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Papers

Being big or growing fast: systematic review of size and growth in infancy and later obesity

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Abstract

Objectives To assess the association between infant size or growth and subsequent obesity and to determine if any association has been stable over time.
Design Systematic review.
Data sources Medline, Embase, bibliographies of included studies, contact with first authors of included studies and other experts.
Inclusion criteria Studies that assessed the relation between infant size or growth during the first two years of life and subsequent obesity.
Main outcome measure Obesity at any age after infancy.
Results 24 studies met the inclusion criteria (22 cohort and two case-control studies). Of these, 18 assessed the relation between infant size and subsequent obesity, most showing that infants who were defined as "obese" or who were at the highest end of the distribution for weight or body mass index were at increased risk of obesity. Compared with non-obese infants, in those who had been obese odds ratios or relative risks for subsequent obesity ranged from 1.35 to 9.38. Ten studies assessed the relation of infant growth with subsequent obesity and most showed that infants who grew more rapidly were at increased risk of obesity. Compared with other infants, in infants with rapid growth odds ratios and relative risks of later obesity ranged from 1.17 to 5.70. Associations were consistent for obesity at different ages and for people born over a period from 1927 to 1994.
Conclusions Infants who are at the highest end of the distribution for weight or body mass index or who grow rapidly during infancy are at increased risk of subsequent obesity.

Introduction

Levels of overweight and obesity have increased markedly during the past decade in all age groups.[1 2] The UK government has set a target to halt the year on year rise in obesity in children aged ≤ 11 by 2010 as part of an overall strategy to tackle the rising prevalence of obesity in the population. Given the lack of evidence of effective treatments, action to achieve this target must focus mainly on prevention.[3] It is not clear, however, how early in life prevention could begin.

Observational evidence suggests that faster growth during childhood is associated with an increased risk of obesity in later life,[4 5] suggesting that interventions aimed at modifying childhood growth could prevent adult obesity. Recent studies in the US and Finland have shown that patterns of growth during infancy may be associated with both childhood and adult obesity,[6 7] suggesting the potential for intervention during infancy. The precise patterns of growth leading to obesity are unclear and both infant size and infant growth have been implicated.[6 7]

We carried out a systematic review to assess the association between infant growth and subsequent obesity and to establish whether groups of infants with particular patterns of growth are at greater risk. We considered both size and growth because each is important in understanding the growth status of an infant—for example, an infant may be small but be growing rapidly. Given secular trends in children's growth,[8] we also assessed whether any associations identified in the past are likely to apply to infants now.

Methods

This research was part of a wider review of scientific evidence on infant growth and health and wellbeing throughout the life course, which was carried out alongside a review of lay perspectives on infant size and growth, supplemented by individual and focus group interviews (J Baird et al, Defining optimal infant growth for lifetime health: a systematic review of lay and scientific literature (unpublished report)).

We sought studies that described the relation between any aspect of infant growth or size and the development of overweight or obesity at any later age. Studies of infant size were eligible for inclusion if they reported at least one measurement of infant size between 3 months and 2 years. We included studies of infant growth if they reported at least two measurements of size up to 2 years, of which at least one was between 3 months and 2 years.

The outcomes we considered were overweight or obesity. We did not specify a definition of obesity as studies may have been published before currently accepted definitions were introduced.[9] We did not impose any limits in relation to language, study timing, or setting.

We searched Medline and Embase from their start dates to June 2005 and hand searched the bibliographies of all included studies. We also contacted first authors of included studies and other experts to identify further published or unpublished analyses.

We followed the methods recommended by the Centre for Reviews and Dissemination.[10] Study quality was assessed by using a checklist and summarised as to whether there was a low, medium, or high risk of bias for study results. The confounding factors we considered important in the relation between infant size or growth and obesity were socioeconomic status, parental size, and method of infant feeding.

Our approach to synthesis was mainly narrative but we explored the potential for meta-analysis according to standard procedures.[10]

Results

We identified 27 949 references. Screening of abstracts and reference lists identified 24 studies that met our inclusion criteria. All 24 studies were observational (22 cohort studies and two case-control). All but two studies were based in developed countries.

