Treatment of adolescent obesity
Katharine S. Steinbeck1, Natalie B. Lister1,2, Megan L. Gow2 and Louise A. Baur1,3 *

Abstract | The increased prevalence of adolescent obesity and associated short-term and long-term complications emphasize the need for effective treatment. In this Review, we aim to describe the evidence for, and elements of, behaviour management and adjunctive therapies and highlight the opportunities and challenges presented by obesity management in adolescence. The broad principles of treatment include management of obesity-associated complications; a developmentally appropriate approach; long-term behaviour modification (dietary change, increased physical activity, decreased sedentary behaviours and improved sleep patterns); long-term weight maintenance strategies; and consideration of the use of pharmacotherapy, more intensive dietary therapies and bariatric surgery. Bariatric surgery should be considered in those with severe obesity and be undertaken by skilled bariatric surgeons affiliated with teams experienced in the medical and psychosocial management of adolescents. Adolescent obesity management strategies are more reliant on active participation than those for childhood obesity and should recognize the emerging autonomy of the patient. The challenges in adolescent obesity relate primarily to the often competing demands of developing autonomy and not yet having attained neurocognitive maturity.

Adolescence is one of the most rapid phases of human development, associated with marked physical, neurodevelopmental, psychological and social changes. The WHO defines an adolescent as a young person in the second decade of life (10–19 years)1. Adolescent obesity has become a globally prevalent health problem affecting young people from low-income and middle-income countries, as well as those from high-income countries2–4. FIGURE 1 shows the trends in obesity for children and adolescents aged 5–19 years from different regions over 40 years from 1975 to 2016 [REF. 3]. A widening social disparity is recognized in economically advanced countries, with an increased prevalence of obesity in more socially disadvantaged adolescents compared with adolescents from higher socioeconomic groups5. Additionally, growing evidence indicates that the prevalence of severe or morbid obesity is increasing in this age group in several countries, including the United States and Australia5–7.

Obesity in adolescence is often complicated by psychosocial distress and can be associated with a range of other health problems; the normal neurobiological development that occurs in this age group also has a considerable effect1. Furthermore, the rate of spontaneous remission of obesity to a healthy weight is low; at least 90% of adolescents with obesity will have overweight or obesity in young adulthood8–9.

For all these reasons, both the prevention and the treatment of adolescent obesity are important. In this Review, we focus on obesity treatment and detail the evidence for, and elements of, behavioural management, the use of adjunctive therapies (such as more intensive dietary therapies, pharmacotherapy and bariatric surgery) and the management of the metabolic complications of obesity such as insulin resistance and polycystic ovaries. The opportunities and challenges presented by the management of obesity specifically in adolescents are highlighted.

Clinical assessment
A thorough clinical history and physical examination of the adolescent is essential to assess current obesity-associated complications, the risk of future complications and whether the patient has any modifiable lifestyle practices. It is beyond the scope of this Review to provide further details on clinical assessment, and readers are referred to recent reviews and clinical guidelines for additional information10–14. Key recommendations for history-taking and physical examination are outlined in BOXES 1, 2.

Factors that affect management
Neurocognitive development
The pace of brain development in adolescence and into young adulthood is second only to that of early childhood15. Pruning of previous synaptic proliferation to optimize neural networks and increasing myelination of nerve fibres for rapid neural messaging are important for the development of mature and efficient neural networks. The maturation of the emotional brain

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Key points

- The preferred treatment approach for adolescent patients with obesity includes management of obesity-associated complications, a developmentally appropriate approach, support for long-term behavioural change, long-term weight maintenance strategies and consideration of other therapies.
- Long-term weight maintenance therapy, through face-to-face or electronic support, phone coaching or group programmes, is likely to be required.
- Bariatric surgery should be considered in adolescents with severe obesity (BMI >40 kg/m\(^2\), or >35 kg/m\(^2\) in the presence of complications), and patients should be treated in centres experienced in bariatric surgery.
- Pharmacotherapy should be used as adjunctive therapy, particularly in the maintenance of weight loss, and for the treatment of obesity-associated complications.
- Clinicians should understand where the adolescent is in puberty development — age does not equal stage — and not support beliefs that young people will grow out of obesity with the onset of puberty.
- Clinicians must work within the contexts of both the normal rapid changes in adolescent brain development and the psychosocial tasks of adolescence that are necessary for mature adulthood.

with its associated reward-seeking, hyperexcitability and proneness to impulse occurs in mid-adolescence (14–16 years). The development of the prefrontal cortex, which is responsible for planning, organization, risk versus benefit assessment and the ability to delay immediate gratification for future gain, occurs later with final maturation in the mid-20s\(^1\) and has important implications for the management of adolescent obesity.

Choices based on emotion or impulse, difficulty in consistently following through with action plans, inability to comprehend future health risks, the need to be like their peers (which makes lifestyle change challenging) and the need to be independent (which reduces responsiveness to adult directives and advice as a result of prefrontal cortex immaturity\(^1\)) are all likely to derail attempts at lifestyle change. The concept that lifestyle change programmes for adolescents need to be formulated differently from those of adults now has a strong neurocognitive rationale and an emerging clinical trial evidence base\(^7,18\).

Puberty

Puberty is an early adolescent event that results in dramatic changes in body composition and has long-term implications for health and well-being\(^1\). Puberty might have both positive and negative effects on weight management. Positives include increasing lean body mass in males and, for both sexes, if obesity management is undertaken before the height growth spurt, then the caloric deficit induced with weight maintenance in a situation where weight would naturally increase with height increase results in reduced adiposity. Negatives include increasing adiposity in females as a result of gonadal hormones and, in both sexes, the possibility that the insulin resistance that occurs during puberty (related in part to increased secretion of growth hormone) might persist after puberty is complete if there are other drivers such as obesity present\(^32,21\). These factors need to be taken into account when managing individuals with obesity.

