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Obesity Etiology

Predicting adult obesity from childhood obesity: a systematic review and meta-analysis

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Summary

A systematic review and meta-analysis was performed to investigate the ability of simple measures of childhood obesity such as body mass index (BMI) to predict future obesity in adolescence and adulthood. Large cohort studies, which measured obesity both in childhood and in later adolescence or adulthood, using any recognized measure of obesity were sought. Study quality was assessed. Studies were pooled using diagnostic meta-analysis methods. Fifteen prospective cohort studies were included in the meta-analysis. BMI was the only measure of obesity reported in any study, with 200,777 participants followed up. Obese children and adolescents were around five times more likely to be obese in adulthood than those who were not obese. Around 55% of obese children go on to be obese in adolescence, around 80% of obese adolescents will still be obese in adulthood and around 70% will be obese over age 30. Therefore, action to reduce and prevent obesity in these adolescents is needed. However, 70% of obese adults were not obese in childhood or adolescence, so targeting obesity reduction solely at obese or overweight children needs to be considered carefully as this may not substantially reduce the overall burden of adult obesity.

Keywords: Childhood obesity, meta-analysis, prediction, systematic review.

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Introduction

Childhood and adolescent obesity is widely perceived as one of the most important public health challenges of the 21st century (1). Adult obesity is associated with significantly increased risk of a range of morbidities and mortality, including type II diabetes, cardiovascular disease and cancer (2--5). Children and adolescents who go on to become obese in adulthood are therefore at increased risk of a range of diseases (6,7). Identifying those children at high risk of adult obesity by measuring obesity in childhood could, when accompanied with weight reduction and lifestyle improvement, lower their risk of becoming obese in adulthood. Theoretically, screening might also lead to significant reductions in the societal health burden of obesity in adulthood.

Body mass index (BMI) is the most commonly used simple measure of adiposity, but it has limitations: it measures presumed excess weight given height, rather than actual body fat, and does not give any indication as to the distribution of fat in the body, and in adults, central adiposity is more closely associated with health risks than general adiposity (8,9). A wide range of alternative simple tools to measure adiposity or obesity is available, such as waist circumference, neck circumference, skinfold thickness, waist-to-hip ratio, waist-to-height ratio, body adiposity index, Rohrer's ponderal index, Benn's index and fat mass index. To our knowledge, no systematic review has assessed the association between these alternative measures and the risk of adult obesity.

No systematic review to date has investigated how well childhood and adolescent obesity predicts adult obesity, using appropriate measures of predictive accuracy such as sensitivity and specificity. This is particularly important as the fact that childhood or adolescent obesity is associated with adult obesity does not necessarily mean that it will be a useful predictor of future obesity. In general, the association between a risk factor (such as obesity) and a subsequent outcome has to be substantial before the risk factor can usefully be employed to predict the future incidence of the outcome (10,11).

This systematic review aimed to address whether childhood and adolescent obesity and overweight are predictive of obesity and overweight in adults and whether the results vary according to the measure of obesity used. However, because of limitations in the published literature, the second aim could not be achieved.

Methods

This systematic review was conducted following the principles recommended in the Centre for Reviews and Dissemination (CRD) guidance for undertaking reviews in health care (12), the Preferred Reporting in Systematic Reviews and Meta-Analyses (PRISMA) statement and the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) guidance for systematic review reporting. The protocol for the review is registered on PROSPERO (PROSPERO registration number: CRD42013005711). This review forms part of a broader Health Technology Assessment, with full methods reported elsewhere (6).

Search strategy

A wide range of sources of published and unpublished studies were searched by an information specialist, including MEDLINE, EMBASE, PsycINFO, CINAHL, The Cochrane Library, DARE and Science Citation Index. Searches were supplemented with reference checking of included studies and relevant systematic reviews. The search strategy was structured using 'obesity', 'adiposity', 'children' and a collection of 'simple anthropometric measures'. References were managed using EndNote X7 software (Thomson Reuters, Philadelphia, PA, USA). An existing systematic review (13) was identified. Therefore, relevant studies in that review were included, and searches to update this review were run from January 2007 (the date of the searches of Singh *et al.*) to June 2013. Both published and unpublished data were sought, and no language restrictions were applied. Where needed, authors were contacted for additional data. A full search strategy is reported in Appendix table A1.

Study selection

Longitudinal cohort studies, with at least 1,000 participants successfully followed up, that measured obesity in childhood (ages 7–18 years) and its prospective association with obesity in adolescence (ages 12–18 years) or adulthood (age 20 years and over) were eligible. The size restriction was used to restrict the review to the larger cohorts, which are likely to be of higher quality and have adequate power to detect associations between childhood and adolescent obesity, and adult obesity. Any measure of obesity, including BMI, was considered. Studies had to report contingency tables of the numbers of children or adolescents classified as normal weight, overweight or obese (however defined) and their weight status in adolescence or adulthood. Studies had to use an acceptable reference standard in adulthood, e.g. hydrostatic weighting or air displacement plethysmography. BMI was also used as a reference standard in the absence of other measures despite its limitations, because it was expected to be the most commonly used obesity measure. Studies were selected by two reviewers in duplicate. Where multiple papers reported on the same cohort, the paper judged to contain the most relevant or recent data was used. Disagreements were resolved through discussion or with a third reviewer when necessary.

Data extraction

Data on study details, patient characteristics and details of weight status (normal weight/overweight/obese) measurement (including classification and reference data used) were extracted. Data on weight status in childhood and adulthood were extracted from contingency tables at all ages for which measurements of BMI were available. Data were extracted by one reviewer using standardized forms and independently checked by another. Discrepancies were resolved by discussion or with a third reviewer. Data from multiple publications of the same study were extracted and reported as a single study, unless there was no overlap.

