

Inclusion criteria

There appears to be very little consensus on an appropriate age for using surgical interventions; guidance is more likely to be offered on developmental stage rather than chronological age. Recommendations include Tanner stage 3 *(31)* or 4 or 5 *(32,33)*, final or near final adult height *(32–34)*, post-pubertal *(35)*, physical maturity (assumed to be > 13 years for girls and > 15 years for boys) *(36)*, complete or near complete skeletal and developmental maturity *(31,37,38)*, minimum bone age of 13 years for girls and 15 years for boys *(32)* and bone age > 13 years for girls and > 15 years for boys *(39)*.

Body mass index (BMI, in kg/m^2) is the most often cited inclusion criteria, although there is much variation in the guidance. Nine guideline documents set minimum thresholds > 35 *(31–34,36–40)* while five suggest > 40 *(36–38)* and one uses BMI standard deviation scores *(35)*.

Nine publications include comorbidities in addition to the BMI criteria *(31–34,36–40)*. Severe comorbidities (i.e. type 2 diabetes, hypertension, non-alcoholic steatohepatitis, benign intracranial hypertension, obstructive sleep apnoea) are mentioned in three publications as mandatory criteria for eligibility for surgical intervention in addition to a minimum BMI threshold *(32,35,38)*.

Ten guidelines require previous attempts at weight loss prior to bariatric surgery *(31–34,36–41)*. Details mentioned include minimum of six month's duration *(32,33,36,38–41)*, lifestyle modification component *(32,33,36,40)*, formal supervision or organized weight loss *(32,34)* and family involvement *(39)*.

The issue of consent is addressed only by four sets of guidelines. These specify the conditions required as assent from the adolescent *(34,39)*, informed consent from the adolescent *(37)*, informed consent from the adolescent and full consent from parent/legal guardian *(32)* and informed permission from caregivers *(34)*.

Patient and family knowledge and attitudes is given as an indication for surgery in some guidelines: these include a requirement that patients be motivated and well-informed *(31,32,34,38,40)*, aware of the risks of surgery *(31,34,41)*, in a supportive family environment *(32,33,39,41)* or psychologically stable *(31,33,37,40,41)*. Preoperative psychiatric or psychological patient *(34,39)* and family *(33,39)* evaluations are also suggested. Capability and willingness to adhere to postoperative guidelines and prolonged surveillance *(32–34,37)* are referred to in inclusion criteria.

Exclusion criteria/major contraindications

In the same review *(30)*, six guidelines were found that describe exclusion criteria or major contraindications for bariatric surgery in the paediatric population. These include pregnancy or breastfeeding *(31–33)*, alcohol or substance abuse *(31,37,40)* and Prader-Willi syndrome or other hyperphagic conditions *(32,33)*. Further cautions are given that recommend against bariatric surgery for adolescents with life-threatening multisystem organ failure, uncontrolled or metastatic malignancy, uncontrolled HIV infection, hypercarbic respiratory failure, active systemic infection or untreated endocrine dysfunction *(31)*, plans to conceive or unresolved eating disorders *(33)*, diseases threatening in the short term or lack of care (self-care or access to family or social support) *(37)* and medically correctable causes of obesity *(34)*.

Surgical interventions for obesity

Bariatric surgery refers to a number of different procedures designed to restrict food intake and/or reduce nutrient absorption (Table 1). The procedures are now usually performed laparoscopically for adults and adolescents *(42)*. The most common operations for adolescents are laparoscopic adjustable gastric banding (LAGB) and Roux-en-Y gastric bypass (RYGB).

Table 1 *Bariatric surgical interventions*

Restrictive	Malabsorptive	Combination
Banding: adjustable gastric band (AGB); laparoscopic AGB (LAGB) **Gastroplasty:** vertical banded (VBG), horizontal (HG), and silicone band (SBG) gastroplasty **Gastrectomy:** laparoscopic sleeve gastrectomy (LSG); sleeve resection (SR) **Other:** intragastric balloon (IGB)	Biliopancreatic diversion (BPD) usually with duodenal switch (DS or BPD-DS)	**Bypass:** gastric bypass (GBP); laparoscopic GBP (LGBP); Roux-en-Y GBP (RYGB); laparoscopic RYGB (LRYGB); open RYGB (ORYGB); distal GBP (DGBP); long-limb GBP (LLGBP) **Other:** vagotomy (VAG); sleeve gastrectomy with entero-omentectomy (SGE)

The least invasive of the purely restrictive bariatric surgery procedures is LAGB, which does not permanently alter gastrointestinal continuity *(43)*. An adjustable band is placed around the uppermost part of the stomach, creating a small gastric pouch that will restrict food intake. Band adjustments are made with saline injections via a subcutaneous access port and are usually done at regular intervals postoperatively until target weight is reached. Although LAGB is not currently approved by the

American Food and Drug Administration for implantation in adolescent patients, it is considered to be the safest operation *(25)* and the most regularly used procedure in Europe *(44)*. Complications with LAGB include those associated with the operative procedure, splenic injury, oesophageal injury, wound infection, micronutrient deficiency, port or tube dysfunction, hiatus hernia, pouch dilation, band slippage, band erosion (or migration), reservoir deflation/leak, persistent vomiting and acid reflux *(9,45)*. Revisional or band-removal surgery may be expected in up to 20% of adult patients after follow-up periods averaging five years *(46,47)*.

The RYGB method involves complex alteration of gastrointestinal anatomy, although reversal is technically possible. To restrict gastric capacity, a small proximal stomach pouch is created at the gastro-oesophageal junction, to which a Roux limb of the small bowel is anastomosed. The majority of the gastric and duodenal alimentary system is bypassed *(44)*, preventing normal absorption of calories and nutrients and necessitating long-term vitamin and mineral supplementation. The beneficial metabolic effects of the RYGB have not yet accurately been defined, but it appears to cause rapid remission of diabetes postoperatively *(48)*. Although complications appear to be higher than for LAGB, occurring at a rate of 20–30% *(42)*, weight loss is typically higher than that achieved with purely restrictive procedures, and it is the only approved procedure for adolescents in the USA *(44,49)*. Associated complications include postoperative bleeding, severe malnutrition (particularly iron, vitamin B_{12} and calcium deficiency), shock, failure of or leak in the staple partition, acute gastric dilatation, delayed gastric emptying, vomiting, wound hernias, bowel obstruction, anaemia, stomal stenosis, gallstone formation, marginal ulceration and dumping syndrome (caused by eating refined sugar, symptoms of which include rapid heart rate, nausea, tremor, faint feeling and diarrhoea) *(9,44,50)*.