Stigmatization

Weight stigmatization is widespread and leads to psychological, social and physical health consequences. Discussion of the causes and effects of weight bias and stigmatization are beyond the scope of this Review, and readers are referred to recent reviews for further details\(^22–25\). Health-care professionals have an important role in reducing the negative effects of obesity stigmatization. The American Academy of Pediatrics recommends that clinical care can be improved through role modelling, using appropriate language, good clinical documentation and ensuring a safe and welcoming environment\(^22\). Elements of behavioural health screening and behaviour change counselling, as outlined in more detail in subsequent sections, can identify and address weight-based victimization to improve outcomes.

Overview of treatment principles

Effective obesity treatment in adolescents can be defined in various ways, including a reduction in BMI or weight outcomes, improvement in obesity-associated complications, a reduction in markers of risk of future complications or a changed weight gain trajectory. In adult studies, effectiveness is often categorized into ‘success’ or ‘failure’; however, no standard definition of effectiveness exists\(^26,27\), and different criteria have been used between and within studies to classify weight maintenance or regain. Calculations can also include initial weight, initial weight loss, postintervention weight, postintervention weight change or final weight. In adolescents, dichotomizing success is even more difficult given the need to normalize measures for age and sex in adolescents aged <18 years (hence the frequent reporting of BMI z-scores) and the variability in the reporting of treatment outcomes. A systematic review and meta-regression published in 2016 reports how weight loss in children and adolescents translates to favourable cardiometabolic outcomes\(^19\) (such as blood pressure and HDL cholesterol levels), which might be more clinically meaningful than weight loss perse.

Findings from systematic reviews

The 2017 Cochrane Review on diet, physical activity and behavioural interventions for the treatment of obesity in adolescents aged 12–17 years included 44 randomized controlled trials (RCTs) with follow-up periods of 6–24 months\(^17\). A range of trials that mostly used multibehavioural change interventions were included in the review, with no specific programme being recommended over another. A meta-analysis of studies comparing intervention groups versus wait-list or no-treatment control groups showed that, at the longest follow-up period, there was a mean reduction in BMI of −1.18 kg/m\(^2\) (95% CI −1.67 to −0.69), in BMI z-score of −0.13 units (95% CI −0.21 to −0.05) and in body weight of −3.67 kg (95% CI −5.21 to −2.13). The effect on weight outcomes persisted in those trials with longer follow-up periods of 18–24 months, a finding that is somewhat at variance with those from studies in adults, which show more weight regain\(^21\).

The authors of the Cochrane Review noted that, where measured, there were improvements in percentage
Improvements in quality of life, although not in self-esteem, were also noted at the longest follow-up. However, outcomes for dietary intake and physical activity were inconsistent across the included studies. The review reported no subgroup differences in interventions with or without parental involvement or by intervention type, setting (such as school, clinic or community) or mode of delivery (group versus individual). The overall quality of evidence for the primary outcomes of interest was rated as low, except for body weight, which was rated as moderate. Adverse effects were only infrequently reported and hence could not be reliably assessed.

The findings of this most recent systematic review add to the evidence base from previous reviews. The 2017 Cochrane Review did not report outcomes for cardiometabolic parameters from behavioural change interventions, although they were previously reported in a 2012 systematic review. This review showed that lifestyle interventions led to statistically significant improvements in levels of LDL cholesterol (−0.30 mmol/l, 95% CI −0.45 to −0.15), triglycerides (−0.15 mmol/l, 95% CI −0.24 to −0.07), fasting insulin (−55 pmol/l, 95% CI −71 to −39) and blood pressure (systolic −3.72 mmHg, 95% CI −4.74 to −2.69; diastolic −1.69 mmHg, 95% CI −3.15 to −0.24) up to 12 months from baseline.

Adapting the findings from such studies to ‘real-world’ obesity clinics that might be more poorly resourced is often difficult. For example, in comparison with clinical trials, in usual clinical practice it might not be possible to review patients as frequently and sufficient specialist nursing, allied health or medical expertise might not be available. Further, the patients in usual clinical practice might have additional comorbidities or be more socially disadvantaged than those who participate in clinical trials, raising challenges in optimizing treatment adherence. Nevertheless, the principles of management are well recognized (Box 3).

Elements of treatment of obesity

Behavioural management

Behavioural strategies are routinely used to support changes in dietary intake, physical activity levels and sedentary behaviours and to facilitate long-term maintenance of these changes. Although most RCTs of adolescent obesity management include a behavioural component, these details are often inadequately described in publications. A 2015 evidence update of behavioural strategies for obesity treatment in children and adolescents identified much stronger evidence (‘well-established interventions’) in children than in adolescents for both parent-only interventions and family-based behavioural
treatments in which parents are specifically targeted to change their own behaviours and achieve weight loss. The update included 11 studies involving both children and adolescents undergoing behavioural weight-loss treatment with family involvement during which the parent facilitates the lifestyle changes. Nine of these studies demonstrated improvements in weight outcomes compared with the control condition. The evidence for family-based interventions in adolescent-only interventions was, however, far more limited in that few studies looked specifically at adolescents. Overall, the authors rated the evidence for behavioural weight-loss treatment with family involvement in adolescents as “possibly efficacious” while commenting that treatment is optimized if parents are included in the treatment programme.