Quality assessment

The quality of included studies was assessed based on a modified version of the Quality in Prognostic Studies (QUIPS) checklist, a tool designed for systematic reviews of prognostic studies (14,15). The quality of the individual studies was assessed by one reviewer and independently checked by another. No primary study was excluded based on the result of the quality assessment; disagreements were resolved by consensus, and if necessary, a third reviewer was consulted. Details of the quality assessment are given in Appendix table A2.

Analysis

The relative risk of adult obesity, with its 95% confidence interval (CI), comparing those obese and non-obese in childhood or adolescence was calculated for each study.

These relative risks were pooled in a DerSimonian–Laird random-effects meta-analysis, stratified by age category at time of obesity measurement. Analyses to investigate possible causes of heterogeneity, such as meta-regressions, were considered but not performed because of the limited numbers of studies in each meta-analysis.

Ages were split into four categories: childhood (ages 7–11), adolescence (ages 12–18), adulthood (20 years and over) and aged over 30 years (to examine longer-term obesity tracking). Data on obesity below age 7 were excluded because adiposity rebound below that age may lead to incorrect estimation of associations. These age categories were chosen to distinguish the change from primary to secondary education (at ages 11 and 12) in the UK and to approximate pre-pubertal and post-pubertal status, although puberty may begin earlier in many children. Analyses were not stratified by gender as these data were too limited.

Four separate tracking analyses were conducted: (i) childhood or adolescent obesity to later (adolescent or adult) obesity; (ii) childhood or adolescent overweight or obesity to later obesity; (iii) childhood or adolescent overweight or obesity to later overweight or obesity; and (iv) childhood or adolescent overweight or obesity to later obesity.

For each comparison, the sensitivity, specificity and positive and negative predictive values (PPVs and NPVs, respectively) of overweight/obesity to predict adult overweight/obesity were calculated. The predictive accuracy data were synthesized in meta-analyses to estimate summary sensitivity and specificity across the studies. This was achieved using a logistic regression model approach, which has been shown to be equivalent to the bivariate model (16,17) and the hierarchical summary receiver operating curve model (18). PPVs were jointly modelled with NPVs using a similar logistic regression model. All results were presented as summary estimates with 95% CIs plotted in the receiver operating characteristic (ROC) space. The more formal 95% joint confidence regions for sensitivity and specificity were not presented for clarity. All analyses were performed using the R software.

Results

Searches identified a total of 16,055 unique references. After initial screening based on titles and abstracts, 186 articles remained for further evaluation. Of these articles, 170 were excluded in the subsequent detailed assessments. Sixteen publications (15 cohorts) (19--34) reported unique data. Two papers reported data from the same cohort, one with BMI measured at age 7 (34) and the other at age 8 (35); only the latter was included in this review. One publication (29) did not report suitable data and was excluded from the meta-analysis. We excluded children aged under 7 years from the analysis; only two cohorts (23,33) reported data on these younger children. Further details are presented in Appendix figure A1.

Although one of the aims of the review was to investigate the use of other simple measures of overweight and obesity, no studies reporting the use of any measure other than BMI were identified for inclusion. Consequently, all the analyses reported here use BMI to assess obesity.

Study quality

The most common methodological weaknesses were the risk of attrition bias and gaps in reporting about attrition rates. In 16 studies, it was unclear if participants at follow-up were representative of the complete initial samples. Risk of bias associated with participant selection, measurements error, reporting of outcomes and methods of analysis was generally considered low (Table A1).

Study characteristics

Study characteristics are summarized in Table 1. All included studies were large prospective cohort studies, with between 1184 and 128,121 participants followed up.

Children and adolescents were classified as overweight if above the 85th centile of BMI and obese if above the 95th centile. Exact definitions of these centiles varied across the studies: 10 studies used International Obesity Task Force/Cole 2000/World Health Organization reference populations (36); others used the Centers for Disease Control and Prevention 2000 reference growth charts (37) or the UK 90 reference (38). All assessments of adult weight status used the BMI cut-offs for overweight and obesity of 25 and 30 kg m^{-2}; one study(25) used the 80th and 90th centiles as the cut-off for overweight and obesity; the effect of inclusion versus exclusion of this latter study was examined in sensitivity analyses.

Association between childhood weight status and adult obesity

Figure 1 shows the forest plot for the meta-analysis of relative risk of being obese as an adult if obese in childhood or adolescence, by age of BMI measurement. The association is strong, with obese children (in both childhood and adolescence) being around five times more likely to be obese as adults than non-obese children [relative risk 5.21 (95% CI: 4.50, 6.02)]. There is no apparent difference in this relative risk between younger and older age groups. Heterogeneity was very high across studies, with $I^2 = 63\%$ in the 7–11 age group and $I^2 = 95\%$ in the 12 years and over age group. Data were too limited to further investigate this heterogeneity, but it appears that the association between childhood and adult obesity may vary substantially across different populations.

