Assessment and management of obesity in childhood and adolescence

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Abstract | The increased prevalence of obesity in childhood and adolescence highlights the need for effective treatment approaches. Initial assessments of these patients should include taking a careful history (investigating comorbidities, family history and potentially modifiable behaviors) and physical examination with BMI plotted on a BMI-for-age chart. The degree of investigation is dependent on the patient's age and severity of obesity, the findings on history and physical examination, and associated familial risk factors. There are several broad principles of conventional management: management of comorbidities; family involvement; taking a developmentally appropriate approach; the use of a range of behavior change techniques; long-term dietary change; increased physical activity; and decreased sedentary behaviors. Orlistat can be useful as an adjunct to lifestyle changes in severely obese adolescents and metformin can be used in older children and adolescents with clinical insulin resistance. Bariatric surgery should be considered in those who are severely obese, with recognition of the need for management in centers with multidisciplinary weight management teams and for surgery to be performed in tertiary institutions experienced in bariatric surgery. Finally, given the high prevalence and chronic nature of obesity, coordinated models of care for health-service delivery for the management of pediatric obesity are needed.

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Introduction

Over the past three decades, the prevalence of obesity in childhood and adolescence in most westernized countries, and, more recently, in countries undergoing economic transition, has increased substantially.[1,2] Countries that have reached a 30% combined overweight and obesity prevalence rate in boys or girls include those from the Americas (Canada, Mexico, USA), the Middle East (Bahrain, Kuwait, Qatar), and Europe (Italy, Portugal, Spain).[3] Very young children are also affected; in 2010, the WHO estimated that 43 million preschool-aged children (35 million in developing countries) were overweight or obese, with the worldwide prevalence having increased from 4.2% (95% CI 3.2–5.2%) in 1990 to 6.7% (95% CI 5.6–7.7%) in 2010.[4] A 2010 systematic review provides evidence of a plateauing of the prevalence of overweight and obesity in children and adolescents in western Europe, the USA, Japan and Australia, although prevalence rates continue to rise in many developing countries.[5]

Pediatric obesity can be associated with several immediate health problems, such as psychosocial distress, orthopedic disorders, insulin resistance and fatty liver disease, as well as a range of longer-term complications, including coronary artery disease, some cancers and premature mortality.[2,6,7] For these reasons, although prevention of obesity in young people is vital, so too is the effective treatment of those already affected.

Competing interests
The authors declare no competing interests.

In this Review, we provide an overview of the assessment and management of obesity in children and adolescents. The Review describes the presentation of obese young people to health-care settings, approaches to assessment (including history-taking, physical examination, anthropometry and investigations), conventional treatment approaches, nonconventional therapies (including pharmacotherapy and bariatric surgery), and models of health-service delivery. Note that discussion of primary prevention of childhood and adolescent obesity is beyond the scope of this Review.

Presentation to health-care settings

In US and Australian studies, children and adolescents who were overweight or obese presented more frequently to both primary and tertiary health-care providers than might be expected from the background prevalence of this condition, although they rarely presented primarily for the problem of obesity.[8–11] For example, 29.6% and 41%, respectively, of 2–18-year-old patients attending randomly sampled Australian general practices[9] or a large tertiary academic health-care system in Ohio, USA,[8] were overweight or obese, compared with background population prevalence rates of 23–25% for Australia and 34–37% in the USA. Unfortunately, such patients are unlikely to have the problem of obesity addressed by the clinician.[8,9,11] The 2007 US Expert Committee recommendations on childhood and adolescent obesity proposed that primary care providers should assess all patients aged 2–18 years for obesity

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Key points

- BMI (weight/height^2) should be plotted routinely on a BMI-for-age chart and provides a reasonable measure of body fatness in children and adolescents with obesity
- Conventional management for childhood and adolescent obesity includes: management of comorbidities; family involvement; developmentally appropriate approaches; behavior change techniques; long-term dietary change; increased physical activity; and decreased sedentary behaviors
- Pharmacotherapy for obesity is limited; orlistat can be used in conjunction with lifestyle changes in severely obese adolescents, while metformin can be used in older children and adolescents with clinical insulin resistance
- Bariatric surgery should be considered in severely obese adolescents, preferably with management in centers with multidisciplinary weight management teams and surgery performed in tertiary institutions experienced in bariatric surgery
- Coordinated models of care for health-service delivery for the management of pediatric obesity are needed

risk, and that those who were overweight or obese should be offered intervention (discussed below).[12] The practical effectiveness of such recommendations is yet to be evaluated.

Clinical assessment

History-taking

Taking a thorough clinical history is vital in the assessment of a child's or adolescent's current and potential future comorbidities, as well as for assessing their modifiable lifestyle practices.[12–16] Key elements of history-taking in children and adolescents with obesity are outlined in Box 1. Assessment of lifestyle factors should include both sides of the energy balance equation. When assessing food intake, establishing the pattern of eating (for example, whether breakfast is consumed regularly, family meal-time routines, snacking habits) is as important as having knowledge of the individual foods consumed. Assessment of physical activity includes both organized sports and incidental activities, such as walking to school, helping with chores and free play; gauging what activities the family participate in as a whole, especially for younger children, is also important. In addition, it is important to determine 'screen time'—the amount of time spent watching television, using computers (for leisure activities) and using gaming consoles—as it is an independent risk factor for childhood obesity[17] and could be a strategic area to target for intervention.