Several common behaviour change techniques are used in obesity treatment. Some commonly used techniques include goal-setting, stimulus control (modifying or restricting environmental influences)
### Box 2 | Notable findings on physical examination

**Skin or subcutaneous tissues**
- Acanthosis nigricans (neck, axillae, skin folds and over joints)
- Keratosis pilaris
- Acrochordons (skin tags)
- Hirsutism
- Acne
- Striae
- Pseudo-gynaecomastia in males
- Intertrigo with or without secondary infection
- Xanthelasmas (hypercholesterolaemia)

**Neurological**
- Papilloedema and/or reduced venous pulsations on fundoscopy (pseudotumour cerebri)

**Head and neck**
- Tonsillar size and obstructed breathing

**Cardiovascular**
- Hypertension
- Heart rate (cardiorespiratory fitness)

**Respiratory**
- Exercise intolerance
- Wheeze (asthma)

**Gastrointestinal**
- Hepatomegaly and hepatic tenderness (nonalcoholic fatty liver disease)
- Abdominal pain (secondary to gallstones or gastro-oesophageal reflux)

**Musculoskeletal**
- Pes planus
- Groin pain and painful or waddling gait (slipped capital femoral epiphysis)
- Lower limb arthralgia and restriction of joint movement

**Endocrine**
- Goitre
- Extensive striae, hypertension, dorsocervical fat pad or ‘buffalo hump’ (signs of Cushing syndrome)
- Pubertal staging
- Reduced growth velocity

**Psychosocial**
- Flat affect and low mood (depression)
- Poor self-esteem and social isolation

**Other — evidence of a possible underlying genetic syndrome**
- Short stature or disproportion
- Dysmorphism
- Developmental delay

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**Dietary interventions**

Following dietary interventions is effective for modest weight loss in adolescents with obesity. Caloric restriction is usually incorporated into multicomponent lifestyle-based interventions for weight management. Importantly, lifestyle interventions that include a dietary component can improve cardiometabolic outcomes in adolescents with obesity even in the absence of weight loss or changes in body composition.

Various dietary manipulations can achieve caloric restriction and resultant weight loss in adolescents, most commonly by using the ‘stop/traffic light approach’ but also by altering macronutrient distributions and/or improving carbohydrate quality. No dietary intervention has been shown to be optimal, and adherence to dietary protocols is the most effective predictor of weight loss. Dietary interventions with evidence of being effective for weight management are discussed in the following sections.

**Stop/traffic light approach.** This calorie-controlled intervention categorizes foods according to caloric density and uses these groups to guide intake frequency (FIG. 2). Low-calorie foods are labelled ‘green’ and can be eaten freely, moderate-calorie foods are labelled ‘yellow’ and should be eaten judiciously and high-calorie foods are labelled ‘red’ and should be eaten rarely. This approach can produce effective weight loss (BMI decreases range from 0.18 to 2.6 kg/m²) in adolescents in the short to medium term (6 months to 2 years).

**Macronutrient distribution.** Altering the macronutrient ratio of a calorie-restricted diet is purported to improve dietary adherence, weight-loss outcomes and cardiometabolic measures. Common diet interventions have different macronutrient distributions (FIG. 3). Conventional interventions are typically referred to as ‘low fat’ and aim for <35% daily energy from fat. A low-carbohydrate diet, aiming for <50 g carbohydrate per day, has often been compared to a low-fat approach; however, a 2014 systematic review found no evidence that either approach was more effective for long-term weight loss in adolescents. Even so, low-carbohydrate diets might provide some benefit for short-term weight loss (BMI decreases from baseline range from 1.2 to 5.2 kg/m²) and insulin concentrations (the decrease in fasting insulin levels from baseline range from 6.0 to 7.5 μU/l) compared with low-fat interventions. In longer-term studies of >12 months, weight loss was not significantly different, possibly owing to eventual migration to a more typical carbohydrate intake.

Increasing protein from a typical 15% of daily energy in conventional diets to 20–40% of daily energy has no demonstrated benefit for weight loss in adolescents under isocaloric conditions. Increasing protein intake is hypothesized to improve satiety and reduce hunger, thereby resulting in a lower ad libitum energy intake and greater weight loss. However, studies in free-living adolescents demonstrate that achieving higher dietary protein targets is difficult, which might contribute to the lack of effect of increased levels of dietary protein in adolescents. The unique challenges to dietary compliance...
Reviews

Obesity50. However, the long-term (>12 months after diagnosis) in newly diagnosed adolescents with type 2 diabetes mellitus (T2DM) in newly diagnosed adolescents with obesity. Nutrient analysis show that, over a 7-day period (3 days restricted to ~2.5–2.9 MJ or 600–700 kcal), intermittent energy-restricted meal plans can be designed to meet adolescents' unique micronutrient requirements47. More intensive dietary therapies (including the provision of meals) and the neurocognitive development issues outlined in a previous section.

Carbohydrate quality. Glycaemic index (GI) and glycaemic load are used to describe carbohydrate quality. Although low-GI diets do not seem to confer any weight-loss benefit for adolescents, a 2015 systematic review found that lower-GI diets improved insulin resistance (HOMA index mean difference of −0.70, 95% CI −1.37 to −0.04, P = 0.04) and triglyceride concentrations (mean difference −15.14 mg/dl, 95% CI −26.26 to −4.00, P = 0.008)45. The major limitation with manipulating GI to improve carbohydrate quality is that lower-GI foods do not always translate to ‘healthy’ options; for example, high-fat discretionary foods such as ice cream and potato chips have a low GI.

