

# The use of measures of obesity in childhood for predicting obesity and the development of obesity-related diseases in adulthood: a systematic review and meta-analysis

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## Scientific summary

### Predicting obesity and development of obesity-related diseases in adulthood

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# Scientific summary

## Background

It is generally accepted that adult obesity is associated with an increased risk of morbidity and premature mortality in adults. However, the nature of the link between childhood obesity and adult morbidity and obesity is less clear. Recent systematic reviews have indicated that childhood obesity is positively associated with adult obesity and that childhood overweight and obesity are positively associated with an increased risk of morbidity in adulthood. However, none has investigated the link between childhood weight status and adult morbidity in terms of predictive accuracy. In addition, these reviews have primarily considered body mass index (BMI) to determine the presence and level of obesity. The question remains of whether or not another simple measure would be better for gauging the association between childhood obesity and adult obesity and (separately) adult morbidity.

The decision problem addressed in this review is, 'What is the best simple measure, or combination of simple measures, of obesity in children for predicting the development of obesity-related health problems such as type 2 diabetes, cardiovascular disease (CVD) and cancer in adolescence and/or adulthood?' The abilities of these simple measures to correctly identify weight status in childhood, and to predict the persistence of obesity from childhood into adolescence and adulthood, were also investigated. Acceptability and ease of use of the measures were also addressed within the review.

## Objectives

This research addressed, through systematic reviews, the questions raised in the decision problem.

1. Is obesity in children and adolescents a risk factor for CVD, type 2 diabetes and/or cancer in adults, and do the results vary according to the simple measure of obesity employed?
2. To what degree do simple measures of obesity in childhood accurately predict the tracking of obesity into adolescence and adulthood?
3. How accurately do simple measures of obesity reflect actual adiposity in children?
4. How acceptable are these simple measures of adiposity to children, their carers and health professionals, and how easy is it for parents and health professionals to implement and understand them?

## Methods

The systematic reviews were conducted following the general principles recommended in the Centre for Reviews and Dissemination guidance for undertaking reviews in health care and the reporting guidance of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

## Literature search

Separate literature searches were undertaken to identify studies for each of the review questions. The searches were limited to the date range 2008–13. A variety of sources was searched including MEDLINE, EMBASE, PsycINFO and Cumulative Index to Nursing and Allied Health Literature (CINAHL), supplemented with reference checking and citation searching.

## Inclusion criteria

For all review question studies, a range of simple obesity measures were considered, including BMI, waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and skinfold thickness (SFT).

For review question 1, prospective, large ( $n \geq 1000$ ) longitudinal studies which measured obesity in childhood were eligible. Adult outcomes considered were CVD, type 2 diabetes and cancer.

For review question 2, large ( $n \geq 1000$ ) longitudinal studies recruiting children and/or adolescents (aged 2–18 years) which measured obesity in childhood and at a later time (at least 5 years later) were eligible.

For review question 3, diagnostic accuracy studies of obesity measurement in children were eligible for inclusion, provided they used one of the following reference standards: a multicomponent model, dual-energy X-ray absorptiometry (DEXA), deuterium dilution or densitometry.

For review question 4, on the acceptability and ease of use of childhood obesity measures, BMI, SFT, WHR and WHtR were eligible for inclusion. Studies on the acceptability and ease of use of these measures, from the perspective of the child, parent or health professional, were eligible. A simple survey was conducted to obtain some indication of the attitudes of children, school nurses and parents to these four measures.

## Quality assessment and statistical analysis

The quality of included studies was assessed using Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) for studies of diagnostic accuracy and Quality in Prognosis Studies (QUIPS) for studies of predictive value. A critical summary of recent relevant systematic reviews was undertaken.

For the review questions evaluating test accuracy, studies with sufficient data were included in meta-analyses generating pooled odds ratios (ORs), and pooled estimates of diagnostic accuracy where possible. Otherwise, results were synthesised narratively.

For the review and elicitation exercise on the acceptability and ease of use of childhood measures, results were tabulated and summarised narratively.