A careful psychosocial history-taking and assessment is required as psychological disturbance is one of the more common obesity-associated complications.[2,6] Although no English-language clinical guidelines recommend specific screening questions for psychological symptoms, they do highlight the importance of recognizing and managing psychological disorders in childhood obesity.[12,14–16] Depression can manifest as flat affect, low mood, fatigue, difficulty sleeping or anxiety. Such symptoms should prompt further psychological review.[12] A history of binge-eating or purging should alert the clinician to the possibility of an eating disorder.

Physical examination

Anthropometry

BMI is defined as weight (in kg) divided by height (in m), squared. Numerous expert groups have recommended BMI as the preferred routine clinical measure of overweight and obesity in children and adolescents over 2 years of age;[9,12,14–16] it correlates well with total body adiposity[18] and has reasonable specificity when used to define overweight and obesity.[18,19] BMI should be plotted against nationally recommended BMI-for-age charts, such as those from the US Centers for Disease Control and Prevention (Figure 1).[20] Some variations exist in the cut-off points used to define overweight and obesity worldwide, and hence readers are advised to check local recommendations. For example, in the USA and Australia, BMI values between the 85th and 94th percentile for age are defined as overweight, whereas those ≥95th percentile are defined as obese.[12,14] However, in the UK, the cut-off points for overweight and obesity are the 91st and 98th percentiles, respectively.[15,16]

Central fat distribution is associated with increased cardiometabolic risk in children, as in adults.[21] Waist circumference for age percentile charts are available for children in a number of countries;[22,23] however, no cut-off points have been established that identify those at the greatest risk of metabolic and cardiovascular complications. A waist circumference to height ratio >0.5 can identify central adiposity and its associated cardiovascular and metabolic risk in normal and overweight or obese school-aged children.[24,25] Some,[14,16] although not all,[12,15] national clinical guidelines recommend routine use of waist circumference measurements in the pediatric age group as an important adjunct to assessing a child's or adolescent's risk of complications.

Additional features

The physical examination is used to assess the child or adolescent for comorbidities associated with overweight and obesity. Signs of underlying genetic and/or endocrine disorders should also be sought and further investigated. Some of the important signs that can be seen on physical examination are outlined in Table 1.

Care should be taken when assessing and interpreting blood pressure in children and adolescents with obesity.[26] The patient should be seated in a relaxed state and an appropriately sized blood-pressure cuff should be used, avoiding one that is too small. Blood-pressure measurements should be compared with reference values based upon sex, age and height percentile.[27]

Insulin resistance is one of the more common complications of obesity and a multitude of symptoms and signs can be seen if present. For instance, the skin should be thoroughly examined for acanthosis nigricans, which is characteristic of insulin resistance and is typically seen on the neck, axillary region, skinfolds and over joints. Early acanthosis presents as additional skin pigmentation in the involved regions, but as it progresses, lesions become increasingly hyperkeratotic, taking on a velvety plaque appearance.[28,29] Ethnicity is an important variable, with darker-skinned people being more

likely to develop these skin changes in the presence of insulin resistance.[28,29]

The presence of short stature, reduced growth velocity or delayed puberty should encourage consideration of endocrine or genetic disorders, which are rare causes of pediatric obesity (<1% in a specialist clinic in Germany).[30] Some genetic syndromes, including Prader–Willi, Bardet–Biedl and Fragile X, can be associated with obesity.[31,32] Findings such as dysmorphism, developmental delay, hypotonia and hypogonadism should prompt further review.[30–32]

Investigations

The degree of investigation in any one child or adolescent is dependent on the patient's age and severity of obesity, the findings on history-taking and physical examination, and associated familial risk factors. The 2007 US Expert Committee recommends that children who are overweight (BMI 85–94th percentile) should have a fasting lipid screen and, if risk factors are present, serum levels of fasting glucose, alanine aminotransferase and aspartate aminotransferase should be measured every 2 years.[12] For those who are obese (BMI ≥95th percentile), the Committee recommends measurement of serum levels of fasting lipids, glucose, alanine aminotransferase and aspartate aminotransferase every 2 years regardless of risk factors.[12] Some other national guidelines also recommend measurement of fasting insulin levels, especially if assessment occurs in a secondary-level care setting.[14–16] Caution should be used in interpreting fasting insulin concentration: no clear cut-off points exist for defining insulin resistance; inter-assay and inter-laboratory differences occur during measurement; insulin has a pulsatile secretion and hence concentrations vary across the day; and, finally, insulin concentrations vary according to the stage of puberty.[33,34]

An oral glucose tolerance test might be required as a second-line investigation, as might further assessment of liver function (for example, liver ultrasonography and exclusion of other causes of liver dysfunction).[12,14–16] More detailed endocrinological assessment is usually not needed, unless other evidence of endocrine disease is observed, such as short stature, hirsutism or menstrual irregularities. Indeed, a prospective assessment of over 1,400 overweight children referred to a specialist clinic in Germany showed that endocrine and syndromal causes of obesity were all associated with clinical signs and none of the children with an endocrine disorder were diagnosed solely by means of a laboratory investigation.[30]

When obstructive sleep apnea is suspected in patients, referral for polysomnography is warranted.[14,35] A range of other investigations, including high-sensitivity tests for C-reactive protein and other markers of low-grade inflammation, could be useful in assessing childhood obesity, but are not as yet recommended for routine assessment by national clinical practice guidelines.[36]

