Journal of Perinatology (2012) 32, 91–96

www.nature.com/jp

ORIGINAL ARTICLE

Evolution of obesity in a low birth weight cohort

PH Casey[1], RH Bradley[2], L Whiteside-Mansell[1], K Barrett[1], JM Gossett[1] and PM Simpson[3]

[1]Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, AR, USA; [2]Family and Human Dynamics Research Institute, Arizona State University, Tempe, AZ, USA and [3]Translational and Biomedical Center, Children's Research Institute, Milwaukee, WI, USA

Objective: The objective of this study was to determine the evolution of obesity status (OS) in a longitudinal cohort of low birth weight preterm (LBWPT) infants to an age of 8 years, and to determine whether rapid weight gain in the first year of life independently predicts 8-year OS.

Study Design: In total, 985 infants (birth weight ⩽2500 g, gestation age ⩽37 weeks) were recruited from the nursery in an eight-site intervention research program and were evaluated at an age of 3, 5, 6.5 and 8 years. Weight and height were measured by standard protocol at each visit and body mass index was calculated. Obesity status is ⩾95% for age and sex. Multiple logistic analyses were performed on 8-year OS with predictor variables including infant race, gender, small for gestational age status, birth weight category, neonatal health index, treatment group and first-year weight gain; maternal education and weight status before conception; and HOME Inventory.

Result: Overall, 2.3% were OS at an age of 3 years, 6.1% at an age of 5 years, 7.7% at age 6.5 years and 8.7% at an age 8 years. OS varied by birth weight category at each visit. The infants born ⩽1500 g had the lowest prevalence of OS at each age. In the logistic regression, maternal race (Hispanic) (adjusted odds ratio = 2.8, confidence interval = 1.2 to 6.8), maternal obese status (adjusted odds ratio 3.4, confidence interval = 1.5 to 7.8) and first-year weight gain (adjusted odds ratio = 2.7, confidence interval = 1.9 to 3.9), significantly predicted 8-year OS.

Conclusion: OS is common in LBWPT infants during childhood, and prevalence varies by birth weight category. High weight gain in the first year of life is an important predictor of the development of OS in LBWPT children.
Journal of Perinatology (2012) **32,** 91–96; doi:10.1038/jp.2011.75; published online 9 June 2011

Keywords: obese children; low birth weight; childhood obesity

Introduction

National surveys have demonstrated that the prevalence of childhood obesity has been increasing since the 1980s.[1] Nearly 11% of children aged from 6 to 19 years in the United States in 1994 were obese compared with nearly 5% in the 1970s.[2] The prevalence of obesity in children aged from 6 to 19 years has gradually increased to more than 17% in 2003 to 2006.[3] During that period, the prevalence of obesity among 2- to 5-year-old children more than doubled from 5% in the 1970s[4] to 12.4% in 2003 to 2006.[3] This impressive increase in the prevalence of obesity, which has been associated with increased severity of obesity,[5] is associated with a large array of long-term negative physical and mental health consequences and economic burden.[6–8]

Low birth weight (LBW) status is associated with later childhood and adult obesity and related diseases such as hypertension, diabetes and cardiovascular disease.[9–12] Although some studies focused on small for gestation age (SGA) status, recent research has demonstrated the association of LBW, regardless of SGA status, with later insulin resistance, hypertension and cardiovascular disease.[13–15] Others have focused on excessive weight gain in the early years of life, demonstrating that excessive weight gain in children in the early years is associated with later childhood and adult obesity.[16–18] Excessive weight gain in the early years of life in LBW infants may be associated with even greater risk for later disease.[19–21]