Table 1 Summary of study and population characteristics

Cohort	Country	Publication	Dates	Number at baseline	Number at follow-up	Childhood age (years)	Adult age (years) at follow-up	% male	Childhood weight status (%)
1988–1990 Slovenian cohort	Slovenia	Starc (19)	1997–2008	21,777	4,833	Mean 7	18	48.2	OW: 13.2% for male; 13.1% for female O: 5.7% for male; 4.4% for female
ALSPAC	UK	Reilly (20)	1998–2004	7,759	5,175	7	13	49.4	OW: 8.1% for male and 9.6% for female O: 8.2% for male and 6.8% for female
ASHFS	Australia	Venn (21)	1985–2005	8,498	4,571	7–15	24–34	48	OW: 8.3% for male; 9.7% for female O: 1.5% for male; 1.4% for female
BCAMSS	China	Cheng (22)	2004–2010	2,189	1,184	6–16	12–22	54	O: 15.3%; OW: 40.8%
Bogalusa	USA	Freedman (23)[A]	1973–1994	11,411	2,610	2–17	18–37	42.7	OW: 7% for male; 6% for female
		Freedman (24)[B]	1973–1996	7,923	2,392	5–14	18–37	44.9	OW: ~7%
Cardiovascular risk in young Fins	Finland	Juonala (25)	1980–2001	3,596	2,260	3–18	24–39	NR	OW: 10.5% O: 8.6%
CATCH	USA	Stovitz (26)	1991–2001	5,106	2,802	Mean 8	Mean 18.3	48.8	OW: 14.9% O: 10.5%
NCDS (1958 British birth cohort)	UK	Power (27)	1958–1991	17,733	11,407	7–16	33	51.7	NR
NGHS/PFS	USA	Thompson (28)	1986–1997	1,963	1,669	10–16	21–23	0	OW: at baseline, 7.4–8.7% for Caucasian; 17.4–18.2% for African–American
NHANES, NLSY79	USA	Goldhaber-Fiebert (29)	1970–2008	NR	4,884	2–15	18	51	OW: 9–10% for 5 years; 14–15% for 15 years O: 12–13% for 5 years; 11–17% for 15 years
NLSAH	USA	Gordon-Larsen (30)	1996–2002	14,438	9,795	13–20	19–26	49	O: 10.9%
NLSY79	USA	Wang (31)	1981–2002	2,513	1,309	16–17	37–38	52	OW: 8 O: 3
None	Norway	Engeland (32)	1963–1999	227,003	128,121	14–19	24–54	NR	OW: 4.9% for male; 7.3% for female
None	Australia	Patton (33)	1992–2003	1,943	1,520	Mean 15	24	46	NR
Tokushima prefecture	Japan	Nakano (35)	2001–2008	22,827	16,245	8	14	51.9	OW: 18.28% for male; 17.09% for female O: 5.94% for male; 4.13% for female

NR, not reported; O, obese; OW, overweight.

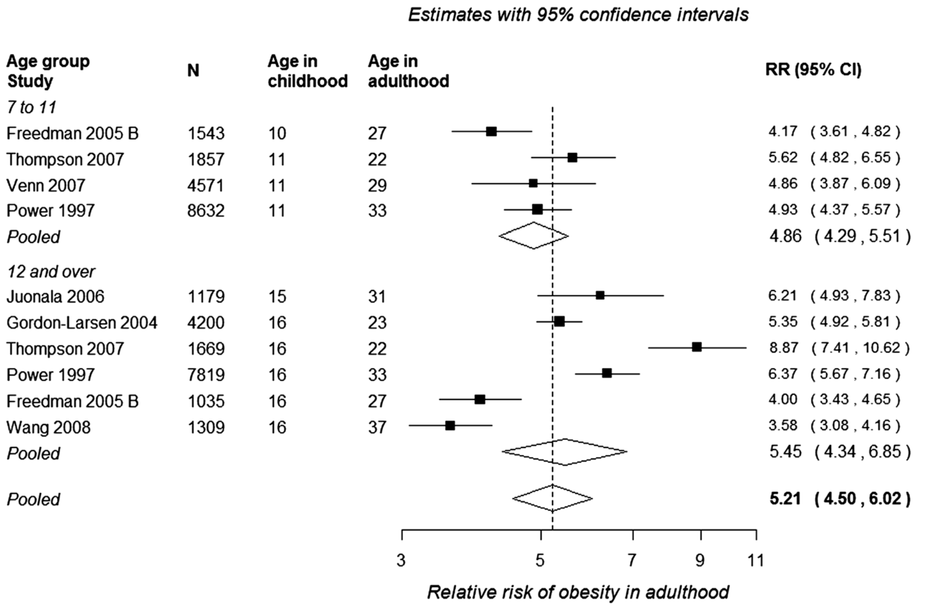

Figure 1 Forest plot of the random-effects meta-analysis of the association between childhood and adult obesity. CI, confidence interval; RR, relative risk.

Predicting later obesity

Sensitivity and specificity of childhood obesity/overweight

Various studies reported BMI measurements at different childhood, adolescent and adult ages and some reported only obesity, some only overweight and obesity, and some both. Table 2 summarizes which studies contributed to the various meta-analyses in the following section.

Figure 2 shows sensitivity and specificity for all studies providing data on the prediction of later obesity (≥95th centile or ≥30 kg m^{-2}) from childhood or adolescent obesity (≥95th centile of BMI). Studies are grouped into four categories: child to adolescent, child to adult, adolescent to adult and adolescent to over 30. With the exception of one outlier (22), the studies are consistent in estimation of specificity, at between 94% and 99%, but show some heterogeneity in sensitivity, between 7% and 62%. The outlier is the only Chinese cohort included in the review. This study classified a large proportion of adolescents as overweight or obese (40.8%). Why this was the case was not clear, but

Table 2 Contribution of each study to the meta-analyses

	Childhood O to				Childhood OOW to				Adolescent O to				Adolescent OOW to			
	Adolescent		Adult		Adolescent		Adult		Adult		Over 30		Adult		Over 30	
Study	O	OOW	O	OOW	O	OOW	O	OOW	O	OOW	O	OOW	O	OOW	O	OOW
Cheng (22)	X	X			X	X										
Engeland (32)													X	X	X	X
Freedman A (23)				X				X								
Freedman B (24)			X				X		X				X			
Gordon-Larsen (30)									X				X			
Juonala (25)									X		X		X		X	
Nakano (35)						X										
Patton (33)										X				X		
Power (27)			X	X					X	X	X	X				
Reilly (20)	X	X			X	X										
Starc (19)	X	X			X	X										
Stovitz (26)						X										
Thompson (28)			X						X							
Venn (21)			X	X			X	X								
Wang (31)									X		X		X		X	
Total	3	3	4	3	3	5	2	2	6	2	3	1	5	2	3	1

O, obese only (95th centile, >30 kg m^{-2}); OOW, obese or overweight (85th centile, >25 kg m^{-2}).