Sources for this review

This report is based on a detailed search of the medical and scientific literature using PubMed and the Cochrane Library databases, supplemented by specific searches for additional papers cited in research studies and review articles. The searches were designed to identify evidence on whether surgical interventions to treat obesity in children and adolescents have long- versus short-term advantages and whether they are cost-effective. The searches followed validated methods for systematic reviews *(51)* and included studies with the following designs: case studies, longitudinal studies, prospective cohorts, prospective longitudinal trials, prospective randomized controlled trials, retrospective analyses, cohorts and multicentre studies. Kin relationships, where multiple publications described overlapping series of patients, were identified and only data from one study were included to avoid double counting cases. The authors defined adolescents as aged 10–19 years

according to the World Health Organization (WHO) definition, and children as < 10 years of age.

The search strategy identified 1410 citations of which 233 articles were included as potentially relevant. Examination of the full text of these articles revealed 46 of sufficient quality for detailed review and inclusion in the assessment, of which 13 were kin studies. Reasons for excluding potentially relevant articles included no original data (n = 78), no paediatric data (n = 42) and unobtainable papers (n = 24). The search strategy is described in more detail in Annex 1.

Findings

Effectiveness of surgical options in children and adolescents

Thirty-three relevant papers on bariatric surgery in children or adolescents were included. These spanned 36 years, but 12 (36%) were published after the December 2007 cut-off used by Treadwell et al. in the only existing systematic review on the topic *(45)*. The majority of studies (26) looked exclusively at adolescents, together covering 604 subjects. Six studies in 199 patients examined both children and adolescents (8 years was the youngest age in the ranges studied), and a single case study was the only research to focus solely on children. The results according to surgery type are described in the following section and in Annex 2 in Tables 2–4. Formal meta-analysis and comparisons between surgery types were not attempted because of the marked heterogeneity of study designs and outcome measures among the included studies.

Gastric banding

Eleven studies examined gastric banding, including four retrospective studies *(52–55)*, four cohort studies *(56–59)*, two prospective longitudinal trials *(60,61)* and a prospective randomized controlled trial *(22)*, together covering 427 patients aged 9–19 years. Eight studies looked at adolescents (n = 266), while three also examined children (n = 161). Mean baseline BMI in patients studied ranged from 42.4 to 50. All but two papers *(54,56)* described baseline comorbid conditions, which included amenorrhoea, depression, dyslipidaemia, hypertension, metabolic syndrome, orthopaedic problems, osteoarthritis, sleep apnoea and type 2 diabetes.

Follow-up time varied greatly, ranging from 3 to 85 months. Ten studies reported preoperative and postoperative BMI measures, with mean BMI reductions ranging from 8.5 to 16.4. One study *(22)* compared BMI reduction in 25 surgical patients with a mean age of 16.5 years with that in patients treated with a lifestyle intervention; it found that mean BMI in patients receiving gastric banding decreased by 12.7 (30%) after two years compared with 1.3 (3%) in the control group. Two studies *(57,59)* did not report on percentage of excess weight loss, while the other nine studies reported an average excess weight loss at 12 months ranging from 34 to 60%. Changes in comorbid conditions were reported in seven studies, with resolution of specific comorbidities reported in 11–100% of cases. Only two studies examined quality of life measures *(58,60)*. Six out of eleven studies did not report

on mortality; five studies reported that there were no surgery-related mortalities *(52–54,56,59)*. All papers reported on surgical complications, with only one reporting no complications *(57)*. The others reported a range of complications including band slippage in 2–13% of cases in five studies *(53,55,56,59,61)*; band removal because of psychological intolerance in 10% of patients in one study *(53)*; repeated vomiting in 18% of cases and band readjustment in 10% of cases in one study *(52)*. No weight regain was reported.

Gastric bypass

Of eight papers examining RYGB *(26,62,65–70)*, three were retrospective studies *(26,62,68)*, two were longitudinal *(67,70)* and three were case studies *(65,66,69)*, covering a total of 135 adolescent patients aged 13–21 years. Mean baseline BMI in patients studied ranged from 48 to 60. All but two studies *(26,66)* described baseline comorbidities, including hypertriglyceridaemia, hypercholesterolaemia, degenerative joint disease, diabetes, osteoarthritis, sleep apnoea, asthma and gastroesophageal reflux.

Follow-up time ranged from 4 to 156 months, with two studies presenting more than one year of follow-up data in 40 patients. All studies reported preoperative and postoperative BMI measures, with mean BMI reductions ranging from 9 to 25. Three studies *(62,65,68)* reported on the resolution of comorbid conditions: in one study *(68)*, three of the four patients reported 100% resolution of hypertriglyceridaemia, hypercholesterolaemia, degenerative joint disease, asthma and gastroesophageal reflux. Improvements such as a decrease in triglycerides, total cholesterol, fasting blood glucose, fasting insulin and blood pressure were also reported *(26,67,70)*. One surgery-related death was reported *(26)*. All studies but one *(67)* reported on postoperative complications, with only two studies reporting none *(65,68)*; the others reported a range of complications including dehydration, peristomal ulcer, intestinal leakage, wound infection, anastomotic stricture *(62,70)*, nutritional deficiencies *(70)* and bowel obstruction *(62,66)*. Weight regain was reported in two patients in one study *(26)*. One study *(67)* examined quality of life measures, citing postoperative improvement.