We considered that 15 studies were at medium risk of bias, six at high risk, and three at low risk. Common sources of bias were insufficient description of participants, high rates of attrition, and inadequate consideration of confounding factors.

Studies of infant size

Eighteen studies assessed the relation between infant size and obesity at ages ranging from 3 to 35 years (table 1). Most focused on "infant obesity" defined in various ways or on infants at the highest end of the distribution of weight or body mass index. Year of birth of infants was 1927 to 1992. Sixteen were cohort studies, two were case-control studies, and all but one were set in developed countries.

Eleven studies described infant obesity with varying definitions based on body mass index,[11–15] weight, weight for height,[16–20] or skinfold thickness[21] (table 1). When reporting the findings of these studies we have used the term infant obesity to describe exposure status, though we recognise that the definition of infant obesity is controversial. The seven other studies assessed infant size in terms of weight,[6 22–24] weight for height,[25 26] or body mass index[7] without using a definition of infant obesity.

All studies used centile points in body mass index, skinfolds, weight for height, or a clinical definition to define obesity as an outcome. Six studies focused on obesity in childhood up to the age of 10: four of these defined obesity according to weight for height[17 18 20 23] and two according to body mass index.[6 22] Five studies focused on obesity in adolescence (9-18 years), three defining obesity by body mass index[14 15 19] and two using weight.[24 25] Seven studies described adult obesity, four using body mass index to define obesity[7 11–13] and three using weight or skinfold thickness measurements.[16 21 26] Most of the studies in adults were of those aged 20-35 years.[7 11–13 16 21 26]

Table 1 Summary data extracted from studies of infant size, ordered by year of birth