The evolution of obesity in an exclusively LBW preterm (LBWPT) population born during the years of rapid increase in childhood obesity has not previously been demonstrated. As LBW infants, and particularly LBW infants who demonstrate excessive weight gain early in life, may be at increased risk of obesity later in childhood, we used the prospective cohort of LBWPT infants followed in the Infant Health and Development Program (IHDP) to evaluate the evolution of obesity in this population to the age of 8 years. The IHDP is a national, collaborative and randomized clinical trial that was conducted at eight medical schools, and was designed to evaluate the efficacy of a comprehensive intervention in the first 3 years of life in a cohort of LBWPT children who were born in 1985.[22,23] The cohort was enrolled in the nursery at eight sites and was followed in standardized study protocol. The broad array of high quality data collected in this unique long-term longitudinal study allows us to avoid many of the limitations in follow-up studies of LBWPT children. Using this large longitudinal

Correspondence: Dr PH Casey, Department of Pediatrics, University of Arkansas for Medical Sciences, 1 Children's Way, Slot 512-26, Little Rock, AR 72202, USA.
E-mail: CaseyPatrickH@uams.edu
Received 2 January 2011; revised 29 April 2011; accepted 5 May 2011; published online 9 June 2011

cohort born in 1985, we examined the following research questions: (1) What is the prevalence of obesity in the IHDP cohort at age 3, 5, 6.5 and 8 years? (2) Does the prevalence of obesity vary by birth weight category? (3) What maternal and child demographic and clinical characteristics, including infant rapid weight gain in the first year of life, best predicts obesity in this LBWPT cohort at the age of 8 years?

Methods

Descriptions of IHDP recruitment and subjects, study design and intervention have been published in detail elsewhere,[22,23] and are reviewed briefly here.

Sample

Infants were eligible for the IHDP study when they had a birth weight of $\leqslant$2500 g, had gestational age of 37 weeks or less, resided in the catchment area and did not have severe medical illness or neurological impairment.[22] Unhealthy infants were included in the sample, unless they had conditions (e.g., neural tube defects, severe sensory deficits) or neurological dysfunction that was recognized before nursery discharge and was judged to be so severe as to preclude participation in the intervention. Only 61 such infants were excluded. The infants were enrolled from October 1984 through August 1985. A total of 985 infants constituted the primary analysis group. These infants were randomly assigned to the intervention group ($N=377$) or the non-intervention group ($N=608$) using a design with two birth weight categories; lighter ($\leqslant$2000 g, ($N=623$)) and heavier (2001 to 2500 g, ($N=362$)). All children assigned in the intervention group, regardless of compliance with intervention, were included in the analyses as intervention children. The intervention program began at discharge from the Neonatal nursery and continued until October 1988, when each child was at least 36 months of age corrected for prematurity. The intervention consisted of home visits (birth to 3 years), center-based child development intervention services (age 1 to 3 years) and parent group meetings (age 1 to 3 years). There was no nutrition focus in the IHDP Program and no nutrition data were collected. After the intervention ended, the sites attempted to find appropriate community education programs for children in both groups before school age entry. Although there were no differences in length or body mass index (BMI) between intervention and non-intervention groups at age of 3 years,[22] the intervention children at 8 years were significantly taller and had larger head circumference.[23] The prevalence of both overweight (9%) and underweight (4.5%) at age 8 years was the same in both groups.[23]

Data collection

Infants in both intervention and non-intervention groups received the same periodic medical, developmental and social assessments through 8 years of age. All children were assessed at 40 weeks postconceptional age and at 4, 8, 12, 18, 24, 30 and 36 months gestation-corrected age and at 4, 5, 6.5 and 8 years. Clinical staff at each site typically included a pediatrician, a nurse clinician and a social worker. Clinicians provided general care instructions during all follow-up clinic visits to intervention and non-intervention children, including nutrition advice as needed. All growth measurements were collected by standardized protocol after careful training.

8-Year sample

Of the original 985 in the primary analysis group, 878 children (89%) were evaluated at 8 years of age.[24] The percentage retained within the intervention and non-intervention groups were similar, both overall and within sites. Overall, 89.7% of the intervention group and 88.8% of the non-intervention group were available; 90.5% of the infants at birth weight $<$1500 g and 86.7% of infants with birth weight from 2001 to 2500 g were available at 8 years.