Intermittent fasting. Over the past decade, intermittent energy-restricted diets have gained popularity as a weight-loss approach in adults45,46. Limited evidence is available for their use in adolescents; however, these diets have been used in clinical practice. Dietary modeling and nutrient analysis show that, over a 7-day period (3 days restricted to ~2.5–2.9 MJ or 600–700 kcal), intermittent energy-restricted meal plans can be designed to meet adolescents’ unique micronutrient requirements47.

More intensive dietary therapies
A very-low-energy diet (VLED) is an intensive dietary regimen, typically consisting of <800 kcal per day, with <50 g of carbohydrate and adequate provision of micronutrients often being achieved using meal replacements such as shakes and bars. Owing to the difficulty of achieving the strict calorie prescription, this diet is typically recommended only for short periods of time (8–12 weeks)48.

In adolescents with obesity, a VLED can safely induce rapid weight loss in the short term (4–15 kg over 3–12 weeks) while preserving lean body mass49,50. VLEDs also lead to short-term improvements in common metabolic risk factors44,46. Published in 2016, a small pilot study demonstrated that VLED reversed type 2 diabetes mellitus (T2DM) in newly diagnosed adolescents with obesity50. However, the long-term (>12 months after completion of VLED) outcomes remain unclear. The severe nature of the diet requires intensive monitoring by health professionals; however, these diets could be an alternative to pharmacological therapies or surgical interventions to treat adolescents with severe obesity.

Eating behaviours
An emerging area of research is the role of eating behaviours in obesity, defined as “self-perceived behaviour and attitudes towards eating behaviour and food” (Ref. 51), which could partly explain the different responses to dietary interventions seen in patients. Longitudinal data on eating behaviours and weight gain are limited, and few intervention studies directly assess more than one eating behaviour53. In adolescents, prescriptive dietary advice consisting of hypocaloric nutrition coaching by a trained dietician can normalize eating behaviours in the short to medium term54. However, more data are needed to prospectively examine the long-term effects of dietary interventions on the eating behaviours of adolescents.

Physical activity
Adolescent obesity is associated with suboptimal physical activity levels, poor fitness and excessive time in sedentary behaviours55. Despite the certain contributions to energy deficit, the specific weight-reducing effect of the physical activity component of a lifestyle intervention in adolescents with obesity is not clear. However, physical activity is still an integral part of obesity treatment owing to the additional health benefits attained through regular exercise, including improved body composition, psychological profile and functional capacities55–62 (FIG. 4). Physical activity is also associated with improvements in the cardiometabolic profile of an adolescent with obesity, including improved insulin sensitivity, blood pressure and cholesterol levels55–62. Hence, regular physical activity has an important role in preventing the development of the metabolic syndrome and T2DM in adolescents with obesity, irrespective of a change in weight. One systematic review comparing diet-only with diet-plus-exercise or an exercise-only intervention found that, although weight loss was not different between the groups, the addition of exercise training to a dietary intervention led to a greater improvement in levels of HDL cholesterol and fasting insulin concentrations in the short term (over 6 months) than a diet-only programme59.

Several national guidelines recommend that all adolescents partake in at least 60 minutes of daily moderate-to-vigorous physical activity and that no more than 2 h per day is spent using electronic media for entertainment (for example, computer games, TV and Internet)53–66. However, few adolescents achieve these targets55. This challenge is exemplified in adolescents with obesity, who often report negative peer experiences around exercise56 and have reduced exercise tolerance, which presents a barrier to participation in physical activity owing to the early onset of fatigue57. Reduced capacity to perform basic physical functioning tasks, including walking and climbing stairs, has led to obesity in adolescents being described as a disability58. Exercise capacity in adolescents with obesity can be enhanced through

Box 3 | Principles of obesity treatment

- Assess and manage obesity-associated disorders
- Ensure a developmentally appropriate approach
- Support long-term behaviour change
- Dietary change
- Increased physical activity
- Decreased sedentary behaviours, including screen behaviours
- Improved sleep
- Strategies for long-term weight maintenance
- Consider more intensive dietary interventions
- Consider pharmacotherapy
- Consider bariatric surgery

During adolescence are not well defined in the literature but include peer influences, reliance on parental support (including the provision of meals) and the neurocognitive development issues outlined in a previous section.

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Box 4 | Examples of common behavioural change techniques