Other forms of bariatric surgery

Of the thirteen studies reporting other forms of bariatric surgery, three were case studies *(71–73)*, five were retrospective reviews *(27,28,64,74,75)* and five were prospective cohort studies *(29,76–79)*. Nine studies looked at adolescents (n = 203); three examined both children and adolescents (n = 38), and one case study considered a child. Mean baseline BMI in patients studied ranged from 42 to 62. Sleeve gastrectomies, a relatively new procedure, were performed in 19 patients *(71–73,78,79)*. Vertical banded gastroplasty was performed in 61 patients in four

studies *(27–29,64)*. Five papers reported on more than one surgical procedure, in 91 patients, and presented combined results *(27,28,74,79,80)*. One Italian retrospective study on biliopancreatic diversion reported two or more years of follow-up data in 68 patients, with mean excess weight loss of 78% *(75)*. With the exception of those with a RYGB component, the procedures reported on below are not commonly used. Jejunoileal bypass and biliopancreatic diversion have both been largely abandoned because of the high risk of nutritional complications, morbidity and mortality resulting from bypassing the majority of the small intestine *(81,82)*, and vertical banded gastroplasty results in modest weight lost and a higher postsurgical complication rate *(83)*. Vertical sleeve gastroplasty is reported to be gaining in popularity because of a predictably lower risk of nutritional complications and a weight loss performance that is potentially comparable to other procedures *(84)*.

Studies described a wide range of baseline comorbidities, including depression *(27,72,73,79)*, hypertension *(27,28,75,76,79)* and diabetes *(28,74,78)*. Follow-up time ranged from 0 to 276 months, with two studies presenting five-year follow-up data in 45 patients. All studies reported preoperative and postoperative BMI measures, with mean BMI reductions ranging from 9 to 24. Changes in comorbid conditions were reported in all but two studies. There were generally high rates of resolution or improvement in physical (e.g. hypertension) *(27,28,75,77)* and mental *(73)* health. Eleven papers reported on surgical complications, four of which reported no complications *(65,71,74,77)*, and the others reporting a range of complications including pulmonary embolism *(28)*; nutritional deficiencies *(27,28,76,78)* such as anaemia, thiamine deficiency, electrolyte imbalance and early protein malnutrition; infections and ulcers *(28,75,78)*; and mechanical problems such as enlarged pouch and disrupted staple lines *(29)*. Three surgery-related mortalities were reported in one study, resulting from protein energy malnutrition, pulmonary oedema and acute necrotizing pancreatitis *(75)*. Weight regain was reported in seven patients in two studies *(27,28)*.

Cost–effectiveness of surgical options in children and adolescents

The only systematic review of the literature on the effectiveness of child and adolescent bariatric surgery (in 2007) concluded that there was insufficient evidence on which to base a comprehensive cost profile of surgical options for paediatric obesity management *(45)*. Since then, only one study examining the cost of bariatric surgery in children has been identified *(85)*. This paper was concerned with modelling the costs of paediatric obesity interventions in comparison with other forms of treatment and prevention of obesity in childhood. It took cost data from a series of 28 patients who had LAGB and gave an average estimated cost of AU$ 31 553 per child (approximately US$ 24 330 or €18 000), exclusive of future cost savings.

These findings are comparable with those reported for adults, although most cost analyses of bariatric surgery appear to have been performed in an American setting, and thus may have limited relevance to European countries with universal health care coverage. One study based in Wisconsin analysed the inpatient hospital discharge data from 1990 to 2003 and concluded that rate and costs of weight loss surgeries had increased dramatically and the incidence of postoperative complications was high *(86)*. In a more recent study, a large employer claims database was analysed for bariatric surgery patients and related costs from 1999 to 2005; the authors found that third-party payers could expect bariatric surgery to pay for itself through decreased comorbidities within two to four years *(87)*.

A recent systematic review and economic evaluation of the clinical effectiveness and cost–effectiveness of bariatric surgery for obesity modelled economic evaluations of bariatric surgery. Based on these, the authors concluded that bariatric surgery was cost-effective compared with non-surgical treatment, but noted that the variability in estimates of costs and outcomes is large and the methodological shortcomings of such models are numerous, making it difficult to provide generalizable estimates of cost–effectiveness of bariatric surgery in comparison with non-surgical treatment *(9)*.

While children and adolescents might benefit from a longer lifetime with associated lower medical costs, lack of data does not permit accurate quantification of lifetime costs and thus calculation of cost–effectiveness ratios.

Summary of recommendations from existing reviews on child and adolescent weight loss surgery

Several papers *(9,15,23,24,44,45,83,88–93)* have made recommendations and clinical guidelines for child and adolescent weight loss surgery, although these are based to a great extent on the data sources presented in the current evidence review, which are underpowered and generally of poor quality. A cross-comparison of recommended BMI thresholds for bariatric surgery in young people demonstrates the great variability across recommendations. They range from “extreme obesity” *(15,23,83,90)* to “morbid obesity” *(45,89)*, “a BMI ≥ 40 or ≥ 35 with significant comorbidity” *(44,88)*, “severe obesity” *(93)*, “a BMI > 40 and one or more comorbidities” *(92)*, “a BMI > 50 or > 40 with significant comorbidity” *(91)*, to “a BMI > 95th percentile with significant comorbidity or a BMI > 99th percentile” *(94)*.

Several reviews concluded that bariatric surgery results in effective or clinically significant weight loss: one 2005 review concluded that weight loss surgery can be a safe and effective treatment option for carefully selected adolescents with severe obesity and serious related comorbidities *(93)*. Another review conducted by the Ontario Medical Advisory Secretariat in 2005 referred to LAGB as safe and effective *(89)*. A more recent review (2009) concluded that RYGB is a safe and effective

option for extremely obese adolescents as long as there is appropriate long-term follow-up provided, and that adjustable gastric banding and sleeve gastrectomy should be considered investigational. Other surgical interventions such as biliopancreatic diversion and duodenal switch procedures cannot be recommended in adolescents because of the substantial risks of protein malnutrition, bone loss and micronutrient deficiencies *(23)*. These recommendations may reflect the varying levels of expertise with specific types of bariatric surgical procedure across countries.