Treatment strategies

The 2009 Cochrane Review on the treatment of pediatric obesity included 64 randomized controlled trials (RCTs).[37] No specific treatment program was recommended over another; however, positive outcomes were identified in several studies. Meta-analysis of studies in children under 12 years of age showed that family-targeted lifestyle intervention, involving various combinations of dietary, physical activity and behavior modification, led to a significantly greater reduction in BMI z-score at 6 months (–0.06; 95% CI –0.12 to –0.01) than did standard care, although the effect was small.[37] In adolescents, a similar finding was observed after meta-analysis of three studies: a –0.14 (95% CI –0.17 to –0.12) change in BMI z-score (and a –3.04; 95% CI –3.14 to –2.94 kg/m^2, change in absolute BMI) with family-based lifestyle intervention at 6 months compared with standard care or control.[37]

Box 1 | Key elements of history-taking in obese children and adolescents

General history

- Prenatal and birth history, including history of gestational diabetes and birth weight
- Infant feeding, including duration of breastfeeding
- Current medications, including glucocorticoids, some antiepileptic agents (e.g. sodium valproate) and antipsychotic drugs (e.g. risperidone, olanzapine)

Weight history

- Onset of obesity and duration of parental and child concerns about their weight
- Previous weight-management interventions
- Previous and current dieting behaviors

Complications history

- Psychological effects of obesity, including bullying, poor self-esteem and depression
- Sleep routine and presence of snoring or sleep apnea (e.g. lack of refreshment after sleep, daytime somnolence, witnessed apneas)
- Exercise tolerance
- Specific symptoms including: acne and hirsutism; morning headache and visual disturbance (potential benign intracranial hypertension); gastrointestinal symptoms (vomiting, abdominal pain, constipation, gastrointestinal reflux); nocturnal enuresis and daytime dribbling; hip and knee joint pain
- Menstrual history (girls), such as abnormal or irregular periods

Family history

- Ethnicity (high-risk groups for cardiometabolic complications include Native American, Hispanic, Maori and Pacific Islander, Australian Aborigine, South Asian, East Asian, Mediterranean and Middle Eastern populations)
- Family members with a history of: obesity; type 2 diabetes mellitus and gestational diabetes; hypertension, dyslipidemia and cardiovascular disease; obstructive sleep apnea; polycystic ovarian syndrome; bariatric surgery; eating disorders
- Home environment including: household members; parental relationship; parental employment, hours and home supervision

Lifestyle factors

- Diet and diet-related behaviors: breakfast consumption; eating patterns (including snacking, sneaking food, fast-food intake, binge-eating); beverage consumption (sodas, juice, other sugary drinks); family routines around food and eating
- Physical activity: transport to and from school; sports participation; after school and weekend recreation; family activities
- Sedentary behaviors: screen time per day (e.g. television, video game and computer use); number of televisions, computers and gaming consoles in the house and bedrooms; pattern of television viewing (e.g. during meals)

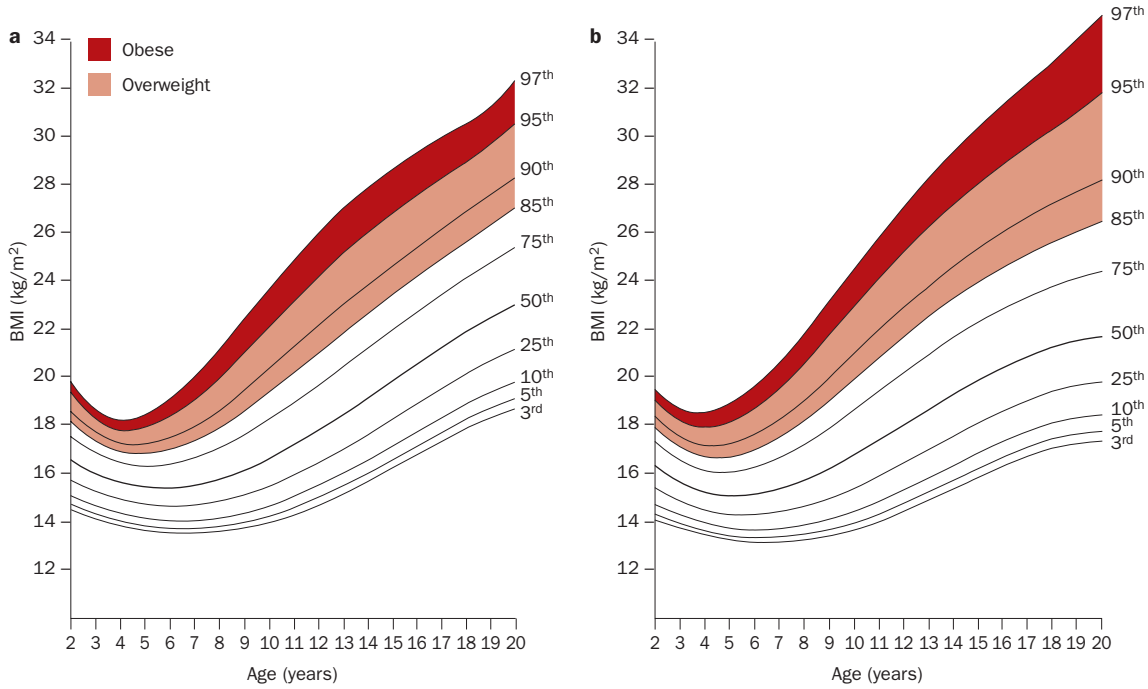

Figure 1 | BMI-for-age charts in boys and girls. **a** | BMI-for-age chart for boys aged 2–20 years. **b** | BMI-for-age chart for girls aged 2–20 years. Cut-off points used to define overweight and obesity in the USA are indicated on both charts. Parts a and b were developed and provided freely by the Centers for Disease Control and Prevention, from Kuczmarski, R. J. *et al.* 2000 CDC growth charts for the United States: methods and development. National Center for Health Statistics. *Vital Health Stat*. **11**, 246 (2002).