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<th>Goal-setting — performance goals</th>
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<tr>
<td><em>“I will decrease my discretionary screen time from 6 h per day to 4 h over the next month. I will do this by moving my cell phone out of my room at night (I will charge it in the family room) and by agreeing to move my laptop to the family room. When I have done this, I will work out some new screen time goals.”</em></td>
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<tr>
<td><em>“I will go to bed an hour earlier on school nights (11 pm instead of midnight). I will do this by charging my cell phone in the family room overnight.”</em></td>
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<td><em>“I will get an extra half hour of physical activity into my day. I will do this by catching the train and bus to and from school instead of asking my parents to drive me. I will also ask my friend to go to the school gym with me twice a week after school.”</em></td>
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<th>Goal-setting — outcomes goals</th>
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<tr>
<td><em>Specific weight-loss goals (amount of weight loss or reduction in waist circumference over a specified time), developed in consultation with the therapist</em></td>
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<tr>
<th>Self-monitoring</th>
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<tr>
<td><em>Daily monitoring and recording of physical activity via pedometer or other activity monitor</em></td>
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<tr>
<td><em>Daily recording of screen time</em></td>
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<tr>
<td><em>Daily recording of eating habits (for example, eating breakfast and eating lunch) or of specific food intake (for example, vegetable intake and soda drink intake)</em></td>
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<td><em>Weekly recording of weight</em></td>
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<th>Stimulus control</th>
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<tr>
<td><em>Parent agrees to not offer to drive the young person to school</em></td>
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<tr>
<td><em>Television, laptops, cell phones and other mobile devices are out of the bedroom at night</em></td>
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<tr>
<td><em>Parent and young person agree to not store unhealthy foods (for example, processed snack foods and soda drinks) in the house</em></td>
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<tr>
<td><em>Parent agrees to serve evening meal using smaller-sized plates</em></td>
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<tr>
<td><em>Parent agrees to have a family rule about eating the evening meal at the table without the television being on</em></td>
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By increasing adolescents’ participation in physical activity, it is anticipated that a flow-on effect will occur, resulting in reduced recreational screen time. However, both issues need to be addressed. A recreational screen time allowance of 2 h per day is increasingly difficult to implement given the prominence and accessibility of digital technologies. Effective interventions for reducing screen time in adolescents with obesity are still needed. Utilization of technologies, such as smartphone apps, is a popular avenue of research in this area.

Sleep behaviours

Cross-sectional studies show an association between short sleep duration and an increased risk of overweight or obesity in children and adolescents, with a pooled odds ratio of 1.89 (95% CI 1.43–1.68) for short sleep duration (different definitions used in the various studies, including <5 h, <6 h and <10 h) and obesity being noted in a systematic review of 12 studies. In a systematic review of 22 longitudinal studies, an inverse association was found between short sleep duration and subsequent BMI in both children and adolescents. On the basis of adult studies, interventions targeting sleep in the management of adolescents with obesity might result in improved weight and body composition outcomes. Trial data in adolescents are limited, and no trials have been conducted in young people already affected by obesity. Strategies might include an earlier adolescent bedtime, removal of electronic screen devices from the bedroom and family rules about exposure to screens before bedtime. Importantly, targeting sleep has additional benefits in terms of general health, mood, school performance and quality of life.

Digital technologies

High-quality studies using digital technologies to manage obesity are lacking. A 2017 meta-analysis of all mobile health interventions in youth concluded that these “appear to be a viable behaviour change intervention modality for youth” (REF). Digital technologies represent a promising area of future clinical research in adolescent obesity, including apps and activity trackers as lifestyle monitors. Apps and activity trackers can give instant feedback on levels of physical activity, sleep and active versus sedentary time, with little input required from the user. Popular apps are also used for tracking diet or providing healthy food alternatives. Technologies including image or photo upload of foods and/or barcode scanning are designed to minimize the time required for input from the user and enable instant feedback on dietary intake or advice on more appropriate choices. However, the capacity of such devices to assist weight loss is not yet clear, with a study published in 2016 demonstrating that adults randomly assigned to the ‘wearable device’ (activity tracker) arm achieved less weight loss at 24 months than those in the control arm. Furthermore, these technologies will never replace a clinician, but they might be a useful tool to enhance motivation and assist in weight-loss maintenance, particularly in adolescents, who generally enjoy digital devices. Discoveries from research in mental health provide support for the use of the Internet to deliver interventions. In order to be engaging and to be considered for long-term use, such interventions (including apps) should be co-designed with adolescents and undergo regular updates. Their commercial viability is questionable.

Long-term weight outcomes

Few high-quality trials report long-term outcomes of obesity treatment in adolescents, as opposed to children. However, in a large central European health-care database from 157 paediatric specialist centres managing obesity (patients aged 5–25 years), 2-year outcomes were reviewed for 3,135 patients. Compared with children aged 5–11 years, adolescents aged 12–15 years had a 41% lower odds of successful weight reduction and maintenance, defined as a decrease in BMI z-score of at least 0.2 from baseline. These findings emphasize the importance of early treatment of established obesity. In a 12 month and 24 month follow-up of adolescents participating in a trial of two different types of dietary intervention, weight loss in the first 3 months predicted long-term weight outcomes, a finding consistent with those from other studies. Such studies suggest that interventions with a focus on early weight loss might have better outcomes than interventions started after the patient has had obesity for some time.
In adults, a comprehensive weight maintenance programme is recommended for those who have had initial weight loss. This programme might entail continued support from a therapist, via phone or face to face, possibly on at least a monthly basis for ≥12 months. The sustainability of such an approach in usual health-care settings and the applicability to the adolescent population remain unclear. However, given the importance of digital technologies to young people, this might prove to be of relevance in weight maintenance strategies.

Pharmacotherapy
In the long term, safe anti-obesity drugs must be a therapeutic goal given that the condition is chronic and lifestyle therapies have had limited results. Current anti-obesity agents are universally limited in both number and availability, with few subsidized by government agencies (Table 1). Trials are mostly performed in adults, and use in adolescents is often off-label. A 2016 Cochrane Review provided data for trials of current (and some previously available) anti-obesity agents in children and adolescents. The authors also identified ongoing trials for topiramate and glucagon-like peptide 1 receptor (GLP1R) agonists. Metformin and orlistat both result in a reduction in weight in favour of the active intervention, albeit around 2 kg. The review also describes a greater overall attrition rate for adolescents than reported in adult trials. Metformin and orlistat are available for adolescent use in most jurisdictions, although use of metformin generally remains off label in those without diabetes mellitus.