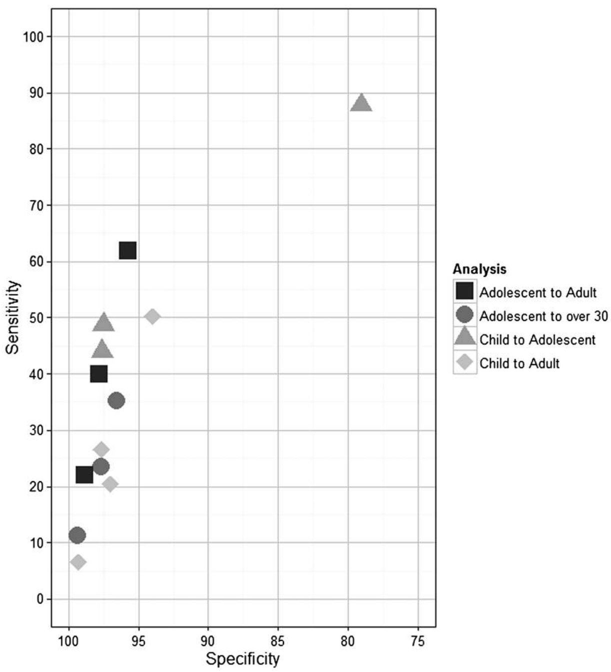

Figure 2 Sensitivity and specificity in studies predicting adult obesity from childhood obesity.

as more adolescents are classified as obese, sensitivity to detect adult obesity will be higher, but specificity lower.

Figure 3A shows the results of the meta-analysis of the studies shown in Figure 2, and Figure 3B shows the results for predicting later obesity from childhood or adolescent obesity or overweight (≥85th centile of BMI). The figure shows the summary sensitivities and specificities with their 95% CIs.

Childhood obesity or overweight is a reasonable predictor of adolescent obesity. From Appendix figure A2A, 62% of obese adolescents were obese in earlier childhood, and from Appendix figure A2B, 90% of obese adolescents were either overweight or obese in earlier childhood. This result is strongly influenced by the outlying study (22). The high specificity of 95% in Appendix figure A2A means that nearly all non-obese adolescents were not obese in earlier childhood.

For prediction of adulthood obesity, the specificities of 95% or more in Appendix figures A2A and A2B mean that nearly all non-obese adults were not obese or overweight in childhood or adolescence. By contrast, the low sensitivities mean that most obese adults were not obese as children or adolescents. From Appendix figure A2, about 70% of obese adults were not obese in childhood or adolescence, and 80% of those over 30 years old were not obese in adolescence.

For the analysis of sensitivity and specificity when predicting later obesity or overweight (≥85th centile or $>30\,\mathrm{kg\,m^{-2}}$) from childhood obesity or overweight, the results were broadly similar to those mentioned earlier (Appendix figure A2). The results for childhood to adolescence suggest that 65% of obese or overweight adolescents were obese or overweight at younger ages and 37% were obese in earlier childhood. The limited data for tracking to adulthood suggest very low sensitivity; only 33% of overweight adults were overweight in adolescence, and only 12% were obese in adolescence. The high specificities suggest that around 95% of adults who are not overweight were also not overweight in adolescence and childhood. There was only one study with data from adolescence to age over 30, so no meta-analysis could be performed.