The only systematic review of the literature on the effectiveness of child and adolescent bariatric surgery *(45)* concluded that LAGB and RYGB for morbidly obese patients (aged 21 or younger) can result in sustained and clinically significant weight loss compared with non-operative approaches, however, the evidence is insufficient to conclude on quantitative estimates of the precise amount of weight loss. Moreover, compared with non-surgical approaches, LAGB and RYGB can help to resolve comorbid conditions such as diabetes and hypertension, although there is not enough evidence to conclude on quantitative estimates of the likelihood of comorbidity resolution, quality of life improvement and survival, or on potential impacts of bariatric surgery on growth and development *(45)*.

Many reviews recommend a cautious approach, however, citing lack of sufficient evidence on adverse effects and a potential for raised risk of postoperative morbidity, weight regain and mortality as a basis for limiting the use of paediatric bariatric surgery to clinical trials only. Guidance from the American Society for Bariatric Surgery in 2004 suggested that, after a thorough medical and psychological assessment, adolescents must have decisional capacity, participate in the decision process and have parental support. In particular, the need for lifelong care must be emphasized to the patient and their family. The authors stressed the importance of collecting and analysing long-term and non-traditional paediatric bariatric surgical data *(88)*. A recent (2009) review of the clinical effectiveness and cost–effectiveness of bariatric surgery for obesity *(9)* found no published studies on clinical effectiveness of surgical intervention for obesity in young people that met the inclusion criteria of the review.

There are several reviews with particular relevance to European countries. In 2005, a European Expert panel, the “Bariatric Scientific Collaborative Group”, was created with representation from the major European scientific societies active in the field of obesity management. The panel published clinical guidelines on surgery for severe obesity, recommending that surgery in children and adolescents (including those with genetic syndromes) could be considered in centres with a multidisciplinary approach and extensive experience with adult bariatric surgery. The recommended criteria for eligibility for surgery included BMI > 40 (or 99.5th percentile for respective age) and at least one comorbidity; more than six months of organized weight-reducing

attempts in a specialized centre; skeletal and developmental maturity; capability to commit to comprehensive medical and psychological evaluation before and after surgery; willingness to participate in a postoperative multidisciplinary treatment programme; and access to a hospital unit with specialist paediatric support (nursing, anaesthesia, psychology, postoperative care) *(37)*. In 2006, the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom produced clinical guidelines on obesity prevention and treatment *(41)*, which suggested consideration of bariatric surgery for young people only in exceptional circumstances, and if they have achieved or nearly achieved physiological maturity.

Recent guidance published in 2010 in Australia and New Zealand *(32)* and in Israel *(39)* in 2009 cited a minimum age of 15 and 13, respectively, for bariatric surgery eligibility. Recommended criteria for eligibility included comprehensive preoperative psychological, social, educational and family assessment; multidisciplinary surgical team with paediatric expertise; regular postoperative dietetic monitoring; and a postoperative audit to collect data on outcomes, complications, quality of life, nutritional status and comorbidities in both the short and long term.

Discussion

The results clearly indicate a much more limited evidence base for bariatric surgery in children compared with adolescents, and in obese adolescents compared with their morbidly obese counterparts. Distinguishing between these groups is further justified by the fact that childhood BMI is associated with adiposity in adulthood, and the magnitude of this correlation increases with the age at which the childhood measurement is obtained *(95)*. Furthermore, the accuracy of childhood BMI as an indicator of body fatness increases with the degree of adiposity *(95)*. This suggests that perhaps age and degree of obesity should be considered on a continuum when making recommendations for bariatric surgery use.

Bariatric surgery is promoted as a treatment option for children and adolescents for several reasons, as outlined above, but these also generate some controversy. Proponents in the surgical community suggest that the procedure is justified by weight loss results from clinical trials in adults and that surgery should form part of a multidisciplinary paediatric weight management strategy to address life-threatening comorbidities seen in morbidly obese children. They add that, in practice, most adult bariatric centres already perform adolescent surgery *(96)*. In principle, treatment risks are accepted when the benefits of treatment outweigh the risks of inaction. So the use of bariatric surgery in paediatric weight management is needs-related not age-related: that is, when the risks of chronic comorbidities outweigh the risks of surgery at any age.

However, most children do not exhibit severe weight-related comorbidities that are associated with significant mortality and morbidity in the short term. For the majority of morbidly obese children, therefore, the risk–benefit ratio of bariatric surgery is extremely difficult to assess. The question arises whether we can be confident that the profound weight loss outweighs the long-term risk of iatrogenic endocrine injury, particularly when the obesity-related health risks for a child do not force immediate surgical intervention? *(63,97)* In contrast, it is claimed that behavioural therapy approaches to weight management have been demonstrated to be more effective for children and adolescents than for adults *(98)*.

Unique challenges of children and adolescents

Children and adolescents have distinctive metabolic, developmental and psychological needs, which must be carefully considered to avoid the inappropriate use of weight loss surgery. In particular, there are several areas of concern, as outlined below.

Complications

Researchers and practitioners point to the high risk of serious operative and postoperative complications and mortality *(18)*. Comparatively higher morbidity and mortality associated with gastric bypass have led to increased use of gastric banding in the United States, particularly for morbidly obese adolescents *(98)*. Clinical evidence demonstrates that complications are directly related to the experience of the surgical team *(99)*. A 2006 study that assessed insurance claims for 2522 adult bariatric surgeries at more than 300 hospitals in the United States identified a significant high complication rate during the six months after surgery (data not typically reported in the literature), resulting in costly readmissions and emergency department visits in nearly 40% of patients *(100)*.

Nutrition

Bariatric procedures increase the risk of malnutrition, through either malabsorption or decreased nutrient intake, although the risk is lower with restrictive procedures *(101)*. With LAGB, these are related to reduced intake of food, and with RYGB are related to both reduced intake and mild malabsorption as a result of bypassing the stomach (diminishing gastric digestion) and the duodenum (a main site for calcium and iron absorption) *(83,102)*. Nutritional complications are particularly important considerations for young patients because of their long life expectancy and reproductive capacity. Patients who have had gastric bypass are at risk of vitamin deficiencies because excess weight loss is rapid during the first year after surgery, and the altered gastrointestinal anatomy reduces absorption of several micronutrients, including iron, calcium and vitamin B_{12} *(103)*. Even patients with restrictive surgeries may suffer from malnutrition because of reduced food intake and lack of improvement in diet quality. The consumption of calorifically dense liquids in obese adolescents raises a concern that restriction alone may not be sufficient for the extremely obese adolescent *(99)*.