Measures

Weight (kilograms) and height (centimeters) were collected by standard protocol after appropriate training procedures. Growth status was assessed by clinic staff who had access to the child's treatment group assignment and history. Obesity status (OS) was defined by BMI (kilograms divided by meters squared) $\geqslant$95th percentile for age and sex, based on the 2000 Center for Disease Control growth charts (http://www.cdc.gov/GrowthCharts/).

- Maternal obesity: BMI $\geqslant$30, based on self-reported preconception weight and length.
- Self-reported maternal education and race.
- HOME Inventory.[25] This is a measure of the quality and quantity of stimulation and support available to a child in the home environment. This was collected at the age of 12 months in a 1-h home visit. To ensure that the HOME Inventory was administered properly, a 2-day training session was conducted for assessors from all IHDP sites. Higher scores indicate better quality home environments.
- SGA status: Less than 10th percentile for gestation-adjusted age on the Lubchenco Growth Standards.
- Neonatal Health Index: this is a measure of the neonatal course, calculated based on the duration of stay in the nursery, adjusted for birth weight and standardized to a mean of 100, with higher scores indicating better health.
- Child weight gain in the first year of life: this was defined as the change in weight from birth to 12 months gestation-adjusted age divided by age in months and was expressed as 100 g per month.

Analyses

Data were available for 336 intervention children and 538 non-intervention children. All available data were used at each step of

the analyses, but the sample size varied because of missing data. The prevalence of obesity was calculated for three birth weight groups of 2001 to 2500 g, 1501 to 2000 g and ⩽1500 g at age 3, 5, 6.5 and 8 years of age. Pearson χ^2-tests and *t*-tests were used to compare intervention and non-intervention groups at baseline. Categorical variables were summarized as *N* (percent). Continuous variables were summarized as mean ± standard deviation.

A multivariable logistic regression model ($N = 686$) was used to predict the log odds of being overweight at 8 years of age (BMI>95th percentile) with mother's race (Black, Hispanic or White/other/Asian), maternal education (below high school, high school, beyond high school), maternal weight status (normal (BMI<25), overweight (BMI>25 to 30), obese (BMI>30)), HOME Inventory at 36 months, infant gender, birth weight category (0 to 1500 g, 1501 to 2000 g, 2001 to 2500 g), SGA status, neonatal health index, IHDP treatment group (intervention, follow-up), weight gain at first year (units of 100 g per month). The model was specified *a priori*. The area under the receiver operating curve was used to check the predictive value of the model. Goodness of fit model was assessed using the Hosmer–Lemeshow goodness of fit test with 10 partitions.

Results

As noted earlier, the sample was stratified to one-third intervention and two-thirds non-intervention (Table 1). There were no differences between intervention and non-intervention group in any of these characteristics. The average birth weight was near 1790 g and the average gestational age was 33 weeks. The average maternal age was near 25 years. About 38% had less than high school education and nearly 33% had some post-high-school education. 53% were African American and about 37% were White. Nearly 50% were male.

The prevalence of obesity in the IHDP cohort at age 3, 5, 6.5 and 8 years is depicted in Table 2. Although the available sample size varied at each data collection, the prevalence increased from 2.3% at age 3 ($N = 876$) to a prevalence of 8.6% for the IHDP sample at age 8 years ($N = 810$).

There is a gradual increase in the prevalence of obesity for each birth weight category at each age, except for the smallest birth weight group between 6.5 and 8 years (Figure 1). The highest prevalence of obesity at each data collection occurred in the largest preterm infants with birth weight category from 2001 to 2500 g. Out of these infants, 11.2% were obese at the age of 8 years. The lowest prevalence of obesity occurred in the preterm infants in the lowest birth weight category of ⩽1500 g. 4.8% of this group was obese at the age of 8 years. The prevalence of obesity of the larger birth weight preterm infants was more than twice that of the smallest preterm infants at each age.