Table 1 | Physical examination and important physical findings in children or adolescents who are overweight or obese[12,14]

Organ system	Physical findings of note
Skin or subcutaneous tissues	Acanthosis nigricans (neck, axillae, skin folds and over joints)*; keratosis pilaris (skin tags)*; hirsutism*; acne*; striae*; pseudogynecomastia in males; intertrigo with or without secondary infection; xanthelasmas (hypercholesterolemia)
Neurological	Papilledema and/or reduced venous pulsations on fundoscopy (pseudotumor cerebri); psychosocial manifestations: flat affect and low mood (depression); poor self-esteem and social isolation
Head and neck	Large tonsillar size and obstructed breathing
Cardiovascular	Hypertension; fast heart rate (cardiorespiratory fitness)
Respiratory	Exercise intolerance; wheeze (asthma)
Gastrointestinal	Hepatomegaly and hepatic tenderness (nonalcoholic fatty liver disease)*; abdominal pain (secondary to gallstones or gastroesophageal reflux)
Musculoskeletal	Pes planus; groin pain and painful or waddling gait (slipped capital femoral epiphysis); tibia vara; 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 (late childhood and adolescence); reduced growth velocity
Other (evidence of a possible underlying genetic syndrome)	Short stature or disproportion; dysmorphism; developmental delay

*Possibly associated with insulin resistance.

Many published studies are limited by varying attrition rates, small sample sizes, different measures of change in adiposity and lack of assessment of other outcomes (for example, broader medical, psychosocial and behavioral outcomes), and have typically involved fairly homogeneous patient samples managed in a tertiary care setting.[37] Although trials from the past few years have started to address some of these issues, the evidence to support effective intervention is limited and the findings might not apply to other clinical settings. For instance, 'real-world' obesity clinics are usually less-well-resourced than programs in clinical trials, and patients seen in such clinics can be quite different from those who volunteer for trials; for example, there might be more social disadvantage, and the presence of psychosocial complications and other comorbidities might make adherence

to treatment more difficult. Not surprisingly, therefore, studies in clinical practice have demonstrated poorer results than in formal clinical trials.[38] Nevertheless, the broad principles of management are well-recognized and include long-term behavior modification and dietary change (Box 2).[12,14–16,37]

Effective management of obesity-associated comorbidities, such as sleep apnea, dyslipidemia, hypertension, nonalcoholic fatty liver disease or type 2 diabetes mellitus, is vital. Ideally, patients should be co-managed, in a coordinated way, by relevant specialist teams. In all cases, effective weight management should be a key element of the treatment of the comorbidity. Further discussion of the management of these comorbidities is beyond the scope of this review, and readers are referred elsewhere for more detail.[39–43]

Box 2 | Principles of obesity management in children and adolescents

- Management of obesity-associated comorbidities
- Family involvement
- A developmentally appropriate approach
- Long-term behavior modification
- Dietary change
- Increased physical activity
- Decreased sedentary behaviors
- Consideration of the use of pharmacotherapy and other forms of nonconventional therapy
- Plan for longer-term weight maintenance strategies

Conventional therapies

Family focus

Many clinical trials show that family-based interventions can lead to long-term (that is, from 2 to 10 years) relative weight loss.[37,44–48] Reviews of the role of family members in pediatric weight-control interventions highlight the importance of parental involvement when managing obese children, although the data for management of obese adolescents are limited.[37,45,49,50] A systematic review of 20 national-level clinical practice guidelines or consensus statements on the management of pediatric obesity noted that most documents emphasized the importance of involving parents or family, although only one-third of these provided age-specific recommendations.[51]

A developmentally appropriate approach

The developmental age of the patient, and the resultant level of parental engagement that will be required, should be taken into account when planning management. A different approach is usually needed for preadolescent children compared with adolescents.

Preadolescent children

An Israeli study was the first to highlight that, in preadolescent children, a parent-focused intervention, without direct engagement of the child, might be superior to a child-centered approach.[48,52] Obese children aged 6–11 years and their parents were randomly assigned to either parent-only group sessions (with an emphasis on general parenting skills), or child-only group sessions. At 1 year and 7 years follow-up from baseline, a statistically significant reduction in overweight was observed in the parent-only group compared with the child-only group.[48,52] At 1 year, a 14.6% reduction in overweight in the parent-only group was observed versus 8.1% in the child-only group ($P<0.03$), with a nine times greater dropout rate in the child-only group.[48] At the 7-year follow-up, 60% of the children in the parent-only group, versus 31% of those in the child-only group, were classified as nonobese.[52] These study findings suggest that when treating preadolescent children with obesity, therapy sessions involving the parent or parents alone, without the young child being present, could be the most effective.

Adolescents

Data for the treatment of adolescent obesity are more limited than for younger children, especially for interventions that would be sustainable in most health-care settings. The previously mentioned 2009 Cochrane review included 27 RCTs involving participants aged 12 years and older.[37] 12 studies used behavioral lifestyle modification, 10 involved pharmacotherapy, three used physical activity and two involved dietary changes. Lifestyle interventions with or without the addition of the drugs orlistat or sibutramine (note: sibutramine was withdrawn from clinical use in 2010) led to a reduction in overweight at 6 months and 12 months from baseline.[37] Most studies included were of high intensity and were offered in secondary or tertiary level care settings. Many offered separate sessions for adolescents and parents.