Compliance

The ultimate success of all bariatric procedures depends on a patient's ability to adhere to a markedly changed and reduced diet. Given the propensity for some adolescents to rebel against strict regimens, continued support must be available to

all of these patients. Postoperative vitamin and mineral supplementation is critical. All non-steroidal anti-inflammatory medications should be avoided *(104)*. After surgery, patients are typically prescribed a multivitamin and monitored periodically for nutrient deficiencies; in younger patients, ability to cooperate with postoperative dietary restrictions and comply with medical requirements may be reduced *(96)*. Adolescents have a variable but low rate of adherence to supplementation and, therefore, may potentially be at higher risk for development of nutritional deficiencies *(105)*.

Family

Given the close association of excess weight in children with excess weight in their parents, it is important to recruit parents into any weight management plan. Bariatric surgery requires the active participation, understanding and consent of the patient and relevant caregivers. However, there are ethical concerns with obtaining paediatric consent. While adolescents are increasingly seeking bariatric surgery for justifiable health reasons, most children are not fully capable of participating in weight loss surgery treatment decisions, nor of comprehending and adhering to the critically important dietary and activity plan needed postoperatively for lifelong success *(13)*. Patient follow-up is important to success for maximal weight loss with the LAGB *(106)*, and parental involvement may be essential to ensure attendance *(107)*.

Growth and development

Surgical timing is controversial for a number of reasons: pubertal development and growth, neuroendocrine and skeletal maturation, sexual development and psychological maturity. There is potential for as-yet-unknown chronic complications *(93)*, although it is assumed that controlled weight loss would not lead to any change in normal growth or maturation *(108)*. Normal growth and development may be affected by rapid weight loss or nutrient deficiencies induced by surgery, but may also be affected by severe excess weight. More evidence is needed in this area. Developmental stage dictates children's control over food choices and involvement in physical activity. Weight management that requires strict, unpalatable activities or schedules may be harder to maintain during changing developmental stages *(109)*.

Lifespan

Children and adolescents have an entire lifetime ahead of them, indicating the need for careful, lifelong, medical supervision of those who undergo bariatric procedures *(13)*. Some procedures have a limited lifespan: in particular, use of the gastric band creates a potential need for reoperation to replace *(13)*. Fertility generally increases after weight loss in adults; however, the potential effect of procedures on future

reproductive ability and pregnancy outcome are unknown. Preliminary data suggest that quality of life and depressive symptoms after RYGB in adolescents dramatically improve, moving close to the level in normal controls *(67,101)*.

Metabolic consequences

In adults, the loss of fat mass, particularly visceral fat, is associated with multiple metabolic, adipokinetic, and inflammatory changes that include improved insulin sensitivity and glucose disposal, reduced free fatty acid flux, increased adiponectin levels, decreased interleukin 6, tumour necrosis factor-alpha and high-sensitivity C-reactive protein levels. Metabolic effects resulting from bypassing the foregut include altered responses of ghrelin, glucagon-like peptide-1 and peptide YY3–36, gut hormones involved in glucose regulation and appetite control *(110)*. In adults, these metabolic changes may be responsible for improvements in comorbidities; however, this has not been studied in children. There is evidence that in younger patients metabolic complications of surgery are potentially greater *(96)*. Surgeries involving removal or bypass of the acid-producing portion of the stomach profoundly decrease circulating ghrelin concentration *(111,112)*. There is evidence to suggest an important role for ghrelin in somatic growth and bone mineralization in childhood that is almost certainly relevant to growing children. It is not known whether the endocrine system of a developing child, which is dependent upon normal production of growth hormone and numerous other hormones, has the capacity adapt to a significant and chronic reduction in ghrelin levels following malabsorptive surgery *(63)*. Adolescence is a time of unusual insulin resistance as part of the normal physiological processes associated with puberty. Obesity amplifies the situation markedly: for a similar fatness, adolescent obese children may have more profound degrees of metabolic abnormality than adults.

Comorbidities

Some reviews suggest that the greatest benefit may be achieved by the earliest intervention, in order to prevent a long duration of comorbidities. The duration of type 2 diabetes significantly predicts poor or incomplete resolution of diabetes after weight loss surgery in adults *(113–116)*. A delay in effective therapy means the condition is typically more severe and the risk of complications higher *(88,117)*. Other reviews suggest that conservative patient selection criteria should be considered for adolescents because, while many comorbidities of obesity can be documented in childhood and adolescence, the severity of these complications for the majority of obese adolescents may not justify surgical intervention for minors *(118)*. Distinguishing the effects of dietary changes from those of weight loss on improvement of comorbid disease conditions is difficult. Weight loss can be assumed to be responsible for mechanical improvements, such as reduced weight

bearing on joints, improved lung compliance and reduced bulky fatty tissue around the neck, which relieves obstruction to breathing *(90)*. As in adults, glycaemic control in patients with diabetes improves almost immediately after RYGB, preceding any significant weight loss. This suggests alterations in gastric hormones that augment insulin secretion may be altered by gastric bypass *(83)*.

Issues requiring further investigation

- *Clear care criteria.* Pre-requirements for surgeons and multidisciplinary teams in centres performing bariatric procedures in adolescents, as well as pre- and postoperative care criteria for this age group must be determined.
- *Rates of weight loss associated with different bariatric procedures.* Slower rates of weight loss associated with gastric banding compared with other surgical interventions highlight the need for long-term monitoring and data collection to compare the efficacy of procedures and ensure the most beneficial results.
- *Sensitive approaches for subpopulations.* Profound metabolic and medical disturbances present in some children despite quite modest increases in obesity. For example, children of some ethnicities appear to have dramatically worse adolescent type 2 diabetes, linked to evidence of higher risk of type 2 diabetes in Asians compared with Whites for a given BMI level *(119)*. There are also questions concerning the value of surgery for young people with monogenic obesities (e.g. with mutations affecting melanocortin 4 receptor or leptin receptor) or syndromic obesity. While an individual approach in these situations is important, it makes the standardization of procedures and selection of patients for randomized trials very difficult.
- *New clinical classifications of obesity.* Reliance on BMI as a primary tool for clinical assessment and care is problematic; the classic adult BMI cut-off points for categorizing patients are even less reliable when used in younger adolescents, and comorbid conditions are an important consideration. Alternative approaches should be considered, such as the obesity staging system proposed by Sharma and Kushner, which describes the morbidity and functional limitations associated with excess weight *(120)*.