The results of the logistic regression on 8-year OS are shown in Table 3. Maternal Hispanic race and maternal OS significantly

Table 1 Baseline characteristics of available IHDP sample

	Int	*NI*	P-*value*
Total no. (% of randomized infants)	336 (89.1)	538 (88.5)	0.68
Birth weight, g[a]	1799 ± 439	1787 ± 466	
Birth weight group, %			
⩽2000 g	64.5	63.9	0.85
2001–2500 g	35.4	36.1	
Gestational age, weeks[a]	32.9 ± 2.5	33.0 ± 2.8	0.52
Neonatal health index[a]	100.6 ± 15.9	99.9 ± 15.4	0.50
Maternal age at enrollment, years[a]	24.5 ± 5.8	25.0 ± 6.1	0.21
Maternal education, %			
<High school	40.8	36.2	0.24
=High school	29.2	28.4	
>High school	30.1	35.3	
Race, % of infants			
African American	53.0	52.8	0.99
Hispanic	9.5	9.8	
White/Other	37.5	37.4	
Male	49.7	49.4	0.94

Abbreviations: IHDP, Infant Health and Development Program; Int, intervention group; NI, non-intervention group.
[a]Values are shown as means ± s.d.

Table 2 IHDP cohort obese by age

Age (in years)	N	*Obese*	*(%)*
3	876	20	2.3
5	782	48	6.1
6.5	639	49	7.7
8	810	70	8.6

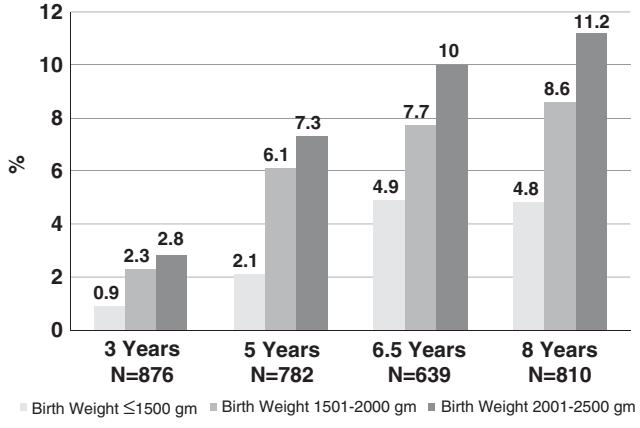

Figure 1 Percent obese by birth weight category and age.

Table 3 Logistic regression 8-year obesity status

	AOR	*Confidence intervals*	P-*value*
Maternal Hispanic race (vs White/other)	2.8	(1.2, 6.8)	0.02
Maternal Black race (vs White/other)	1.5	(0.7, 3.2)	0.33
Maternal education (high school vs less than high school)	0.36	(0.2, 3.8)	0.36
Maternal obesity status (vs normal)	3.4	(1.5, 7.8)	0.004
HOME inventory at 12 months	1.0	(0.97, 1.1)	0.63
Infant gender (male vs female)	0.75	(0.4, 1.3)	0.33
Birth weight category ($\leqslant$1500 vs $\geqslant$2001 g)	2.1	(.94, 4.7)	0.07
SGA status	0.6	(0.26, 1.5)	0.3
Neonatal health index	1.0	(0.98, 1.02)	0.9
IHDP treatment group (intervention vs follow-up)	1.0	(0.5, 1.7)	0.9
Weight gain at first year (100 g per month)	2.7	(1.9, 3.9)	0.0001

Abbreviations: AOR, adjusted odds ratio; IHDP, Infant Health and Development Program; SGA, small for gestation age.

predicted OS of 8-year-old child. Neither the IHDP treatment group nor the 12-month measure of the quality of the child's home environment (HOME Inventory) predicted 8-year OS. Infant gender, SGA status and the Neonatal Health Index did not predict obesity at the age of 8 years. Infant weight gain in the first year of life was the strongest infant characteristic which predicted to 8-year child OS.