Study	No of subjects, year of birth	Measure of infant size	Definition of obesity	Analysis	Size of effect	Risk of bias
Mossberg (1989)[26] Stockholm, Sweden	27 (sex not reported), 1927-47	Diagnosed as clinically obese by age 2 years	Weight for height SD scores at 40-50 years *v* reference population	Weight for height SD scores with obesity reported in infancy and at follow-up in adulthood	SD scores (SE of mean): 2.3 (0.31) on admission; 1.8 (0.46) in late childhood; 0.2 (0.28) in adulthood (40-50 years)	High
Guo (1994)[3] USA	555 (50% male), 1929-60	BMI at 75th centile *v* 50th centile	BMI >28 kg/m^2 (men) or >26 kg/m^2 (women) at 35 years	Logistic regression giving odds ratio for overweight in adulthood by higher BMI centile in infancy *v* lower one (50th, 75th centiles used)	Odds ratios (95% CI) at 1 year 1.48 (0.99 to 2.21) for males, 1.54 (1.01 to 2.35) for females; at 2 years 1.63 (1.04 to 2.54) for males, 1.51 (0.96 to 2.38) for females	Medium
Eriksson (2003)[7] Helsinki, Finland	2135 male, 2380 female, 1933-44	BMI at 6 months	Maximum lifetime risk of obesity defined as BMI ≥30 kg/m^2 at 60-70 years	Incidence (%) of adult obesity in each of four BMI categories at 6 months	Cumulative incidence (95% CI): males: 28.6 (24.1 to 33.1) in lowest 6 month group (<16.3 kg/m^2), 44.1 (40.0 to 48.5) in highest 6 month group (>18.0 kg/m^2), P<0.0001 for trend; females: 27.5 (23.8 to 31.3) in lowest 6 month group (<16.3 kg/m^2), 36.8 (32.0 to 41.7) in highest 6 month group (>18.0 kg/m^2), P=0.001 for trend	Medium
Heald (1965)[24] Washington DC; Massachusetts, USA	158 cases, 94 controls (all female), 1945-50	1 year weight (lb)	Cases (clinically obese) and controls (not obese) at mean age 15 years	Mean values for infant size reported for cases and controls, with SDs and *t* tests for differences	Mean difference in 1 year weight (lb): cases–controls 1.446 (P=0.009)	High
Charney (1976)[16] Rochester, USA	366 (sex not reported), 1945-55	Infant obesity: weight centile >90% at 3 and 6 months	Weight ≥20% above median for height and age at 20-30 years	Contingency tables of heavy, average, and light infants and underweight, normal, overweight, and obese adults, from which relative risks of adult obesity in "obese" *v* non-obese infants were derived	Relative risks: 1.63 (1.14 to 2.33) for unadjusted (n=366), 1.81 (0.96 to 3.44) for neither parent overweight (n=225), 3.37 (1.69 to 6.70) for at least one parent overweight (n=110), and 2.51 (2.25 to 2.80) for combined (n=335)	High
Asher (1966)[17] Birmingham, UK	137 (sex not reported): 21 cases, 24 controls, 1950	Infant obesity: weight >90th centile at 6 months; >97th centile at 6 months	Childhood obesity: weight >90th centile at 3-5 years; weight for height >97th centile at 5 years	Relative risk for child obesity in "obese" *v* non-obese infants	Relative risks: 9.33 (0.52 to 167) for weight >90th centile at 3-5 years; 6.56 (2.90 to 14.8) for weight for height >97th centile at 5 years	High
Rolland-Cachera (1987)[12] France	164 (52% male), 1950	Infant obesity: BMI >75th centile at 1 year	BMI >75th centile: >23.4 kg/m^2 (men) or >22.3kg/m^2 (women) at 21 years	Relative risk of obesity at 21 years in "obese" *v* non-obese infants	Relative risk (95% CI) 2.76 (1.32 to 5.77)	Medium
Garn (1985)[21] Tecumseh, USA	135 (39% male), 1957-60	Infant obesity at 1 or 2 years: triceps skinfold >85th centile for age/sex. Same definition for subscapular skinfold	Same definitions as for infancy at 21-22 years	Percentage of "obese" infants who remained obese 20 years later, with P value for deviation from chance figure of 15% (with binomial test)	Percentage of obese infant (triceps): 33.3% (P=0.21) at 1-21 years; 18.2% (P=0.77) at 2-22 years; percentage of obese infant (subscapular) 33.3% (P=0.21) at 1-21 years; 20.0% (P=0.66) at 2-22 years	Medium
Johnston (1978)[25] Philadelphia, USA	798 (51% male), 1958-65	Relative weight: weight for height ≥1 SD at 1year (high) *v* ≤–1 at 1 year (low)	At 9-15 years: relative weight (predicted weight/actual weight) ≥120%; triceps skinfold >90th centile for age, sex/race	Relative risk of obesity at ages 9-15 years, according to whether subjects had high or low relative weight or skinfold thickness at 1 year, stratified for sex	Relative risk (95% CI) for relative weight 3.75 (2.15 to 6.54) for males, 4.06 (2.52 to 6.53) for females; for triceps skinfold 2.97 (2.03 to 4.35) for males, 2.70 (1.74 to 4.17) for females	High