Conclusions

The existing evidence, although based primarily on small-scale retrospective or observational studies, suggests that bariatric surgery in severely obese adolescents results in the majority experiencing significant weight loss and improvements in comorbidities and quality of life. However, surgical complications in this age group remain a concern, and the evidence base is not sufficient to permit mortality rate calculations and assess whether mortality for this population is more or less likely than it is for adults. Furthermore, compliance and follow-up may be more problematic in adolescents than adults, and evidence for the long-term safety, effectiveness and cost–effectiveness remains largely unavailable *(18)*. Studies involving older, severely obese adolescents are more common than ones with children and youth at lower BMI values, and conclusions about the former group are better supported than those for the latter.

Long-term metabolic and psychological consequences of bariatric surgery may differ between adolescents and adults. Effective surgical intervention earlier in the life of a morbidly obese person may be preferable to delayed intervention after decades of exposure to the health effects of morbid obesity. There are many other unresolved questions emerging from the limited evidence at hand.

- Is a standard approach best or will distinct paediatric subpopulations (characterized by age, ethnicity, degree of obesity, type of comorbidity, etc.) benefit from specific bariatric procedures?
- To what extent can we extrapolate adult results to children and adolescents?
- Are improvements in quality of life and comorbidities derived from surgery-induced weight loss long lasting?
- What are the predictors of success and safety with bariatric surgery?
- What is the most appropriate timing for bariatric surgery in young people?
- What is the likelihood of risk-taking behaviour after successful weight loss?
- What is the durability of weight loss?

The resolution of these issues requires long-term prospective studies to establish safety and efficacy of surgical procedures and to clarify whether reductions in morbidity and mortality outweigh the risks of serious surgical complications and lifelong nutritional deficiencies *(18)*. The relatively small number of adolescent bariatric procedures performed suggests that multicentre research and coordination between adult and adolescent bariatric programmes will be necessary for better

quantification of benefits and risks of early surgical intervention for adolescent morbid obesity. Cooperation is needed to ensure better multicentre data and the development of general guidelines *(92)*.

While bariatric surgery may be appropriate for adolescents who are severely obese, there is still an urgent need to develop alternatives to surgery, such as practical lifestyle programmes that are effective, even modestly, for overweight and obese children *(121)* to inhibit progression to greater degrees of obesity. Public health experts must continue to employ the precautionary principle to convince governments of the importance of implementing health-promoting public policies to support primary prevention programmes and adequate long-term research for treatment.

Annex 1. Search strategy

Scientific and biomedical literature

The present review was based upon a bibliographic search of databases, concluded on 19 April 2010.

Databases

The PubMed and Cochrane Library databases were searched, using keywords (and roots of keywords) as set out in the search terms below.

Search terms

#1. obes*[TIAB] OR overweight*[TIAB] OR weight loss[TIAB] OR weight reduc*[TIAB] OR BMI[TIAB] = 172,843

#2. child[TIAB] OR children[TIAB] OR adolescen*[TIAB] OR pediatr*[TIAB] OR paediatr*[TIAB] = 909,583

#3. bariatric[TIAB] OR gastric surgery[TIAB] OR gastroplasty[TIAB] OR gastrectomy[TIAB] OR gastric bypass[TIAB] OR jejunoileal bypass[TIAB] OR gastrointestinal diversion[TIAB] OR gastrointestinal surgery[TIAB] OR biliopancreatic diversion[TIAB] OR biliopancreatic bypass[TIAB] OR gastric band*[TIAB] OR gastrectomy[TIAB] OR gastroenterostomy[TIAB] OR LAGB[TIAB] OR stomach stapl*[TIAB] OR lap band*[TIAB] OR lap-band*[TIAB] OR roux-en-y[TIAB] OR malabsorptive procedure[TIAB] OR malabsorptive surgery[TIAB] OR restrictive surgery[TIAB] OR restrictive procedure[TIAB] OR duodenal switch[TIAB] OR antiobesity surgery[TIAB] OR weight loss surgery[TIAB] OR weight reduction surgery[TIAB] OR surgery[TIAB] OR surgical[TIAB] = 973,334

#4. **#1** AND **#2** AND **#3 = 903**

#5. cost[TIAB] OR cost-effective[TIAB] OR econom*[TIAB] OR financ*[TIAB] OR ICER[TIAB] = 306,845

#6. **#1** AND **#3** AND **#5 = 507**

Selection criteria

Inclusion. Peer-reviewed research studies, meta-analyses and reviews of the literature about the effects of surgical interventions to treat obesity in children and adolescents; cost–effectiveness of surgical interventions to treat obesity; Danish, English, French, Norwegian, or Spanish language.

Exclusion. Surgical interventions to treat obesity in adults; clinical guidelines, reviews and commentary on surgical interventions to treat adult obesity; studies with subjects > 19 years of age; follow-up time less than one year; reporting combined results for different procedures; no pre- and postoperative weight measure; no postoperative weight loss measure.

Grey literature

A review was undertaken of major documents and web sites of governments, health councils and advisory and expert groups.