Behavior modification

In weight management, the term behavioral modification encompasses the set of techniques employed to change thought processes and actions associated with eating, physical activity and sedentary behaviors.[53] Many RCTs of pediatric obesity management have included a behavioral component, although these are often poorly described.[37] The use of a greater range of behavior change techniques is associated with improved weight outcomes.[45] Three key behavior modification techniques are goal setting, stimulus control and self-monitoring; these methods were used in most of the studies included in the 2009 Cochrane review.[37]

Goal setting can include performance goals (such as changing eating or activity behaviors) or outcome goals (such as specific weight loss). An example of a well-specified goal for a parent is: "I will not buy any cookies, chocolates or other high-fat foods during the weekly shopping. In order to make this easier, I will leave the children at home and shop on my own. If the children ask for junk food, then I will offer yoghurt or fruit instead." Of note, considerable session time might be required to set and review behavior change strategies with families and young people.[54]

Stimulus control refers to modifying or restricting environmental influences to aid weight control. The broader environment, whether at home, school or beyond, has a profound influence on a person's decisions around eating, physical activity or sedentary behaviors.[2] Although

many of these environmental influences are beyond the scope of an individual or family to change (for example, food marketing or food pricing), many opportunities exist for families to implement stimulus control in the everyday environment. Examples include: not eating in front of the television; not having television or other screens in bedrooms; using smaller plates, bowls and spoons; and not storing unhealthy food choices in the house.[44]

Self-monitoring is the detailed recording of a specific behavior and can contribute to better weight control in children and adolescents.[55] This self-monitoring can take several forms; for example, use of a food diary, television use diary, daily pedometer measurement of physical activity, or weekly weighing.[56]

Motivational interviewing is a "client-centered, directive method for enhancing intrinsic motivation to change by exploring and resolving ambivalence" that is increasingly being used in obesity management.[57] It requires an empathetic and collaborative therapist who responds to the patient's (or parent's) ambivalence to change in a nonjudgmental fashion. In addition, the therapist uses open-ended questions and reflective listening techniques to help direct communication toward change in behavior.[12,54–58]

Dietary change and eating behaviors

A 2006 systematic review of RCTs of pediatric obesity assessed specific dietary interventions to treat childhood or adolescent obesity.[59] Although the lack of high-quality studies and the heterogeneous characteristics of the identified studies meant that direct conclusions could not be drawn, interventions containing a dietary component were effective in achieving relative weight loss. The 'Traffic Light' (also know as 'Stop Light') diet was the most commonly used dietary intervention in the included research studies.[59] Briefly, in the Traffic Light diet, foods are color-coded on the basis of energy content and selected nutritional value to indicate those to be eaten freely (green) and those to be eaten more cautiously (amber and especially red).[53] Although food or kilojoule exchange programs were also identified as common dietary interventions in the 2006 review,[59] only one RCT at the time compared diets of varying macronutrient composition. Since then, a substantial body of evidence has accumulated on the effects of diets with different macronutrient profiles on weight loss or maintenance, especially in adults, with results tending to favor diets proportionately higher in protein relative to carbohydrate and with a low glycemic index.[60–64] For example, results published in 2010 from the DiOGenes RCT compared the effect of five *ad libitum* diets (with variations in glycemic index and protein content) on body composition in European children: a low protein–high glycemic index diet increased body fat, whereas overweight or obesity decreased in the high protein–low glycemic index diet group.[63]

What recommendations should currently be given? Dietary interventions should follow national nutrition guidelines and have an emphasis on regular meals, eating together as a family, choosing nutrient-rich foods that are lower in energy and glycemic index, increased vegetable and fruit intake, healthier snack food options, decreased portion sizes, promotion of water as the main beverage, and a reduction in sugary drink intake.[12,14,15,44,64,65] Of critical importance is the involvement of the entire family in making the change to a sustainable and healthy food intake.[46,50]

In advising patients and families on dietary change, is there a potential risk of an eating disorder developing? On the one hand, although most people with obesity do not have a binge-eating disorder, the more severe the obesity, the more likely the patient is to have such an eating disorder.[66] In addition, obesity in childhood, or parental obesity, is a risk factor for later bulimia, and overweight adolescents are more likely to use a range of unhealthy behaviors to binge-eat.[67] However, evidence indicates that professionally-run pediatric obesity programs do not increase the risk of disordered eating and might, indeed, improve psychological well-being.[68] For these reasons, Hill highlighted the need for "properly and expertly managed" weight-control interventions to avoid the risk of an eating disorder.[69]

Physical activity

Participation of children with obesity in a lifestyle program (for example, walking, running, cycling or swimming, based on the family's preference) leads to greater reductions in percentage overweight at 6 months and 17 months when compared with a program of isocaloric programmed aerobic exercise.[70] A study of similar design, but including a third control group involved in calisthenics and with follow-up for 10 years, showed that the lifestyle and aerobic exercise programs were superior in terms of percentage overweight reduction to the calisthenics control group.[71]