Discussion

In this large cohort of LBWPT infants, the prevalence of obesity gradually increased from 2.3% at the age of 3 years to 8.6% at the age of 8 years. The prevalence of obesity among the smallest LBW infants (birth weight $\leqslant$1500 g) was only 4.8% at age of 8 years. This contrasts with an obesity prevalence of 11.2% among the larger LBW infants (birth weight 2001 to 2500 g). Infant weight gain in the first year of life significantly and independently predicted 8-year OS, along with maternal Hispanic ethnicity and maternal preconception obesity.

To our knowledge, ours is the first descriptive report of the evolution of OS in a longitudinal cohort of LBWPT infants. How does the prevalence of OS in this group compare with the general population of children born in the same birth cohort? These children were born in 1985, and they turned 8 years old in 1993. An increasing prevalence of OS was already being noted in various national surveys and longitudinal research projects at that time. This increase was noted as early as in 1976,[1,2,26] and has continued until recently.[4,27,28] A recent analysis of clinical data suggested that the number of children diagnosed as obese may have stabilized or decreased since 2005.[29] Although data specific to 8-year-old children born in 1985 are not available, an MMWR report of 6- to 11-year-old children evaluated in the 1988 to 1994 NHANES III found a prevalence of 13.7% obese children.[30] Using the same NHANES III, Troiano[31] reported an obesity prevalence in 6- to 11-year-old children of 10.6%. NHANES found a prevalence of obesity in 6 to 11-year olds of 15.3% by 1999 to 2000[4] and 18.8% in 2003 to 2004.[32] Thus, the overall prevalence of OS of the IHDP LBWPT cohort of 8.6% was not greater than the general population as represented in the national survey.[5] In fact the prevalence of 11.2% in the largest LBW group was nearly the same as the general population.

There is increasing concern that rapid weight gain in the early years of life, whether the infant is born normal birth weight at term, small for gestational age or preterm and LBW, is associated with greater risk for obesity and glucose dysregulation in later childhood or adult years, independent of birth weight.[16–21,33] The association of high weight gain to later child and adult weight status in general populations of children has been noted as early as the first weeks of life,[34–36] the first 3 to 6 months,[16,17,37,38] the first year[35,39,40] and the first 2 years[17,41,42] and beyond.[38] There has been no uniform definition of high or excessive weight gain, but methods have included absolute weight gain (gram per months),[16,37] change in weight adjusted standard deviation score[38,42] and change in *Z* scores.[35,43] Reports have been cross-sectional,[37] retrospective[42,44] and longitudinal.[16,18,38] There has been less focus on the evolution and prediction of later childhood obesity in LBW or LBWPT infants. In a cohort of 463 Intrauterine growth-restricted infants born $<$2211 g at term, the BMI at 7 years of age was linearly related to postnatal gain in the first 4 months of life.[33] Euser[21] evaluated 403 (19-year old) adults born at $<$32 weeks gestation and found that greater weight gain from 0 to 3 months of age was associated with higher BMI at the age of 19 years. To our knowledge, our report is the first that describes in a longitudinal cohort of LBWPT infants the association of high weight gain in the first year of life with later childhood obesity. As there is no gold standard to define rapid weight gain, we chose to use absolute weight gain in the first year. We also performed analyses using change in weight *Z* scores in the first year of life, and found similar results as the absolute weight gain.