Institutional libraries

NICE – National Institute of Clinical Excellence (www.nice.org.uk); all guidance documents

IASO-IOTF – International Association for the Study of Obesity - International Obesity TaskForce (internal document repository)

Annex 2 Results tables

Table 2 *Results of studies employing laparoscopic adjustable gastric band*

Study (country)	Study type	No./age (years)[a]	Follow-up (months)[a]	Baseline BMI[a]	Postoperative BMI[a]	Adverse effects[b]
Abu-Abeid et al. 2003 (Israel) *(57)*	CO	11/15.7 (range, 11–17)	23	46.6 (range, 38–56.6)	32.1	NR
Al-Qahtani 2007 (Saudi Arabia) *(52)*	RR	51/16.8 (range, 9–19)	16 (range, 3–34)	49.9 (range, 38–63)	NR	Yes
Angrisani et al. 2005 (Italy) *(53)*	RR	58/17.96 (SD, 0.99; range, 15–19)	Range, 0–84	46.1 (SD, 6.31; range, 34.9–69.25)	35.9 (SD, 8.4) at 1 year (n = 48) 37.8 (SD, 11.27) at 3 years (n = 37) 34.9 (SD, 12.2) at 5 years (n = 25) 29.7 (SD, 5.2) at 7 years (n = 10)	Yes
Dillard et al. 2007 (USA) *(54)*	RR	24/18 (SD, 2; range, 14–20)	Range, 3–48	49 (SD, 10; range, 38–81)	43 (SD, 10; range, 28–75) at 3 months (n = 24) 42 (SD, 13; range, 25–75)at 6 months (n = 16) 40 (SD, 13; (range, 26–75)at 12 months (n = 14) 35 (SD, 10; range, 24–47) at 18 months (n = 8) 37 (SD, 6; range, 30–41) at 2 years (n = 3) 38 (SD, 9; range, 30–50) at 3 years (n = 4) 43 (SD, 14; range, 33–53) at 4 years (n = 20)	Yes
Dolan & Fielding 2004 (Australia) *(56)*	CO	17/16.5 (range, 12–19)	Median 25 (range, 12–46)	43.1 (range, 30.3–70.5)	30.4 (range, 22.6–39.4)[c]	Yes

Study (country)	Study type	No./age (years)[a]	Follow-up (months)[a]	Baseline BMI[a]	Postoperative BMI[a]	Adverse effects[b]
Fielding & Duncombe 2005 (Australia) *(55)*	RR	41/range, 12–19	33.8 (SD 19; range 1–70)	42.4 (range, 31–71)	29 (SD, 6; range, 23–47)	Yes
Holterman et al. 2010 (USA) *(60)*	PLT	20/16 (SD, 1; range, 14–17)	29 (SD 9; range, 15–42)	50 (SD, 10; range, 39–74)	mean reduction, 8.5 (SD, 5) at 12 months (n = 20) mean reduction 9.4 (SD, 5.4) at 18 months (n = 12)	Yes
Nadler et al. 2009 (USA) *(61)*	Trial	45 (12-month data for 41)/16.1 (SD, 1.2; range, 14–17)	Range, 12–24	48 (SD, 6.4)	36.3 (SD, 7.5) at 12 months (n = 45) 35.8 (SD, 7.9) at 24 months (n = 41)	Yes
O'Brien et al. 2010 (Australia) *(22)*	RCT	LAGB, 25/16.5 (SD, 1.4) Lifestyle, 25/16.6 (SD, 1.2)	24	45.2 (SD, 7.6; range, 32.5–76.7)	32.6 (SD, 6.8)	Yes
Silberhumer et al. 2006 (Austria) *(58)*	CO	50/17.1 (SD, 2.2; range, 9–19)	34.7 (SD 17.5; range, 3.6–85.4)	45.2 (SD, 7.6; range, 32.5–76.7)	32.6 (SD, 6.8)	Yes
Yitzhak et al. 2006 (Israel) *(59)*	CO	60/16 (range, 9–18)	39.5	42.7 (range, 35–61)	30 (range, 20–39)	Yes

Notes: [a]Presented as mean unless otherwise indicated; [b]Complications, reoperation, mortality; [c]Calculated based on reported data; BMI: Body metabolic index (kg/m^2); LAGB: Laparoscopic adjustable gastric band; NR: Not reported; SD: Standard deviation.

Study type: CO: Cohort study; PLT: Prospective longitudinal trial; RCT: Randomized controlled trial; RR: Retrospective review.

Table 3. *Results of studies employing Roux-en-Y gastric bypass (laparoscopic or open)*

Study (country)	Study type	No./age (years)[a]	Baseline BMI[a]	Follow-up (months)	Postoperative BMI[a]	Adverse effects[b]
Fowler et al. 2009 (USA) *(65)*	CS	1/17	56.8	14	32; mean reduction, 24.8	NR
Inge et al. 2010 (USA) *(70)*	LS	61/17.2 (SD, 1.88)	60.2 (range, 41.4–95.5)	12	37.7[c]; mean reduction, 37.4%	Yes
Lawson et al. 2006 (USA) *(26)*	RMS	Surgery, 39/ range,13–21 Non-surgical, 12/range 13–21	Surgery, 56.5 (range, 41.9–95.5)	> 12	Surgery, 35.8 (range, 26.7–52); mean reduction, 20.7 (range, 3.3–43.5); $p < 0.001$	Yes
Leslie et al. 2008 (USA) *(69)*	CS	1/12.8	48	36	25; mean reduction, 23	Yes
Loux et al. 2008 *(67)*	LS	16/18.6 (SD, 1.7; range, 14–20)	54.1 (SD, 7.6)	17.1 (mean; SD, 12.3)	35.1 (SD, 9.3); mean reduction, 9	NR
Stanford et al. 2003 (USA) *(68)*	RR	4/range 17–19	55.14 (range, 45–66)	17 (mean)	34.8; mean reduction, 20.3 (range, 22–55)	NR
Strauss et al. 2001 (USA) *(62)*	RR	10/16 (range, 15–17)	52.4 (range, 41.4–70.5)[c]	68.8 (mean; (range, 8–156)	35.2[c]; mean reduction, 17.2 (range, 26.9–52.8)	Yes
Towbin et al. 2004 *(66)*	CS	3/15.3 (range, 14–17)	59.9 (range, 56.2–63.4)	5 (mean; range, 4–6)	38.9; mean reduction, 21 (range, 16.4–26.6)	Yes

Notes: [a]Presented as mean unless otherwise indicated; [b]Complications, reoperation, mortality; [c]Calculated based on reported data; BMI: Body metabolic index (kg/m^2); NR: Not reported; SD: Standard deviation.

Study type: CS: Case study; LS: Longitudinal study; RMS: Retrospective multicentre study; RR: Retrospective review.