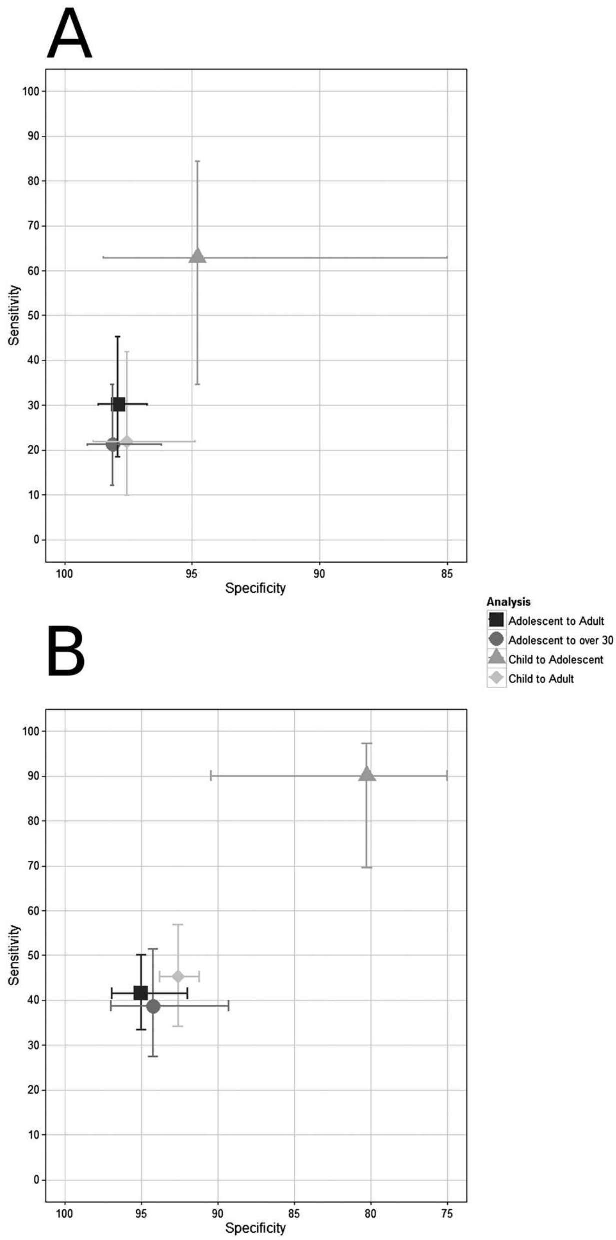

Figure 3 Meta-analyses of sensitivity and specificity when predicting adult obesity from childhood obesity (A) or from childhood obesity or overweight (B).

Positive predictive values for childhood obesity/overweight

Figure 4 shows PPVs, which estimate the proportion of obese or overweight children who will go on to become obese adults, and NPVs, which estimate the proportion of non-obese children who will be non-obese adults. Results are given for all studies providing data on the prediction of later obesity from childhood or adolescent obesity, grouped into four categories as in Figure 2. As in Figure 2, there is one outlying study (19). There is no obvious explanation for why this trial has discordant results; potentially, Slovenians have a different obesity profile in adulthood than in other countries. There is substantial heterogeneity in both PPV and NPV. This may be because both PPV and NPV are related to obesity prevalence, so different prevalence of obesity affects the estimates. In these studies, PPV increased by around 20% for every 10% increase in prevalence of obesity in adulthood. The results of the meta-analyses therefore show the PPV and NPV at average prevalence of adult obesity (around 17% in these studies).

Meta-analyses of the PPVs and NPVs are presented in Figure 5A (for obese children and adolescents) and Figure 5B (for obese and overweight children and adolescents). The analyses are similar to those presented earlier for sensitivity and specificity, with the same numbers of studies in each analysis as for the equivalent analyses given earlier.

Obesity is moderately persistent into adulthood. In Figure 5A, 79% of obese adolescents were still obese as adults, although that declines to 70% when adult ages are restricted to over 30 years. From Figure 5B, 66% of obese or overweight adolescents go on to be obese in early adulthood, dropping to around 55% by age 30 years. The NPV results show that non-obesity does track into adulthood. In Figure 3A, more than 85% of non-obese children will still be non-obese in adulthood. However, this does mean that 10–15% of non-obese children will be obese by early adulthood.

Childhood obesity does not persist strongly into adolescence. From Figure 3A, only 55% of obese children are still obese as adolescents, and from Figure 3B, only 32%

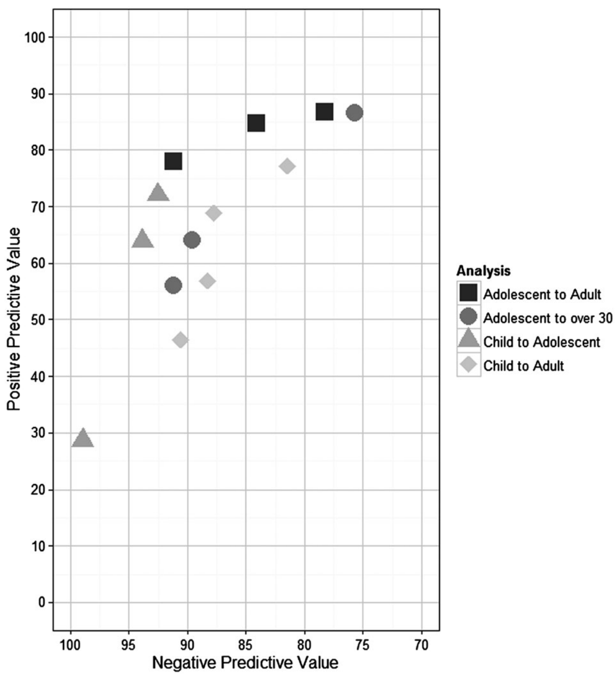

Figure 4 Positive and negative predictive values in studies predicting adult obesity from childhood obesity.