Others have evaluated maternal and child characteristics, which predicted obesity in children and adults in general populations. Data of 3022 children in the National Longitudinal Survey of Youth found that the best predictors of childhood overweight status at age 6 to 7 years were maternal ethnicity and pre-pregnancy obesity, along with the child being overweight at an earlier time between 2 to 3 years and 4 to 5 years.[44] In a cohort of 1780 children in France, the best predictors of overweight status at the age of 4 years were having an overweight mother and the child being overweight by 9 to 24 months of age.[45] Finally, the best

predictor to adult BMI in a group of 261 (40-year old) women was rapid weight gain from age 1 to 7 years.[46] Our findings in the IHDP cohort mirror these studies, and demonstrates the significant contribution of maternal pre-pregnancy OS, maternal race and infant weight gain at the first year of life to childhood OS at 8 years in previously LBWPT infants. SGA status did not independently contribute to the prediction of 8-year obesity in this LBW cohort when taking into account the other environmental and child characteristics. Clearly, the ultimate development of obesity during childhood for LBW infants is determined by a variety of parent and child characteristics. Unfortunately, we do not have access to information such as the parent feeding style, the diet the children consumed or other environmental features, which would be important to better understand the evolution of childhood obesity.

The IHDP cohort provides much methodological strengths, including infants being born in eight communities and families with a broad array of demographic characteristics. Data were of high quality as all growth data were collected in research protocol by evaluators trained to reliability. However, the generalizability of the IHDP sample to a contemporary group of LBWPT children is somewhat restricted, as these infants were born in 1985. The medical and nutritional care of LBWPT infants born at that time varies from current treatment practices, and it is unclear how this difference may affect the growth of contemporary LBWPT children. In addition, the IHDP cohort did not include a large number of extremely LBW infants, as the mortality of those infants was much greater in 1985 compared with current mortality rates. Finally, 89% of the original IHDP sample was available for data collection at the age of 8 years, despite significant efforts at each IHDP site to evaluate the entire longitudinal cohort. The effect of this loss of subjects on these results is uncertain.

In summary, the prevalence of obesity in this LBWPT cohort was greater in the larger infants born 2001 to 2500 g (11.2%) as compared with the infants born <2000 g (4.8%). This prevalence in the larger preterm infants was similar to the prevalence of obesity noted in general populations of children born in the same birth cohort. If LBWPT children are at greater risk for obesity as compared with normal birth weight term infants, the onset of obesity likely occurs at an age later than 8 years. As in the general population of children, the associations of high weight gain in the first year of life in these LBWPT infants strongly predicted obesity in 8-year-old children. Clinicians who provide ongoing care for LBWPT infants have historically attempted to facilitate growth rebound to normal size in the early years of life. These data suggest that clinicians should be cautious in their nutritional treatment and attempt to assure gradual catch up of weight with weight symmetric to length in order to avoid excessively rapid weight gain early in life. Further longitudinal follow-up of LBWPT children into adult years will better document the impact of rapid weight gain in LBWPT infants on obesity as adults.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The participating universities and site directors in the IHDP were as follows: Patrick H Casey, University of Arkansas for Medical Sciences (Little Rock, AR); Cecelia M McCarton, Albert Einstein College of Medicine (Bronx, NY); Michael W Yogman and Marie C McCormick, Harvard Medical School (Boston, MA); Charles R Bauer and Keith G Scott, University of Miami School of Medicine (Miami, FL); Judith Bernbaum, University of Pennsylvania School of Medicine (Philadelphia, PA); Jon E Tyson and Mark Swanson, University of Texas Health Science Center at Dallas (Dallas, TX); Clifford J Sells and Forrest Bennett, University of Washington School of Medicine (Seattle, WA); and David T Scott, Yale University School of Medicine (New Haven, CT). The Infant Health and Development Program was supported in its first three years by the Robert Wood Johnson Foundation; follow-up evaluations were supported by the Pew Charitable Trust, the National Institute of Child Health and Human Development and by the Maternal Child Health Bureau, with the Robert Wood Johnson Foundation. Statistical analyses for this manuscript were supported by a Children's University Medical Group grant from the Arkansas Children's Hospital Research Institute.