Table 4. *Results of studies employing other surgical interventions*

Study (country)	Study type	Intervention	No./age (years)[a]	Baseline BMI[a]	Follow-up (months)	Postoperative BMI[a]	Adverse effects[b]
Baltasar et al. 2008 (Spain) *(71)*	CS	LSG	1/10	42	9	27	NR
Barnett et al. 2005 (USA) *(27)*	RR	VBG (n = 7), RYGB (n = 5), JIB (n = 3)	14/15.7 (range, 13–17)	55.1 (SD, 14.8)	72 (mean; range, 9–261)	Mean reduction, 24 (SD, 13.8) (n = 9)	Yes
Breaux 1995 (USA) *(64)*	RR	VBG (n = 5), RYGBP (n = 14), BPD (n = 4)	22 (11 with sleep apnoea, 11 without)/ range, 8–18	62 (range, 41.3–105)	36	Initial sleep apnoea, 46.5 at mean of 32 months (n = 11) No initial sleep apnoea, 35.5 at mean of 50 months (n = 11)	Yes
Capella & Capella 2003 (USA) *(76)*	CO	VBG–RYGB	19/range, 13–17	49 (range, 38–67)	66 (mean; range, 12–120)	28 (range, 23–45)	Yes
Dan et al. 2010 (Trinidad & Tobago) *(72)*	CS	LSG	1/6	53.2	12	33.33	NR
Fatima et al. 2006 (USA) *(74)*	RC	Mostly RYGB, some VBG	12/≤ 18	55 (range, 39–74)	48 (mean; range, 12–96)	36 (range, 27–53)	None
Leon et al. 2007 (Ecuador) *(73)*	CS	LSG	1/12	44.2	12	29	NR
Mason et al. 1995 (USA) *(29)*	CO	VBG	47/18.1 (SD, 1.84)	48.4 (SD, 6.9)	0–120	36.2 (SD, 5.99) at 5 years (n = 25) 39.2 (SD, 7.15) at 10 years (n = 14)	Yes
Papadia et al. 2007 (Italy) *(75)*	RR	BPD	68/16.8 (range, 14–18)	46 (range, 26–71)	132 (mean; range, 24–276)	NR	Yes

Study (country)	Study type	Intervention	No./age (years)[a]	Baseline BMI[a]	Follow-up (months)	Postoperative BMI[a]	Adverse effects[b]
Sugerman et al. 2003 (USA) *(28)*	RR	HG (n = 1), VBG (n = 2), GBP (n = 17), distal GBP (n = 3), long-limb GBP (n = 10)	33/16 (SD, 1; range, 12.4–17.9)	52 (SD, 11; range, 38–91)	0–168	36 (SD, 10) at 1 year (n = 31) 33 (SD, 11) at 5 years (n = 20) or 29 (SD, 5) if 5 with weight regain excluded 34 (SD, 8) at 10 years (n = 14), or 30 (SD, 4) if 5 with weight regain excluded 38 (SD, 16) (n = 6) at 14 years, or 31 (SD, 2) if 1 with weight regain excluded	Yes
Till 2008 (Germany) *(77)*	CO	LSG	4/14.5 (range, 8–17)	48.4 (range, 40.6–56.3)	12 (mean; range, 6–19)	Mean reduction, 9.2	Yes
Velhote & Damiani 2008 (Brazil) *(78)*	CS	SGE	10/16.3 (range, 14–19)	51.7 (range, 44–72)	12	32.8 (range, 27–47); mean reduction, 83.9%	Yes
Widhalm et al. 2008 (Austria) *(79)*	CO	LAGB (n = 7), SR (n = 2), GBP (n = 1)	10/17.3 (SD, 30	49.1 (SD, 6.8; range, 40.6–63.7)	LAGB, 44 (SD, 10) SR, 32 (SD, 1) GBP, 8 (reoperation) (SD, 3)	Mean reduction 10.33 at 41months:	Yes

Notes: [a]Presented as mean unless otherwise indicated; [b]Complications, reoperation, mortality; BMI: Body metabolic index (kg/m^2); NR: Not reported; SD: Standard deviation.

Study types: CO: Cohort study; CS: Case study; RC: Retrospective cohort; RR: Retrospective review.

Surgical interventions. Banding: LAGB: Laparoscopic adjustable gastric band; Gastroplasty: VBG: Vertical banded gastroplasty; HG: Horizontal gastroplasty; Bypass: GBP: Gastric bypass; RYGB: Roux-en-Y gastric bypass; Gastrectomy: SR: Sleeve resection; LSG: Laparoscopic sleeve gastrectomy; SGE: Sleeve gastrectomy with entero-omentectomy; Other: BPD: Biliopancreatic diversion; JIB: Jejunoileal bypass.

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Abstract

The prevalence of childhood and adolescent obesity in the WHO European Region has risen in recent decades. Obesity in this population is linked to increased risk factors for cardiovascular diseases, type 2 diabetes, sleep apnoea and psychological distress. While bariatric surgery is seen as an effective intervention under clear conditions for obese adults, the indications for medical and surgical treatment of overweight and obese children are still not well defined. Moreover, children and adolescents have distinctive metabolic, developmental and psychological needs, which must be carefully considered to avoid the inappropriate use of weight-loss surgery.

This review looks at the effectiveness and cost–effectiveness of surgical interventions for overweight and obese children and adolescents, and finds that the majority of relevant studies are methodologically limited and long-term data remain largely unavailable. Some evidence suggests that bariatric surgery in severely obese adolescents can result in significant weight loss, and improvement in co-morbidities and quality of life. A conservative approach to child and adolescent bariatric surgery is warranted until further long-term prospective studies on the subject are conducted, so there remains an urgent need to develop alternatives to surgery, such as lifestyle programmes that are even modestly effective.

This Health Evidence Network (HEN) evidence report is part of a series designed to synthesize key and high quality evidence from existing reviews, in order to be used to inform policy-making. These reports are initiated by the HEN team in response to a policy issue or question of interest to one or more Member States in the WHO European Region. HEN is part of the Division of Information, Evidence, Research and Innovation's (DIR) programme on Evidence and Information for Policy (EIP).

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