Table 1 continued

Study	No of subjects, year of birth	Measure of infant size	Definition of obesity	Analysis	Size of effect	Risk of bias
Wilkinson (1977)[23] Newcastle upon Tyne, UK	48 cases; 48 controls (42% male), 1960-2	Weight at 6 and 12 months (obese >90th centile)	Obesity at 10 years, defined as weight for height >97th centile. Controls defined as weight for height 25th-75th centile	Odds ratio of obesity at 10 years according to weight at 6 and 12 months	Odds ratio (95% CI) of obesity at 10 years in children who had been obese at 6 or 12 months *v* non-obese infants: 6 month weight (n=48) 2.00 (0.88 to 4.56); 12 month weight (n=42) 1.62 (0.63 to 4.15)	Medium
Whitaker (1997)[11] Washington State, USA	854 (36% male), 1965-70	Infant obesity: BMI >85th centile (obese) or >95th (very obese) at 1-2 years	BMI ≥27.8 kg/m^2 (men) or ≥27.3 kg/m^2 (women) at 25 years	Logistic regression giving odds ratios for obesity in adulthood by whether "obese"' or "very obese"' in infancy *v* "not obese"	Odds ratio (unadjusted): 1.3 (0.7 to 2.5) for obese or very obese; 2.0 (0.7 to 5.7) for very obese (findings remained non-significant after adjustment for parental obesity)	Medium
Poskitt (1977)[18] Dudley, UK	203 (49% male), 1968-70	Percentage weight at age when height is at 50th centile, measured at around 5 months (obese >120%)	Same, at around 5 years	Relative risk of childhood obesity at 5 years of age for "obese" infants *v* non-obese infants	Relative risk (95% CI) 9.38 (1.64 to 53.6)	Medium
Tienboon (2002)[15] New South Wales, Australia	83 (48% male), 1972	BMI >1 SD from group mean for age at 1 year	BMI >1 SD from group mean at 15 years	Relative risk of obesity at 15 years for "obese" *v* non-obese infants	Relative risk (95% CI) 2.03 (0.47 to 8.82)	Medium
He (1999)[14] Gothenburg, Sweden	3650 (51% male), 1972-5	Infant obesity: BMI >18 kg/m^2 (both sexes) at 1-2 years	BMI ≥25kg/m^2 (both sexes) at 18 years	Odds ratio of obesity at 18 years according to whether "obese" at 1 or 2 years	Odds ratio 995% CI) at 1 year: 1.62 (1.10 to 2.38) for males, 2.31 (1.57 to 3.41) for females, 1.93 (1.47 to 2.54) for both; at 2 years: 3.00 (2.03 to 4.43) for males, 2.90 (1.95 to 4.31) for females, 2.92 (2.22 to 3.86) for both	Medium
Monteiro (2003)[19] Pelotas, Brazil	1041 (52% male), 1982	Weight for height SD score at 2 years	BMI ≥85th centile at 14-16 years	Odds ratio of overweight and obesity in adolescence associated with 1 unit change in infancy z scores for size	Unadjusted odds ratio (cut off +1 SD at 2 years) 3.54 (2.53 to 4.96); odds ratio for 1 unit z score increase in weight for height SD 1.35 (1.53 to 1.73) adjusted for socioeconomic status, maternal size, and infant feeding	Low
Stettler (2002)[6] USA	19 397 (50% male), 1985-90	Infant size: weight at 1 year (g)	BMI >95th centile for age and sex at 7 years	Logistic regression giving odds ratio for risk of overweight at 7 years according to each unit (100g) increase in weight at 1 year	Odds ratios (95% CI):1.05 (1.04 to 1.05) unadjusted, 1.50 (1.38 to 1.63) adjusted for sex, birth weight, maternal BMI, and education	Medium
Mei (2003)[20] USA	380 518 (51% male), 1986-90	Weight for height ≥95th centile at 0-11 months (1); weight for height ≥95th centile at 12-23 months (2)	Weight for height ≥95th centile at 24-35 months (3); weight for height ≥95th centile at 36-47 months (4)	Relative risk of childhood obesity according to infant obesity category. No confidence intervals reported	Relative risk 3.3 for (1) and (3), 2.9 for (1) and (4), 6.4 for (2) and (3), 5.3 for (2) and (4)	Medium
Reilly (2005)[22] Avon, UK	857 (sex not stated for infant growth analysis 51% in entire cohort), 1991-2	Weight SD scores at 8 and 18 months	Obesity at age 7 years, defined as BMI ≥95th centile relative to UK 1990 reference population	Logistic regression giving odds ratio of obesity at 7 years of age for children in highest quarter for weight SD score at 18 months *v* children in other quarters	Odds ratio (95% CI) for weight at 8 months: 3.03 (1.89 to 4.85) unadjusted, 3.13 (1.43 to 6.85) adjusted; weight at 18 months: 3.71 (2.29 to 6.00) unadjusted, 2.65 (1.25 to 5.59) adjusted (adjusted for birth weight, maternal smoking, parental obesity, hours of sleep at age 30 months, time spent watching television at 30 months, diet, maternal education, sex)	Low

There was considerable consistency in study findings. Eleven studies found that infants who were heavier during infancy or were defined as obese were more likely to develop obesity in childhood,[6 18 20 22] adolescence,[14 19 24 25] and adulthood.[7 12 16]