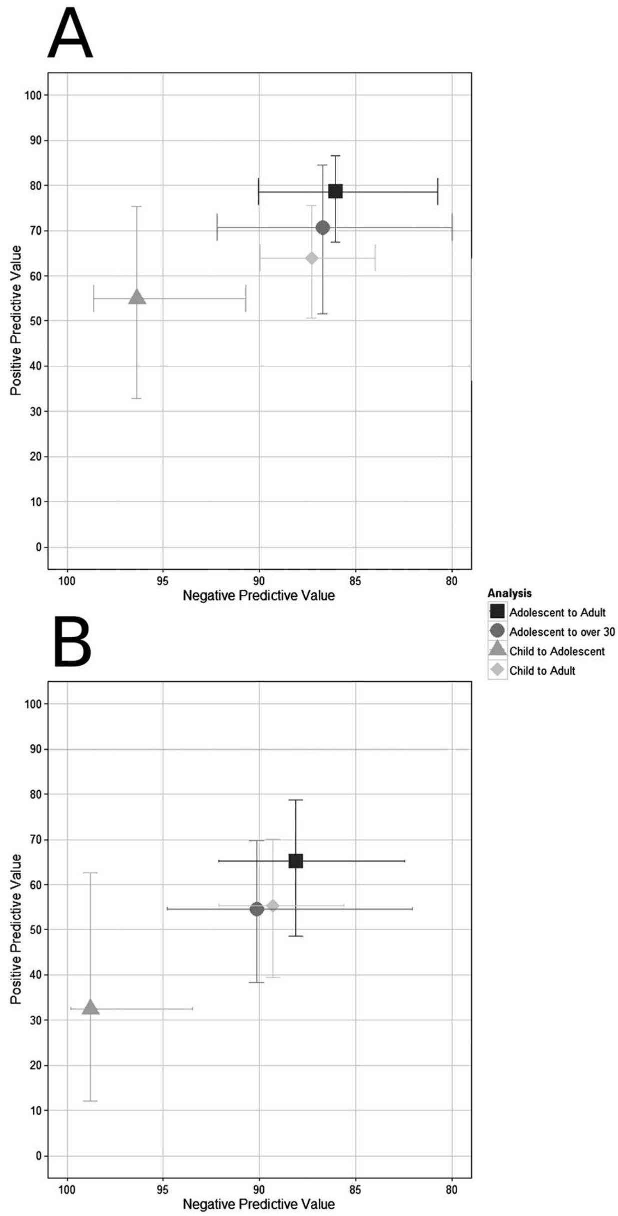

Figure 5 Meta-analyses of positive and negative predictive values when predicting adult obesity from childhood obesity (A) or from childhood obesity or overweight (B).

of obese or overweight children will go on to be obese in adolescence. The NPVs are high: from Figure 3B, 98% of children who are not overweight will not be obese in adolescence. Data were limited, and heterogeneity is substantial, so CIs are wide. Data were too sparse for any formal analysis on the effect of gender, but visual inspection of receiver operating characteristic plots stratified by gender (not shown) did not show any clear evidence that tracking of obesity differs between boys and girls. There was also no evidence that sensitivity or PPVs varied with the years in which the cohort data were collected.

Discussion

A total of 15 cohorts were included in this meta-analysis. All cohorts used BMI to measure obesity; no data on other obesity measures were available. The association between childhood obesity (≥95th centile of BMI) and obesity in adults (age ≥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 5.21 (95% CI: 4.50, 6.02)]. There was no apparent difference in this relative risk between younger and older age groups, but heterogeneity across studies was substantial. The association between childhood obesity and adult obesity may therefore vary across differing populations.

Obesity persisted from adolescence to adulthood: about 80% of obese adolescents were still obese in adulthood and 70% were still obese after age 30. No data were available for tracking beyond the age of 40. Obesity persisted less strongly from childhood into adolescence: around half of obese children were still obese in adolescence. This suggests that any targeting public health action to reduce obesity at pre-pubescent obese children may have limited impact, because many obese younger children will not be obese after puberty. However, the morbidity impact of obesity in childhood itself must also be considered.

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 were not obese in adolescence, so childhood BMI has poor sensitivity to predict adult obesity. Analyses of the tracking of childhood overweight (≥85th centile) to adult overweight gave broadly similar results. This may partly be a consequence of the classification of obesity being less stringent in adulthood than childhood and adolescence, as most studies used absolute BMI in adulthood, but BMI centiles in childhood and adolescence. Consequently, a larger proportion of adults were classified as obese, which reduces sensitivity. However, this analysis shows that obesity is primarily an adult-onset condition.

Strengths and limitations of the review

This is, to our knowledge, the first systematic review to investigate whether childhood obesity is predictive of adult obesity by synthesizing data in terms of predictive accuracy such as sensitivity, specificity and PPV. Rigorous systematic review methods were used, and PRISMA and MOOSE reporting guidelines were followed. Extensive searching was undertaken to identify published and unpublished studies, so that all relevant appropriately powered studies were included.

All the studies were from large or very large cohorts, most being from large national or community datasets. However, large proportions of participants were lost at final follow-up in many studies, making attrition the most common source of bias. Studies were very diverse with weight status measured at different ages, in different populations, often using different reference population and obesity thresholds. Follow-up duration and age at final follow-up also varied significantly between the studies.

Studies recruited children from 1958 to 2004. Obesity prevalence and social conditions for children have changed considerably during that time. Therefore, it is not clear whether the association between childhood obesity and adult obesity from such cohorts, particularly the older ones, accurately reflects the association in present-day children.

Although the review identified 15 cohort studies, differences in the choice of ages at which obesity and overweight were reported limited the extent to which meta-analyses of the cohorts could be performed, and it was not possible to investigate causes of the substantial heterogeneity across studies. No studies reporting the use of any measure of obesity other than BMI were identified for inclusion. Hence, it is unclear whether the relationships between childhood, adolescent and adult BMI identified would also be found for other measures of obesity.

Conclusions

This systematic review found that obese children, and particularly obese adolescents, are likely to become obese adults. This is because childhood obesity (when measured using BMI) is strongly associated with adult obesity. This strong association was matched by a strong persistence of adolescent obesity into adulthood, although whether this persists into later adulthood is uncertain. However, childhood and adolescent BMI is not a good predictor of the incidence of adult obesity or overweight: most obese adults were not obese in childhood or adolescence, 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. There was no eligible evidence on the predictive accuracy of measures of obesity other than BMI.

This review has confirmed that adolescent obesity is a major public health problem as it is very likely to persist into adulthood. Taking action to reduce obesity and overweight in adolescents may therefore reduce rates of adult obesity. The persistence of obesity into adulthood may also indicate that, once a child has become obese, it is difficult to reverse this; therefore, early action is likely to be appropriate. As childhood obesity does not always persist into adolescence, it is unclear whether it is better to target obesity in younger childhood, to reduce the obesity burden in adolescence, or wait until adolescence to intervene, to avoid needlessly intervening in children whose obesity will not persist past puberty.