A 2006 systematic review and meta-analysis of exercise interventions in overweight children and adolescents indicated that 155–180 min per week of supervised moderate-to-high intensity physical activity (with or without a concomitant dietary intervention) was effective in reducing body fat (standardized mean difference was −0.4%, range −0.7 to −0.1), although the effects on body weight and abdominal adiposity were inconclusive.[72] The review concluded that evidence to determine the role of isolated or adjunctive weight training was insufficient. In 2008, the effect of resistance training on metabolic fitness in children and adolescents was investigated in a systematic review of 12 trials, with eight of these targeting an overweight and obese population.[73] Most of the interventions included in that review involved circuit-type resistance training (moderate–high velocity, low–moderate load) that involved use of machine weights. However, limitations in study design and reporting prohibited definitive conclusions being established, although the beneficial effect of resistance training on health outcomes in adults was highlighted by the study authors.[73] In overweight and obese adults, a meta-analysis performed for a 2006 Cochrane review determined that exercise alone can produce small weight losses and improvements in metabolic parameters, including levels of diastolic blood pressure, triglycerides and fasting glucose.[74] Addition of

exercise to a dietary intervention resulted in a greater weight reduction than dietary intervention alone, with higher intensity of exercise resulting in greater reductions in weight and fasting glucose.[74]

Sedentary behaviors

Several studies and clinical guidelines address the issue of targeting sedentary behaviors.[12,14–16] In one study, 90 families with children aged 8–12 years who were obese were assigned to different arms of a behavioral weight-control program, in which either sedentary behaviors or physical activity were targeted, with two different levels of behavior change being required.[75] At 2 years, similar improvements in aerobic fitness, body fat percentage and percentage overweight were observed for all treatment arms, indicating that modifying sedentary behavior is as effective as changing physical activity levels.[75]

What recommendations can be given in terms of physical activity and reduction of sedentary behavior?[12,14–16,37,65] Increased physical activity might best result from a change in incidental or unplanned activity; for example, increased walking or cycling for transport, household chores and playing with friends or family. Organized exercise programs also have a role, although, in our experience, issues of access and sustainability need to be addressed. Children and adolescents should be encouraged to choose activities that they enjoy as these activities are therefore more likely to be sustainable. Limiting television and other 'small screen' recreational viewing to less than 2 h per day is particularly strategic,[65] but may be extremely challenging given the multiple types of screen-based activities available to most young people. Parental involvement is crucial if an increase in physical activity or a decrease in sedentary behavior is to occur, including monitoring and limiting television use, role-modeling healthy behaviors and providing access to recreation areas or recreational equipment.[44]

Nonconventional therapies

The evidence to guide the use of less orthodox treatment approaches—such as very-low-energy diets (VLEDs), pharmacological therapy or bariatric surgery—in the treatment of severe pediatric obesity is more limited than for behavioral interventions. In general, such therapies should be applied in conjunction with a behavioral weight-management program and be restricted to specialist centers with expertise in managing severe obesity.[12,14–16]

Very-low-energy diets

VLEDs are dietary preparations that provide nutritional requirements together with <800 calories (3.3 MJ) per day. They can be provided as complete or partial meal replacements and exist in two forms: normal foods, or commercial liquid or powder formula. In adults, they are used to achieve rapid weight loss before, or in conjunction with, the use of other longer-term treatment interventions.[76] VLEDs can be associated with safe and substantial rapid weight loss in adolescents, typically producing 6–15 kg weight loss over 3–12 weeks.[77–79] However, most studies have been based on small sample sizes (<20 participants) and have lacked a control group, with very few studies having long-term follow-up.[80] To date, no RCTs have examined the effectiveness of a weight-management program incorporating initial VLED treatment in obese adolescents. The US Expert Committee recommended that VLEDs should ideally be used with severely obese patients who are managed by a multidisciplinary team in a tertiary care setting[12]—they are not appropriate for use in young children.

Pharmacological therapy

The gastrointestinal and pancreatic lipase inhibitor, orlistat, has been shown to aid weight loss and limits weight regain in large placebo-controlled trials in adults.[81,82] The serotonin and norepinephrine reuptake inhibitor, sibutramine, which in the late 1990s and 2000s was used as an approved weight-loss agent in adults, and to a limited extent in adolescents, was withdrawn from the international market in 2010 owing to adverse cardiovascular effects in adults with pre-existing heart disease.[83] Hence, only a limited armamentarium of drugs are available for obesity therapy and we therefore focus on those that are recommended by national guidelines or addressed in systematic reviews of RCTs.

Orlistat

Orlistat is approved by the FDA for prescription to people aged ≥12 years. A 2009 Cochrane review included three RCTs of orlistat (120 mg three times a day, with multivitamin supplements) in adolescents with obesity; in each RCT, orlistat was given in conjunction with a lifestyle intervention.[37,84–86] A meta-analysis of two of the RCTs, involving 579 participants, showed that orlistat had an additional effect on BMI over placebo of –0.76 kg/m^2 (95% CI –1.07 to –0.44; P <0.00001).[37] The most commonly reported adverse events in the studies were gastrointestinal in nature, including fatty or oily stools, increased stool frequency, oily spotting, cramps and abdominal pain.[37,84–86] These distressing adverse effects can limit the potential acceptability of orlistat to at least some, and possibly most, adolescents with obesity who can find it difficult to adhere to low-fat diets in the medium to long term. However, when orlistat is used in conjunction with therapist support for a lifestyle intervention, the appearance of these adverse effects, which is a dramatic illustration of the consequence of eating a high-fat diet, can be used to highlight the need for behavioral change (that is, to a reduced-fat diet).