Six studies related infant size to obesity in childhood. Four found that infants who had been obese[18 20] or who were in the highest end of the distribution for weight[6 22] were more likely to be obese at age 5-7 years than non-obese infants, with odds ratios ranging from 1.50 to 9.38. Three of the studies were based on cohorts of children born since 1985.[6 20 22] The fourth was of children born between 1968 and 1970, suggesting that these relations have been consistent over time.[18] Of the two other studies in childhood, one study failed to show an association.[23] The other study failed to show an association in the overall sample, though did find an increased risk of obesity at 5 years in a subsample of infants who had been obese.[17]

Of the five studies of adolescence, four found that larger size in infancy was related to increased risk of obesity at 9-18 years.[14 19 24 25] Effect sizes ranged between relative risk of 1.35 and odds ratio of 3.0 for adolescent obesity in infants at the highest end of the weight distribution[19 24 25] or in obese compared with non-obese infants.[14] The years of birth ranged from 1945 to 1982, suggesting that these relations have been consistent over time. In the remaining study the direction of the association, though not significant, was consistent with the findings of the other studies.[15]

Of the seven studies in adulthood, three reported significant associations between infant size and later obesity. Two studies showed that obese infants were more likely to be obese as young adults at ages 20-30 years than non-obese infants,[12 16] and the third found that larger size at 6 months of age was associated with increased lifetime risk of obesity.[7] The findings of three other studies of adults suggested a positive relation between infant size and later obesity but were not significant.[11 13 21] The final study, which was based on only 27 participants, failed to show an association.[26] Year of birth in the studies of adults ranged between 1929 and 1970, suggesting that associations have been consistent over time.

Studies of infant growth

Ten studies assessed the relation between infant growth and subsequent obesity (table 2). Nine were cohort studies,[6 19 22 27–32] and one was a case-control study.[24] Definitions of infant growth varied. Eight studies used weight gain during the first year of

Table 2 Summary data extracted from studies of infant growth, ordered by year of birth