Some antidepresants have weight loss as a benefit but are not first-line obesity pharmacotherapies. In some countries, bupropion is used as an antidepressant and in others it is licensed only for addiction therapies. When bupropion is combined with naltrexone as a slow-release preparation, there is benefit compared with placebo for weight loss. The data for topiramate’s effect on body weight in adults are positive but compromised by adverse effects such as dizziness and drowsiness.

Topiramate is currently marketed for epileptic seizures and migraine and could be considered in adolescents with obesity who fulfill prescribing criteria. Topiramate has been trialled for weight loss in adults in combination with phentermine, with a significant dose-dependent percentage change in body weight of 7–9% compared with placebo. However, a pilot RCT in 30 adolescents consisting of 24 weeks of topiramate following 4 weeks of meal replacement therapy did not result in significant BMI reduction.

Glucagon-like peptide 1 (GLP1) is a naturally occurring incretin produced by the gut. GLP1R agonists were originally marketed for the treatment of T2DM. An additional effect is appetite suppression and weight loss, and obesity management has become an additional indication for the use of this drug class. In adults, the effects of liraglutide, which is approved for weight loss in many countries as a once-a-day injection, are impressive compared with the effects of standard oral anti-obesity therapy. Published in 2017, the results of an RCT showed that the oral GLP1R agonist semaglutide had a statistically significant effect on weight loss of 2–7 kg as well as control of diabetes mellitus in participants with T2DM and a mean age of 57 years. This finding suggests that oral therapy is a future, adolescent-attractive weight-loss option. In a pilot RCT, 3 months of exenatide therapy in 26 adolescent patients with severe obesity led to a greater percentage reduction in BMI, as well as absolute weight and BMI, than placebo.

Bariatric surgery
In adults, bariatric surgery is a well-recognized form of therapy for severe obesity as an adjunct to behavioural therapy and pharmacotherapy. The role of bariatric surgery in adolescents is being established.

Evidence for bariatric surgery
To date, there has been only one published RCT of bariatric surgery in adolescents: an Australian study of 50 patients aged 14–18 years (25 patients in both the intervention and the comparator groups). The study compared laparoscopic adjustable gastric banding (LAGB) with a multicomponent lifestyle programme. At 2 years, weight in the surgery group was reduced by a mean of 34.6 kg (95% CI 30.2–39.0) compared with 3.0 kg (95% CI 2.1–8.1) in the lifestyle group. Although both groups had improvements in the quality-of-life subscore of general health, the surgical group had better performance in four additional subscores (physical functioning score, self-esteem, family activities and change in health score), with no difference between the groups for three other subscores. Revisional procedures were required in 28% of the surgical group. The authors commented that although this incidence is within the range of other studies, there might be a need, in adolescents, for additional education and supervision of eating to ensure they eat small meals slowly. This approach might help reduce the need for revision. This study was the only one included in the 2015 Cochrane Review of bariatric surgery in adolescents.

A systematic review with broader inclusion criteria than the 2015 Cochrane Review investigated...
indicate overlap between the percentage energy contributions. The purple and green areas
manipulated to achieve an energy intake level for weight loss. The purple and green areas
The percentage of energy contributions from carbohydrate, protein and fat can be
Fig. 3 | Macronutrient distribution of common diet interventions39,42,43.
The percentage of energy contributions from carbohydrate, protein and fat can be
surgical and nutritional complications, to determine whether weight and cardiometabolic risk improvements
are maintained well into adulthood and to identify which patients benefit most from surgery99.

Clinical guidelines
Consensus guidelines on bariatric surgery in adolescents have been established by various medical professional
bodies in several countries11,94–101. In terms of patient characteristics, the recommendations generally cover: a
minimum age, usually in mid-adolescence; the patient to have reached sexual maturity; the presence of severe obe­
sity, usually BMI >35 kg/m² with an obesity-associated complication, or BMI >40 kg/m²; the persistence of obe­
sity despite involvement in a formal multidisciplinary programme of lifestyle modification and pharmacother­
apy; the patient being able to give informed consent; and the adolescent and family being willing to partici­
active in the treatment programme and agreeing to ongoing review following the surgery.

Recommendations generally specify that the sur­
Recurrence locally for the type of sur­
When treating complications, it might be appropriate to manage these when
the need to ensure equitable access to such services for
affected adolescents, because, in most health systems,
bariatric surgery remains largely available only in the
sector, and bariatric surgery services for adoles­
ents are sparse10. Thus, specific strategies for the pro­
vention of bariatric surgery for adolescents in the public
sector are likely to be needed in most jurisdictions.

Treatment of complications
Many obesity-associated complications, such as dys­
lipidaemia, fatty liver disease and elevated blood pres­
sure, will improve following weight loss. Nevertheless,
depending on the type and severity of such complica­
tions, it might be appropriate to manage these when
identified and not to wait until weight loss has occurred,
as weight loss might be difficult to achieve101.

During adolescence, the prevalence of individual
obesity-associated complications increases, as does the clustering of such complications. In addition, adoles­
eces see the emergence of components of the meta­
bolic syndrome and the development of sex-specific
differences in risk factors for cardiovascular disease102.

No long-term data are available in contemporary cohorts
that enable quantification of future combined or specific risk of obesity-associated complications or the cost of that risk.