Interestingly, most obese adults were not obese or overweight in childhood. Targeting weight-reduction interventions specifically at obese or overweight children, although potentially beneficial for those children, is therefore unlikely to have a substantial impact on reducing the overall obesity burden in adulthood.

Author contributions

A. L., M. S., N. W. and C. O. contributed to the study protocol. A. L., M. S. and N. W. conducted the systematic review, and M. S. performed the analyses. All authors contributed to the interpretation of data. A. L. and M. S. drafted the article. All authors critically revised the article for important intellectual content and approved the final version to be published.

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Conflicts of interest statement

All authors declare that they have no support from any organization for the submitted work, no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years and no other relationships or activities that could appear to have influenced the submitted work.

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Appendix

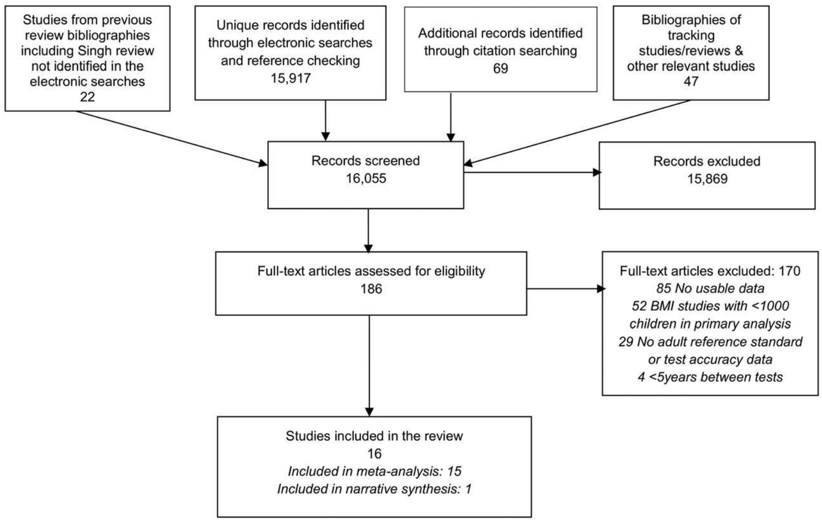

Figure A1 Flow of studies in review.

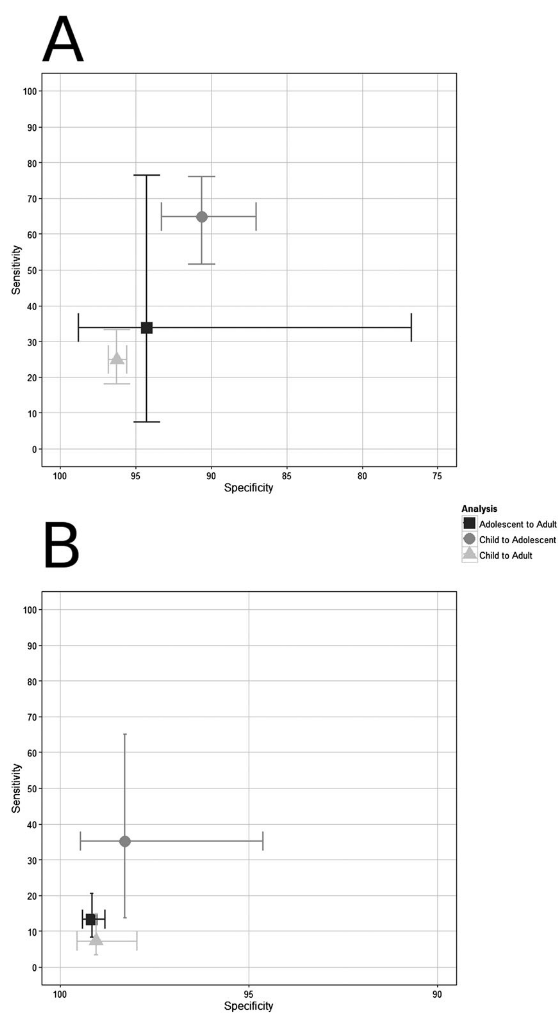

Figure A2 Sensitivity and specificity when predicting adult obesity or overweight from childhood obesity (A) and childhood obesity or overweight (B).