## Results

### *Review of prediction of adult morbidities*

Thirty-seven studies (22 cohorts) met the inclusion criteria. Of these, 26 studies (13 cohorts) were included in meta-analyses. All studies included BMI. Three measured WC, and one used WHR and the sum of SFT measurements (sum SFT). No evidence was found for other simple childhood measures.

Elevated childhood BMI was modestly associated with an increased risk of adult morbidities. The association between a 1-standard deviation (SD) increase in BMI and adult diabetes had an OR of 1.7 [95% confidence interval (CI) 1.30 to 2.22], approximately equivalent to a 24% increase in risk per BMI unit in an adolescent. The association between a 1-SD increase in BMI and adult coronary heart disease (CHD) had an OR of 1.2 (95% CI 1.20 to 1.31), approximately equivalent to an 8% increase in risk per BMI unit in an adolescent. There was no convincing evidence of an association between childhood obesity and stroke. Across a range of cancers, there was evidence that childhood obesity was associated with a higher risk of cancer in adulthood. Increases in odds were generally around 20% per SD of BMI. There was no evidence of an association between childhood BMI and breast cancer. These analyses were not adjusted for adult BMI, in order to investigate whether or not childhood obesity alone can predict adult morbidities.

Despite the positive association between childhood BMI and morbidities, childhood BMI was not found to be a good predictor of adult disease. Only 40% of adult diabetes and 20% of CHD and cancers would occur in overweight or obese children. Hence, the majority of adult morbidity occurs in people who were of healthy weight as children.

In the narrative review, childhood obesity was found to be associated with adult metabolic syndrome, and there was some very limited evidence that BMI had poor sensitivity to predict this disorder. Evidence on the association between childhood BMI and hypertension and hypercholesterolaemia was very limited. Evidence was too limited to draw any firm conclusions on other childhood measures of obesity.

### ***Review of tracking of obesity into adulthood***

Twenty-three studies from 16 cohorts met the inclusion criteria for this review. All studies relied on BMI as the measure of obesity, except one which used triceps SFT. The association between childhood obesity ( $\geq 95$ th centile) and obesity in adults (age  $\geq 20$  years) was strong, with obese children being more than five times more likely to be obese as adults than non-obese children [pooled relative risk (RR) 5.21, 95% CI 4.50 to 6.02]. There was no apparent difference in this RR between younger and older age groups.

Obesity tracked moderately well from childhood into adolescence; around half of obese children were still obese in adolescence. It tracked well from adolescence to adulthood; about 80% of obese adolescents were still obese in adulthood and 70% were still obese after age 30 years. No data were available for tracking beyond age 40 years.

Body mass index was less effective at identifying who would be obese in adulthood; 70% of obese adults were not obese as children or in adolescence, and 80% of obese people aged over 30 years were not obese in adolescence, so childhood BMI has poor sensitivity to detect adult obesity. Analyses of the tracking of childhood overweight ( $\geq 85$ th centile) to adult obesity or overweight gave broadly similar results.

### ***Review of diagnostic accuracy of childhood measures of obesity***

Thirty-four studies were included in the review of diagnostic accuracy. Thirty assessed BMI, 10 SFT, seven WC, four WHR, two WHtR and six looked at other childhood measures of obesity. Most of the studies used DEXA as the reference standard, which is the least reliable of the eligible reference standards. Of the 34 studies, only eight were considered to be high quality.

Overall, the sensitivity of BMI for diagnosing both obesity and overweight varied considerably; specificity was less variable. Meta-analyses showed that, of those who were obese according to the reference standard, 74% were classified as obese using BMI, and of those who were not obese according to the reference standard, 95% were not classified as obese.

Data on other measures of obesity were more limited. The most commonly evaluated non-BMI test was SFT.

Most of the simple measures had high specificities. When fat mass index was evaluated alongside BMI (one study), it looked like a promising alternative, but this would require further research. Sum SFT also showed potential. Of the measures that incorporate a waist measurement, it seems that WHtR was more accurate than WC alone or WHR, although WHtR was evaluated in fewer studies.