Multiple definitions of the metabolic syndrome in adolescence exist, all of which have agreed core elements — obesity, dyslipidaemia, abnormal glucose metabolism and hypertension — but these vary in the specifics of cut points and reference standards. The International Diabetes Federation definition, which uses age-specific cut points for the core metabolic elements listed above for 10–16 years of age (adult cut points for those >16 years) and which specifies abdominal obesity as defined by waist measure, is probably the most common in use. Concerns about which definition to use, or whether the metabolic syndrome is present or not, should never impede management of the individual components. The prevalence of the metabolic syndrome rises over the decade of adolescence and might be present in up to 50% of adolescents with obesity, depending on both the definition used and the population being studied.

Medication doses used in the treatment of obesity-associated complications will be closer to adult recommendations given their body weight. An important adolescent proviso is that some of these medications are not considered safe in pregnancy, and countries vary in their labelling of safety recommendations. Many drugs recommended for the treatment of metabolic morbidity in obesity have not been trialled in the reproductive age group; studies of safety in pregnancy will never be undertaken and translating animal exposure results to humans is not always reliable. Given that these newer medications remain the optimal choice for treatment of metabolic complications of obesity, a more nuanced approach than previously used is being advocated by the FDA, which introduced a new labelling system, the PLLR (Pregnancy and Lactation Labelling), published in 2016. The European Medicines Agency is due to release its updated pregnancy guidelines for consultation in 2018. The categorization system of the Australian Therapeutic Goods Administration (TGA), which provides currently accessible and regularly updated ratings for some common medications used in the management of obesity and its complications.
### Medications for the management of obesity and its complications

<table>
<thead>
<tr>
<th>Name</th>
<th>Indication</th>
<th>Comments</th>
<th>Safety in pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orlistat</td>
<td>Obesity</td>
<td>Inhibits gut lipase with resulting steatorrhoea with high-fat meals — easy to manipulate</td>
<td>B1</td>
</tr>
<tr>
<td>Phentermine</td>
<td>Obesity</td>
<td>Sympathomimetic amine that has addictive potential. Rejected by some agencies in its combination with topiramate owing to mental health and cardiovascular system concerns</td>
<td>B3</td>
</tr>
<tr>
<td>Topiramate</td>
<td>Obesity</td>
<td>If epilepsy or severe migraine are present, this fulfils prescribing indications. If prescribed off-label, cost might be prohibitive</td>
<td>D</td>
</tr>
<tr>
<td>GLP1R agonists</td>
<td>Obesity</td>
<td>Mostly by daily injection. Nausea and vomiting are significant adverse effects</td>
<td>B3</td>
</tr>
<tr>
<td>Metformin</td>
<td>Type 2 diabetes mellitus, prediabetes and insulin resistance, polycystic ovary syndrome, acanthosis nigricans and adjunctive treatment for weight loss</td>
<td>Gastrointestinal upset if not up-titrated slowly. Induces ovulation; consider contraception needs. Monitor vitamin B₁₂ levels.</td>
<td>Approved for use (C)</td>
</tr>
<tr>
<td>Statins</td>
<td>Hypercholesterolaemia (LDL cholesterol)</td>
<td>No data on long-term adverse effects, including myopathy and increased risk of type 2 diabetes mellitus</td>
<td>Teratogenic in animals, but risk appears lower in humans (D)</td>
</tr>
<tr>
<td>ACE inhibitors and ARBs</td>
<td>Hypertension and diabetic nephropathy</td>
<td>Single daily dose and low adverse effect profile improve compliance</td>
<td>Might increase malformation risk and pregnancy loss in second and third trimesters (D)</td>
</tr>
<tr>
<td>SSRIs</td>
<td>Depression and anxiety in which talking therapy is not successful</td>
<td>Package warnings that these antidepressants may increase risk of suicidal ideation and behaviours</td>
<td>C</td>
</tr>
<tr>
<td>COCP</td>
<td>Polycystic ovary syndrome: lower oestrogen doses and newer gestagens have fewer adverse effects</td>
<td>COCP-induced weight gain is disputed. Contraindicated in paralytic migraine or thromboembolism</td>
<td>B3</td>
</tr>
</tbody>
</table>

Australian categories for prescribing medicines in pregnancy: the Australian Therapeutic Goods Administration (TGA) system is currently accessible and regularly updated, providing ratings from A (the safest drugs to take during pregnancy; no known adverse reactions) to D (adverse reactions have been found in humans)\(^\text{110}\). The TGA system provides guidance that aims to assist both clinicians and the women who use the medications and is reliable evidence-based information for patients who use the Internet for health advice. Health professionals should refer to the TGA website for further information (Australian Government Department of Health). Practitioners should also be aware of local approvals and prescribing rules for medications in pregnancy. ACE, angiotensin-converting enzyme; ARBs, angiotensin receptor blockers; COCP, combined oral contraceptive pill; GLP1R, glucagon-like peptide 1 receptor; SSRIs, selective serotonin reuptake inhibitors.

Concentrations of triglycerides >5 mmol/l, and if lifestyle change is ineffective and aggravating factors are excluded, omega-3 fatty acids, niacin or fibrates should be trialled\(^\text{122}\).

Elevated blood pressure is defined as blood pressure (adjusted for age, sex and height) >90th percentile to <95th percentile or 120/80 mmHg (whichever is lower), stage 1 hypertension is blood pressure >95th percentile to <90th percentile + 12 mmHg, or 130/80 to 139/89 mmHg (whichever is lower) and stage 2 hypertension is blood pressure >95th percentile + 12 mmHg, or >140/90 mmHg (whichever is lower)\(^\text{123}\). Pharmacotherapy should not be withheld if weight loss does not occur. The updated 2017 American Academy of Pediatrics guidelines\(^\text{123}\) provide a management guide and discussion around drug choices.