Table A1 MEDLINE search strategy

1	exp Obesity/ (133,174)
2	Overweight/ (10,590)
3	Weight Gain/ (21,800)
4	Weight Loss/ (22,928)
5	obes$.ti,ab. (152,595)
6	(overweight or over weight).ti,ab. (32,221)
7	(weight gain or weight loss).ti,ab. (82,269)
8	or/1–7 (267,570)
9	Adiposity/ or Adipose Tissue/ (63,551)
10	exp Body Composition/ (35,621)
11	Body Weight/ (159,105)
12	(adiposity or adipose).ti,ab. (56,741)
13	(body adj2 (composition or fat)).ti,ab. (37,403)
14	fatness.ti,ab. (2,835)
15	or/8-14 (468,298)
16	body mass index/ (75,120)
17	Skinfold Thickness/ (5,477)
18	Waist Circumference/ (3,853)
19	Waist-Hip Ratio/ (2,715)
20	Electric Impedance/ (11,187)
21	((body mass adj3 (index$ or indices)) or bmi or quetelet$).ti,ab. (113,508)
22	((fat mass adj3 (index$ or indices)) or fmi).ti,ab. (824)
23	((fat free mass adj3 (index$ or indices)) or ffmi).ti,ab. (345)
24	(body adipos$ adj3 (index$ or indices)).ti,ab. (35)
25	(body fat adj2 percentage$).ti,ab. (3,478)
26	((skin fold or skinfold) adj3 (thickness$ or test$ or measure$ or ratio$)).ti,ab. (4,810)
27	((waist or hip or neck) adj3 circumference$).ti,ab. (13,212)
28	((waist-to-hip or waist-hip) adj3 (ratio$ or test$ or measure$)).ti,ab. (6,373)
29	((waist-to-height or waist-height) adj3 (ratio$ or test$ or measure$)).ti,ab. (523)
30	(((bioelectric$ or electric$) adj3 (impedance or resistance)) or bia).ti,ab. (10,305)
31	(near infrared interactance or NIR).ti,ab. (4,648)
32	((benn$ or rohrer$ or ponderal or corpulence) adj3 (index$ or indices)).ti,ab. (1,001)
33	(sagittal abdominal diameter$ or supine abdominal diameter$).ti,ab. (108)
34	or/16–33 (169256)
35	track$.ti,ab. (65,784)
36	traject$.ti,ab. (26,434)
37	(persistence or persistent$).ti,ab. (199,631)
38	(observ$ adj3 (repeat$ or regular$ or continu$ or frequent$ or period$ or recurr$ or perenn$ or prolong$ or perpetu$ or long term)).ti,ab. (72,559)
39	(monitor$ adj3 (repeat$ or regular$ or continu$ or frequent$ or period$ or recurr$ or perenn$ or prolong$ or perpetu$ or long term)).ti,ab. (34,703)
40	(surveil$ adj3 (repeat$ or regular$ or continu$ or frequent$ or period$ or recurr$ or perenn$ or prolong$ or perpetu$ or long term)).ti,ab. (6,320)
41	(measure$ adj3 (repeat$ or regular$ or continu$ or frequent$ or period$ or recurr$ or perenn$ or prolong$ or perpetu$ or long term)).ti,ab. (58,971)
42	((annual$ or regular$ or recurr$) adj3 (interview$ or questionnaire$)).ti,ab. (1,252)
43	(lifespan or life span or lifecourse or life course).ti,ab. (32,271)
44	or/35–43 (482,887)
45	*Cohort Studies/ (916)
46	*Longitudinal Studies/ (1,144)
47	((cohort or panel) adj1 (study or studies or analy$)).ti,ab. (82,658)
48	(longitudinal adj1 (study or studies or survey or surveys or analy$ or pattern$ or data)).ti,ab. (50,985)
49	*Follow-up Studies/ (497)
50	(follow up adj1 (study or studies or survey or surveys or analy$ or data)).ti,ab. (50,500)
51	or/44–50 (646,777)
52	exp child/ (1,511,291)
53	exp Infant/ (917,072)
54	Adolescent/ (1,569,130)
55	Young Adult/ (311,210)

(Continues)

Table A1 (Continued)

56	(child$ or infant$ or pediat$ or paediat$ or schoolchild$ or school age$ or schoolage$).ti,ab. (1,205,816)
57	(adolescen$ or juvenile$ or youth$ or teenage$ or youngster$).ti,ab. (236,753)
58	(girl or girls or boy or boys or kid or kids).ti,ab. (155,425)
59	(young people or young person or young persons or young adult$).ti,ab. (67,269)
60	or/52–59 (3,200,696)
61	exp Adult/ (5,408,792)
62	(adult$ or midadult$ or middle age$ or later life).ti,ab. (765,494)
63	61 or 62 (5,769,283)
64	15 and 34 and 51 and 60 and 63 (2,818)
65	(relation$ or association$ or predict$ or risk or risks or mortality).ti,ab. (3,350,562)
66	(obes$ or overweight or weight status or BMI or body mass index).ti,ab. (231,751)
67	(adult$ or middle-age$ or men or women or later life).ti,ab. (1,444,222)
68	((relation$ or association$ or predict$ or risk or risks or mortality) adj5 (obes$ or overweight or weight status or BMI or body mass index) adj6 (adult$ or middle-age$ or men or women or later life)).ti,ab. [65 adj5 66 adj6 67] (3,566)
69	68 and 60 (1,519)
70	64 or 69 (4,012)
71	(2007$ or 2008$ or 2009$ or 2010$ or 2011$ or 2012$ or 2013$).ed,dc,ep. (5,166,979)
72	70 and 71 (2,677)

Table A2 Risk of bias assessment

Study	Risk of selection bias	Risk of attrition bias	Risk of bias associated with the prognostic factor	Risk of bias associated with outcome	Risk of bias due to confounders	Risk of reporting or analysis bias
Cheng (22)	Low	High	Low	Low	UC	Low
Engeland (32)	Low	UC	UC	UC	Low	Low
Freedman (23)	Low	UC	Low	Low	Low	Low
Freedman (24)	Low	Low	Low	Low	Low	Low
Goldhaber-Fiebert (29)	Low	UC	UC	UC	Low	Low
Gordon-Larsen (30)	Low	UC	Low	High	Low	Low
Juonala (25)	Low	High	UC	UC	High	Low
Nakano (35)	Low	UC	Low	Low	Low	Low
Patton (33)	Low	UC	UC	UC	Low	Low
Power (27)	Low	UC	Low	Low	Low	Low
Reilly (20)	Low	UC	Low	Low	UC	Low
Starc (19)	Low	Low	Low	Low	Low	Low
Stovitz (26)	Low	UC	Low	Low	UC	Low
Thompson (28)	Low	UC	Low	UC	Low	Low
Venn (21)	Low	UC	UC	UC	UC	Low
Wang (31)	Low	Low	UC	UC	Low	Low
All studies	All low	11 UC, 2 high, 3 low	10 low, 6 UC	7 UC, 8 low, 1 high	11 low, 1 high, 4 UC	All low

UC, unclear.