Study	No of subjects, year of birth	Measure of infant growth	Definition of obesity	Analysis	Size of effect	Risk of bias
Heald (1965)[24] Washington DC/ Massachusetts, USA	158 cases 94 controls (all female), 1945-50	Weight (lb) or height (in) gain from 0-6, 6-12, and 0-12 months	Cases and controls defined for outcome (obesity) at mean age 15 years	Difference in mean values for weight or height gain at various intervals in infancy for cases and controls	For cases–controls: +0.540 (P=0.174) for weight gain (lb) 0-6 months, +0.565 (P=0.206) for height gain (in) 0-6 months, +1.586 (P=0.003) for weight gain (lb) 0-1 year, +0.558 (P=0.262) for height gain (in) 0 to 1 year, +0.842 (P=0.144) for weight gain (lb) 6-12 months, +0.035 (P=0.904) for height gain (in) 6-12 months	High
Stettler (2002)[6] USA	19 397 (50% male), 1959-65	Growth from birth to 4 months (g/month)	BMI >95th centile for age and sex at 7 years	Logistic regression giving odds ratio for obesity at 7 years by rate of weight gain from birth to 4 months in units of 100 g/month	Odds ratio (95% CI): 1.29 (1.25 to 1.33) unadjusted, 1.17 (1.11 to 1.24) adjusted (adjusted for sex, birth weight, maternal BMI, and education and other size/growth variable)	Medium
Stettler (2003)[27] Philadelphia, USA	300 (54% male), 1959-66	Increase in weight for age score ≥1 SD above mean from birth to 4 months (rapid weight gain)	BMI ≥30 kg/m^2 at 20 years	Logistic regression giving odds ratios for risk of obesity or overweight at 20 years by presence of rapid weight gain from birth to 4 months	Odds ratios (95% CI): 2.73 (1.20 to 6.23) unadjusted, 5.22 (1.55 to 17.6) adjusted for maternal size and education, birth weight and sex	Medium
Eid (1970)[28] Sheffield, UK	224 (54% male), 1961	Weight gain >90th centile over first 6 months of life (rapid weight gain)	Weight >20% over expected for height and sex at around 8 years	Relative risk of obesity at 8 years associated with rapid weight gain up to 6 months of age	Relative risk (95% CI) 4.05 (0.94 to 17.5)	Medium
Mellbin (1973)[29] Uppsala, Sweden (Medline)	465 males 507 female, 1965	Rapid growth: weight gain over 1st year ≥7.5 kg, or weight gain over months 1-4 and 9-12 >97th centile for age	Weight >20% above standard for height at 7 years	Relative risk of childhood obesity by infant weight gain ("rapid" or "normal")	Relative risk (95% CI) for weight gain over 1st year ≥7.5 kg: 2.32 (0.76 to 7.07) for males, 1.72 (0.60 to 4.94) for females ; for weight gain over months 1-4 and 9-12 >97th centile for age: 16.9 (4.70 to 61.0) for males, 1.33 (0.46 to 3.86) for females	Medium
Stettler (2005)[31] Iowa, USA	653 (52.4% male), 1965- 78	Weight gain from birth to 112 days of age (g)	Weight gain from birth to 112 days of age (g)	Logistic regression giving odds ratio (95% CI) for adult overweight according to both absolute weight gain (g) and changes in weight for age SD score between birth and 132 days	Odds ratio (95% CI) for weight gain (expressed in 100 g units). 1.04 (1.01 to 1.08), for change in weight for age SD score. 1.41 (1.09 to 1.82) (adjusted for birth weight, sex, type of formula feed, parental overweight status, subject's income)	Medium
Monteiro (2003)[19] Pelotas, Brazil	1041 (52% male), 1982	Weight-for-height SD score at 2years ("rapid growth": >0.67 z score change 0-2 years)	BMI ≥85th centile at 14-16 years	Odds ratio of overweight and obesity in adolescence associated with rapid growth	Odds ratio (95% CI) of overweight and obesity at 14-16 years 1.66 (1.20 to 2.31) adjusted for socioeconomic status, maternal size, and infant feeding	Low
Stettler (2002)[30] Seychelles	5514 (49% male), 1985- 90	Weight gain during 1st year of life (kg)	Obesity, using international obesity task force charts at ages 4.5-17.4 years	Logistic regression giving odds ratio (95% CI) for childhood overweight and obesity according to rate of weight gain in first year (rapid *v* normal)	Odds ratio (95% CI) 1.62 (1.39 to 1.88) unadjusted, 1.59 (1.29 to 1.97) adjusted for age, sex, maternal BMI, and parental occupation	Low
Reilly (2005)[22] Avon, UK	857 (% male not stated for infant growth analysis, 51% in entire cohort), 1991-2	Weight gain from birth to 1 year of age (g)	Obesity at age 7 years, defined as BMI ≥95th centile relative to UK 1990 reference population	Logistic regression giving odds ratio of obesity at 7 years of age by rate of weight gain from birth to 12 months of age in units of 100 g per month	Odds ratio (95% CI) 1.07 (1.05 to 1.10) unadjusted; 1.06 (1.02 to 1.10) adjusted for birth weight, maternal smoking, parental obesity, hours of sleep at 30 months, time spent watching television at 30 months, diet, maternal education, sex	Low
Toschke (2004)[32] South Germany	4235 (% male not stated) 1992-4	Weight gain from birth to 2 years of age (g)	Overweight status at school entry (age 5 to 6.9 years) according to IOTF definitions (BMI ≥85th centile for age and sex)	Odds ratio for overweight at school entry in children with weight gain greater >9764 g at age 2 years *v* those with weight gain at or below this level	Odds ratio (95% CI) 5.7 (4.5 to 7.1)	High

life.[6 22 24 28–32] Two studies used increase in weight for age[27] or weight for height z scores.[19]

Six studies examined obesity in children, four with body mass index[6 22 30 32] and two with weight.[28 29] Of two studies of adolescents, one defined obesity according to body mass index and the other used a clinical definition.[19 24] Both the studies of young adults defined obesity by body mass index.[27 31]

Seven of the ten studies examining infant growth found that more rapid growth in infancy was associated with greater risk of obesity at ages ranging from 4.5 to 20 years. In four studies of childhood, odds ratios of obesity in children who grew more rapidly in infancy compared with those who grew less rapidly ranged between 1.06 and 5.70.[6 22 30 32] The studies of adolescents and young adults reported odds ratios of later obesity ranging from 1.41 to 5.22.[19 27 31] The analyses in six of the seven studies were adjusted for important confounding factors,[6 19 22 27 30 31] and we considered three studies to have a low risk of bias.[19 22 30] Associations between infant growth and later obesity were consistent over time: year of birth ranged from 1945 to 1994. Three studies, two in children and one in adolescents, failed to show an association between infant growth and later obesity.[24 28 29]

We could not carry out a meta-analysis of the relation between infant size or growth and later obesity because the definitions of both the exposures (infant size or growth) and outcomes (childhood or adult obesity) varied widely between studies.