### ***Review of acceptability and ease of use of childhood measures of obesity***

Five studies were identified for the review of acceptability and ease of use, all eliciting opinions about BMI. None of the studies elicited the opinions of children, three elicited the opinions of caregivers/guardians and two those of health professionals (school nurses in one study and family doctors and paediatricians in the other). The opinion of parents and nurses regarding the usefulness of BMI was generally positive. The usefulness of measuring BMI in preschool children was less well accepted among doctors.

In the elicitation exercise, although most children did not seem to have a problem with their height being measured, a large proportion were embarrassed, or had other adverse reactions, to being weighed. The 71 parents/caregivers questioned were generally unfamiliar with WHR, WHtR and SFT, and therefore with their potential accuracy and usefulness. Many felt that BMI was a more meaningful indicator of a child's weight status than height and weight alone; age- and sex-adjusted BMI were considered valuable.

## Limitations and uncertainties

Despite there being a reasonable number of studies identified for the three main review questions, the number from which the necessary data could be obtained was small. Furthermore, across all reviews the limited reporting of most studies and their heterogeneity further reduced the number of studies that could be combined in meta-analyses, producing results with large uncertainty and wide CIs. There was limited scope to test for the impact of important confounders such as age and sex.

A number of assumptions had to be made in order to conduct the analyses. These assumptions, especially the assumption of normality for BMI, may not be accurate and this limits the reliability of the results.

Little evidence was available regarding childhood measures other than BMI. This greatly hampered the review's ability to address the project brief.

The cohort studies of the association between childhood obesity and adult morbidities were, of necessity, long-term studies, with recruitment often occurring in the 1960s or earlier. As this was before the rise in general obesity, it is unclear whether or not the findings from this part of the review apply to present-day children living in societies where obesity is more prevalent.

## Conclusions

The review found that childhood obesity (measured using BMI) was associated with moderately increased risks of adult obesity-related morbidity. However, the increase in risk was not large enough for childhood BMI to be a good predictor of the incidence of adult morbidities; the majority of adult obesity-related morbidity occurs in adults who were of healthy weight in childhood.

The review of tracking studies found that childhood obesity (measured using BMI) is strongly associated with adult obesity. This strong association was matched by a strong persistence of childhood obesity into adulthood. Obese children, and particularly obese adolescents, are likely to still be obese in adulthood. However, childhood BMI is not a good predictor of the incidence of adult obesity or overweight; most obese adults were not obese in childhood, so overall adult obesity is not primarily determined by childhood obesity. No information was available on tracking of obesity into later adulthood, when most obesity-related morbidities are likely to occur.

The usefulness of BMI as a screening tool therefore depends upon the objectives of screening. It may be useful for identifying a group of obese or overweight children who may benefit from intervention, but does not identify all children who will go on to be obese or to develop obesity-related morbidities in adulthood.

Body mass index was found to be reasonably good at diagnosing obesity during childhood, with around 75% of genuinely adipose children being classified as obese using BMI, and around 95% of non-obese children also being correctly classified. This result was, however, based mostly on studies using DEXA, which is not generally regarded as a gold standard for diagnosing obesity. BMI therefore appears to be a reasonably good measure of obesity in children, as it effectively identifies childhood adiposity and children likely to be obese in adulthood.

There is a lack of evidence to help determine whether or not any simple measure is better or worse than BMI for assessing childhood weight status, either for diagnosing obesity in childhood or for predicting adult obesity or obesity-related morbidities.

The opinion of parents and nurses as to the usefulness of BMI was generally positive. However, its usefulness in preschool children was less well accepted among doctors, although it was considered useful for selected young children.

## Recommendations for research

- Further investigation of individual-level data to avoid the limitations and assumptions made in this review and, potentially, to analyse measures other than BMI that have not been reported.
- A full assessment of diagnostic accuracy, including identifying studies using magnetic resonance imaging as the reference standard to assess abdominal obesity.
- Further primary studies of the diagnostic and predictive accuracy of measures other than BMI, should the research described above suggest that they are merited.
- Cohort studies to assess tracking of obesity and incidence of obesity-related morbidities to investigate the effect of contemporary childhood obesity on long-term obesity and morbidity. This could be achieved through appropriate maintenance and analysis of NHS records.

## Study registration

This study is registered as PROSPERO CRD42013005711.

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