The Endocrine Society’s Clinical Guideline for polycystic ovary syndrome\(^\text{124}\) considers adolescents separately. The diagnosis should be based on clinical and/or biochemical hyperandrogenism in the presence of persistent oligomenorrhoea and should not rely on multicystic ovarian change, which might be developmentally normal. Although obesity and insulin resistance are present in most patients with polycystic ovary syndrome, insulin resistance at the receptor level is not present in the ovary, and high insulin concentrations drive ovarian androgen production and subsequent hirsutism and menstrual cycle disturbances. Metformin prescribed together with the combined oral contraceptive pill might ameliorate any weight gain associated with the use of combined oral contraceptives\(^\text{125}\).

**Access to health care**

One of the six major recommendations of the 2016 Report of the WHO Ending Childhood Obesity Commission was the provision of weight management services for both children and young people as part of Universal Health Coverage\(^\text{126}\). Given that health systems vary considerably between countries and that there is little published on obesity models of care in young people, there will be a range of challenges in the delivery of treatment services for this group. Importantly, the report highlighted the potential for weight bias by health professionals and hence the need for strategies to avoid stigmatization of young people with obesity.

Adolescent obesity can be managed in paediatric or adult care teams. Neither of these approaches is likely to

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\(^\text{126}\) One of the six major recommendations of the 2016 Report of the WHO Ending Childhood Obesity Commission was the provision of weight management services for both children and young people as part of Universal Health Coverage.
be optimal for adolescents, in whom health care is best served by clinicians with expertise in treating adolescents and young adults\textsuperscript{127}. Supported transitional care from paediatric to adult care has not been reported in the literature\textsuperscript{128}, which is of concern given the prevalence of obesity and the need for ongoing management to avoid further weight gain in young adulthood.

**Conclusions**

The importance of effective management of adolescent obesity is underscored by its high prevalence in many countries and the short-term and long-term impacts of the condition. Although the evidence base for the management of adolescent obesity is growing, more pragmatic clinical trials in young people are needed. These trials are needed because of the acknowledged challenges in conducting traditional RCTs at this developmental stage and in this condition and because pragmatic trials offer information that informs the real-world implementation of therapies. Additionally, improved data are needed on how best to manage young people with obesity who are from disadvantaged environments and those from low-income and middle-income countries. Finally, it is vital that obesity in young people is not dismissed as being too difficult to be addressed by clinicians. Instead, there should be a recognition of the WHO concept of adolescence as “a key decade in the life-course” where there is “a second chance in the second decade” to improve health outcomes and provide high-quality clinical services\textsuperscript{1}.

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**Skin**

- Skin tags might require physical removal. For intertrigo, keep dry and use topical antifungals. Metformin seems to be effective for acanthosis nigricans, but much of the evidence is case-based. Clinically, this effect might be positive for adolescents and metformin might assist in reduction in BMI in combined obesity treatment regimens.

**Lipids and other cardiovascular risk factors**

- Statins are suggested for nonfamilial hypercholesterolaemia if LDL cholesterol is >4.1 mmol/l and if additional risk factors are present, such as obesity, hypertension and diabetes mellitus. Concerns regarding long-term safety exist, and data in younger patients with secondary lipid disorders are lacking.

**Fatty liver**

- Weight loss is the only proven therapy. Insulin sensitizers and vitamin E have been used.

**Polycystic ovary syndrome**

- Metformin will produce a more regular menstrual cycle and induce ovulation, of which the adolescent should be warned. Weight loss, physical hair removal, and the combined oral contraceptive pill to suppress ovarian androgen production are all standard therapies. Weight gain induced by the combined oral contraceptive pill might occur in susceptible individuals.

**Skin**

- Skin tags might require physical removal. For intertrigo, keep dry and use topical antifungals. Metformin seems to be effective for acanthosis nigricans, but much of the evidence is case-based. Clinically, this effect might be positive for adolescents and metformin might assist in reduction in BMI in combined obesity treatment regimens.

**Obstructive sleep apnoea**

- The American Academy of Pediatrics Clinical Guidelines give the evidence for weight management in obstructive sleep apnoea as grade C. CPAP therapy should be initiated if symptoms and/or signs of objective evidence of obstructive sleep apnoea persist after adenotonsillectomy or if adenotonsillectomy is not performed (grade B). Intranasal glucocorticoids might also assist as adjuvant therapy.

**Hypertension**

- Preferred agents are thiazide diuretics and/or ACE inhibitors or angiotensin receptor blockers. Once-a-day dosing and a low adverse effect profile make these drugs particularly useful in adolescents.

**Insulin resistance, prediabetes and diabetes mellitus**

- Lifestyle intervention is essential in all three conditions. Metformin also has a role in all three conditions. Metformin is a first-line therapy for type 2 diabetes mellitus in adolescents, but medical instability at presentation might require insulin. Continuation of insulin use should be reviewed at regular intervals as weight gain, accompanied by worsening insulin resistance, is an undesirable effect of long-term therapy.

**Soft tissue injuries**

- Strength and balance training might be useful.

**Pes planus**

- Supportive shoes and orthotics.

**Affective disorders, depression and anxiety**

- Depression and anxiety increase in prevalence in adolescence, with a female preponderance. Treatment in adolescents with obesity is along standard lines. Fluoxetine is less likely to be associated with weight gain than the newer antipsychotics, which are associated with weight gain and insulin resistance, and should be avoided.

**Benign intracranial hypertension**

- Patients without visual defects are treated with acetazolamide, a carbonic anhydrase inhibitor.