Discussion

This review suggests that both size and growth during infancy are related to risk of obesity in children and adults. Most studies of infant size found that infants who were defined as "obese" or who were at the highest end of the distribution for weight or body mass index were more likely to develop obesity in childhood, adolescence, or early adulthood than other infants. The evidence relating to infant growth was also consistent across most studies reviewed. Infants who grew more rapidly (usually measured as weight gain) were more likely to be obese in childhood, adolescence, and early adulthood than other infants. There was no evidence to suggest that exposure at a particular time during infancy was critical: larger size or a rapid phase of growth at a range of intervals during the first and second year of life predisposed to later obesity. Associations were also consistent across a range of settings in developed countries; for obesity measured in childhood, adolescence, and early adulthood; and over time for people born from 1927 to 1994.

Strengths and limitations of this review

Our review used rigorous and standard methods and was supported by an expert advisory group.[11] There were several challenges in interpreting the evidence. Most studies had at least a medium risk of bias in relation to the review question. Less than half of the studies of infant size took adequate account of confounding factors, though seven of the ten studies of infant growth considered most important confounders. Definitions of both the exposure (infant size or growth) and the outcome (obesity) varied between studies making meta-analysis impossible. This limits our ability to make precise conclusions about the size of the effect, though the consistency of the associations we observed between both infant size and growth and later obesity across a range of settings and time periods suggest that the association is robust.

Systematic reviews are subject to publication bias. Although we attempted to limit the impact of this through contact with first authors and experts, we did not identify any unpublished analyses. This review was part of a much larger review and so it was impractical to obtain original data from study authors to carry out secondary analyses. We therefore relied on published data from studies that were of variable quality.

Comparison with other research

Our findings amplify those of earlier systematic reviews. These found that rapid growth at different ages in childhood was associated with greater risk of later obesity.[4 33] One review also found that birth weight was positively associated with adult body mass index.[4] In our review odds ratios and relative risks of subsequent obesity in infants who had been obese compared with non-obese infants ranged between 1.35 and 9.38. Though not directly comparable, odds ratios tended to be lower in the studies of birth weight. For example, in a study of young Swedish men odds ratio of overweight increased from 1.07 to 1.67 going from the lowest (≤5th centile) to the highest (>95th centile) birthweight group.[34] In our review both large infant size and rapid infant growth were associated with later obesity. Babies who are small at birth experience rapid growth, at least in early infancy. Taken with other evidence, our review suggests that both prenatal and infant growth trajectories may be important in predicting adult obesity.

Conclusions

Infants in the highest end of the distribution for weight or body mass index and those who grow rapidly are at increased risk of obesity in childhood and adulthood. This suggests that factors during infancy or before that are related to infant growth influence the risk of later obesity. To inform public health policy aimed at reducing levels of childhood obesity, future research needs to investigate the determinants of these patterns of growth. The relation of infant growth with other health outcomes should be explored to assess whether interventions to alter infant growth to prevent obesity are likely to be associated with other benefits or harms. It will also be important to assess whether factors influencing infant growth are amenable to change, to establish which strategies might alter infant growth, and to find out whether these are acceptable to parents.

What is already known on this topic

Levels of overweight and obesity are increasing in all age groups

It is not clear how early in life prevention of obesity could begin nor what form it could take

Birth weight and childhood growth are related to risk of adult obesity, but the associations of infant size and growth with obesity have not been systematically assessed

What this study adds

Infants who are in the highest end of the distribution for weight or body mass index, or who grow rapidly during infancy, are at increased risk of subsequent obesity

Strategies for prevention of childhood and adult obesity may need to address factors during or before infancy that are related to infant growth

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