Metformin

Studies from the past 5 years have considered the use of metformin versus placebo in adolescents with obesity who have nondiabetic hyperinsulinemia and have shown at least medium-term (6 months) improvement in body composition and metabolic parameters.[87–90] In a systematic review of four trials,[87] three were pooled into a meta-analysis of metformin versus placebo, plus or minus lifestyle intervention.[88–90] At 6 months, a marked improvement in fasting insulin levels (67 pmol/l, 95% CI 44–91) and BMI (1.7 kg/m^2; 95% CI 1.1–2.3) was observed.[87]

Two studies published subsequent to this review provide additional supportive evidence and extend the potential role of metformin to other clinical situations.[91,92] One, in which 77 adolescents with obesity who were nondiabetic, but not necessarily insulin resistant, were randomly allocated to receive metformin extended release or placebo for 48 weeks, and then followed up for an additional 48 weeks post-treatment, showed a small but statistically significant reduction in mean BMI of –1.1 (SE 0.5) at 1 year, although no changes in insulin or lipid indices were observed.[91] Another trial, in which 100 severely obese insulin-resistant children aged 6–12 years were randomly allocated to receive metformin or placebo for 6 months, showed greater decreases in BMI (–1.09 kg/m^2; 95% CI –1.87 to –0.31), plasma glucose level and homeostasis model assessment insulin resistance index in the metformin-treated group than the placebo group.[92] Gastrointestinal symptoms were the most commonly reported adverse events in these various studies.[83,92]

Other forms of pharmacotherapy

Some novel pharmacological approaches to the treatment of obesity are currently being investigated in adults and might eventually prove useful for the management of pediatric obesity.[93] These include the antiepileptic drugs topiramate and zonisamide, which have the side effect of appetite suppression, and the atypical antidepressant, bupropion, a norepinephrine and dopamine reuptake inhibitor that increases satiety. None of these drugs has yet been investigated in weight-management trials in the child or adolescent population.[93]

Guidelines on pharmacological therapy

Existing national guidelines or expert recommendations on management of overweight and obesity in children and adolescents provide only some guidance on the use of pharmacological therapy. In general, drug therapy (largely just orlistat) is recommended in severely obese adolescents, in the context of a tertiary care protocol provided by a multidisciplinary care team, and incorporating continued dietary and activity counseling.[12,14–16]

Bariatric surgery

Bariatric surgery is a well-recognized form of therapy for adults with severe obesity, especially if medical therapy has failed,[94] but its role in adolescent obesity is unknown. Almost all of the literature in this area is of case studies or case series, with only one published RCT to date.[95]

Evidence for bariatric surgery

A 2008 systematic review of bariatric surgery for adolescent obesity incorporated studies that reported outcome data for patients under the age of 21 years (mean age 16.8 years; range 9–21) who were followed up for at least 12 months.[96] 19 papers were included, including eight studies of laparoscopic gastric banding, six studies of Roux-en-Y gastric bypass and five studies of other surgical procedures (such as vertical banded gastroplasty, biliopancreatic diversion or banded bypass). The laparoscopic adjustable banding procedures, with 1–3 years follow-up, had a 95% CI for weight loss of–10.6 to –13.7 BMI units.[96] No perioperative deaths were reported, and the main complication reported was the need for re-operation (for band slippage), which occurred in 8% of patients. For Roux-en-Y gastric bypass procedures, the mean weight loss was greater, with a 95% CI of –17.8 to –22.3 BMI units, albeit over a longer period of follow-up (as the procedure has been established for longer). Four deaths were reported between 9 months and 6 years after surgery. The most frequently reported complications were related to protein–energy malnutrition and micronutrient deficiency. Note that none of the included studies in this systematic review was an RCT, and hence the strength of evidence could only be classed as moderate to weak.[96] However, these findings are similar to those seen for comparisons of bariatric surgery in adults.[94]

After the publication of the above-mentioned systematic review in 2008, the first RCT of bariatric surgery in adolescents with severe obesity was subsequently published in 2010.[95] This RCT included 50 adolescents with severe obesity (BMI >35 kg/m^2) aged 14–18 years who were randomly assigned to receive either a supervised lifestyle intervention, involving reduced energy intake, increased physical activity and behavior modification, or laparascopic adjustable gastric banding. By 24 months, the surgical group had a mean reduction in BMI of 12.7 units versus 1.3 units in the lifestyle group. The surgical group also had marked improvements in both cardiometabolic status and quality of life.[95] However, seven patients required a revisional procedure.[95]

Guidelines on bariatric surgery

The few consensus guidelines for bariatric surgery in adolescents have highlighted its use in those with severe obesity, rather than in younger children, with consideration of the adolescent's decisional capacity and attainment of physical maturity (that is, the patient should be in late puberty and have achieved near-final adult height), as well as the presence of a supportive family environment.[12,15,16,97–99] In addition, an emphasis has been placed on the need for patient management in centers with multidisciplinary weight management teams, for the surgery to be performed in tertiary institutions experienced in bariatric surgery and for long-term multidisciplinary follow-up. In our opinion, a challenge for health-care systems is how to ensure equitable access to such services for affected adolescents.

Long-term weight maintenance

Few high-quality studies have reported long-term outcomes of treatment of childhood and adolescent obesity.[37] In those with long-term outcomes reported, a high proportion of participants maintained a reduction in overweight from 2–10 years from baseline without additional intervention after the initial treatment phase (weeks to months).[37,46,100,101] However, in those who have undergone initial weight management intervention, a period of further therapeutic contact (varying from 4 to 12 months) seems to slow weight regain.[102] At present, the evidence to guide the nature and type of weight

maintenance interventions in the child and adolescent age group is limited.

Health-service delivery issues

Given the high prevalence of pediatric obesity in most westernized, and rapidly westernizing, countries, and its chronic nature, coordinated models of care for health-service delivery are needed. However, no country has yet established a cost-effective model of care for obesity management. Figure 2 shows one potential approach, which is adapted from the UK National Health Service[103] and Kaiser Permanente[104] pyramids of care. This approach is based upon a tiered level of service delivery relating to severity of disease. Thus, although most people affected by the problem of obesity can be managed via self-care or family-based care, with support from primary care or community-based health-service providers, treatment by multidisciplinary care teams and possibly tertiary care clinics is needed for those who are more severely affected. Individual clinicians should be aware of the presence of other services within their geographical region, and the capacity of these services to take referrals or to co-manage patients. For instance, these services could include group programs, individual consultations with allied health professionals or nurses, or specialized tertiary services.

The 2007 US Expert Committee recommendations highlight a similar, staged approach to the management of pediatric obesity.[12] The first stage—'prevention plus'—involves counseling patients who are overweight or obese to encourage lifestyle changes and healthy eating and activity habits. The second stage—'structured weight management'—includes more targeted recommendations for behavioral changes, supported by a structured meal plan, and involvement of a dietitian. Stage three—'comprehensive multidisciplinary intervention'—increases the intensity of behavior change and frequency of visits, and involves structured behavioral change supported by a multidisciplinary team of therapists, a service that is unlikely to be available in primary care settings. The final stage, 'tertiary care intervention', which is offered to young people with severe obesity, can include provision of pharmacotherapy, VLEDs, or bariatric surgery. The patient's age, severity of obesity and obesity-associated complications, and level of engagement with, and success of, previous interventions should determine which stage of therapy is offered.

Conclusions

Childhood and adolescent obesity is a 21st century health challenge that cannot be addressed by primary prevention alone. Treatment largely focuses upon providing support for sustained lifestyle changes, incorporating family involvement, adopting a developmentally appropriate approach, behavior modification techniques, long-term dietary change, increased physical activity and decreased sedentary behaviors. Drug therapy options are limited: orlistat can be used in adolescents with severe obesity and metformin can be used in older children and adolescents with clinical insulin resistance. Bariatric surgery has a role in severely obese adolescents, provided that the bariatric surgery is performed in experienced tertiary institutions and in the context of ongoing management in centers with multidisciplinary weight management teams. Importantly, given the high prevalence and chronic nature of obesity, coordinated models of care for health-service delivery are required for the management of pediatric obesity. The many knowledge gaps in this area emphasize the importance of ongoing evaluation and research.

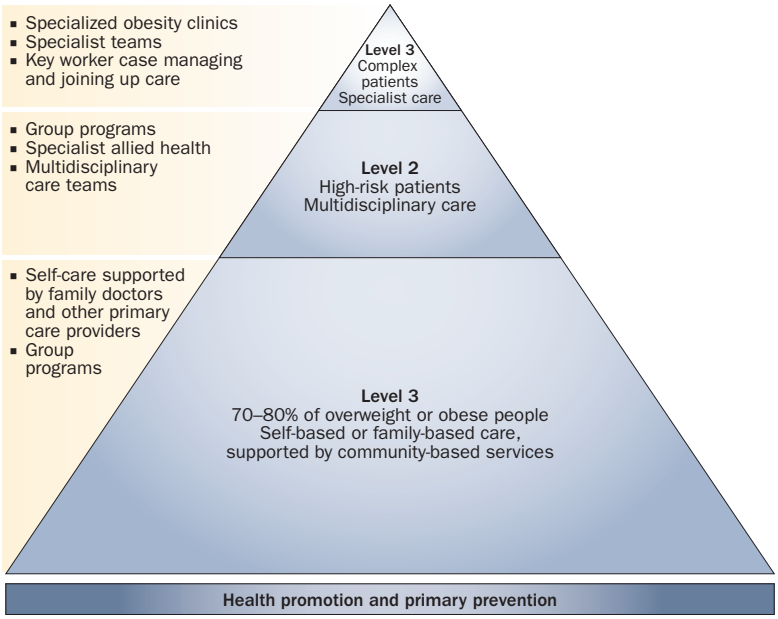

Figure 2 | Chronic disease management pyramid for pediatric overweight and obesity. The schematic diagram shows a tiered level of health-service delivery relating to the severity of disease in children and adolescents who are overweight or obese. Adapted from the Kaiser Permanente[103] and UK National Health Service[104] chronic disease management pyramids of care.

Review criteria

This Review is based upon data from systematic reviews, review papers and individual studies known to the authors. Other relevant studies were identified by a MEDLINE search of English-language papers published up to the end of May 2011 using the search term "obesity" and either "child" or "adolescent". When appropriate, the reference lists of key papers were checked to identify additional articles of interest. We also searched for clinical guidelines on the management of obesity. For the latter to be considered, documents had to be developed or endorsed for current use by a national or international health professional body (and available to nonmembers) or government agency, and available in English. They were sourced by checking a range of databases—OvidSP (MEDLINE, PreMEDLINE, PsycINFO); all evidence-based medicine reviews (Cochrane Database of Systematic Reviews, American College of Physicians Journal Club, Database of Abstracts of Reviews of Effects, and Cochrane Central Register of Controlled Trials); EMBASE; Web of Science; Scopus; the Cumulative Index to Nursing and Allied Health Literature database; InformIT; and TRIP—as well as the National Guideline Clearinghouse.

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