References

1 Troiano RP, Flegal KM, Kuczmarski RJ, Campbell SM, Johnson CL. Overweight prevalence and trends for children and adolescents: the National Health and Nutrition Examination Surveys, 1963-1991. *Arch Pediatr Adolesc Med* 1995; **149**: 1085–1091.

2 Troiano RP, Flegal KM. Overweight children and adolescents: description, epidemiology, and demographics. *Pediatrics* 1998; **101**: 497–504.

3 Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003-2006. *JAMA* 2008; **299**: 2401–2405.

4 Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. *JAMA* 2002; **288**: 1728–1732.

5 Jollife D. Extent of overweight among US children and adolescents from 1971-2000. *Int J Obes Relat Metab Disord* 2004; **28**: 4–9.

6 Dietz WH, Robinson TN. Overweight children and adolescents. *N Engl J Med* 2005; **352**: 2100–2109.

7 Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics* 1998; **101**(3 Part 2): 518–526.

8 Wang G, Dietz WH. Economic burden of obesity in youths aged 6 to 17 years: 1979-1999. *Pediatrics* 2002; **109**(5). Available at: www.pediatrics.org/cgi/content/full/109/5/e81.

9 Casey PH. Growth of low birth weight preterm children. *Semin Perinatol* 2008; **32**: 20–27.

10 Gluckman PD, Hanson MA, Cooper C, Thornburg KL. Effect of in utero and early-life conditions on adult health and disease. *N Engl J Med* 2008; **359**: 61–73.

11 Kensara OA, Wooten SA, Phillips DI, Patel M, Jackson AA, Elia M. Fetal programming of body composition: relation between birth weight and body composition measured with dual-energy x-ray absorptiometry and anthropometric methods in older Englishmen. *Am J Clin Nutr* 2005; **82**: 980–987.

12 Barker DJ, Eriksson JG, Forsen T, Osmond C. Fetal origins of adult disease strength of effects and biological basis. *Int J Epidemiol* 2002; **31**: 1235–1239.

13 Huxley R, Owen CG, Whincup PH, Cook DG, Rich-Edwards J, Smith GD *et al.* Is birth weight at risk factor for ischemic heart disease in later life? *Am J Clin Nutr* 2007; **85**: 1244–1250.

14 Hovi P, Anderson S, Eriksson JG, Järvenpää AL, Strang-Karlsson S, Mäkitie O *et al.* Glucose regulation in young adults with very low birth weight. *N Engl J Med* 2007; **356**: 2053–2063.

15 Hofman PL, Regan F, Jackson WE, Jefferies C, Knight DB, Robinson EM *et al.* Premature birth and later insulin resistance. *N Engl J Med* 2004; **351**: 2179–2186.

16 Stettler N, Zemel BS, Kumanyika S, Stallings VA. Infant weight gain and child overweight status in a multicenter cohort study. *Pediatrics* 2002; **109**: 194–199.

17 Toschke AM, Grote V, Koletzko B, von Kries R. Identifying children at high risk for overweight at school entry by weight gain during the first 2 years. *Arch Pediatr Adolesc Med* 2004; **158**: 449–452.

18 Stettler N, Kumanyika K, Katz SH, Zemel BS, Stallings VA. Rapid weight gain during infancy and obesity in young adulthood in a cohort of African Americans. *Am J Clin Nutr* 2003; **77**: 1374–1378.

19 Regan F, Cutfield WS, Jefferies C, Robinson E, Hofman PL. The impact of early nutrition in premature infants on later childhood insulin sensitivity and growth. *Pediatrics* 2006; **110**: 1943–1949.

20 Law CM, Shiell AW, Newsome CA, Syddall HE, Shinebourne EA, Fayers PM *et al.* Fetal, infant, and childhood growth and adult blood pressure. *Circulation* 2002; **105**: 1088–1092.

21 Euser AM, Finken MJJ, Keijzer-Veen MG, Hille ET, Wit JM, Dekker FW. Associations between prenatal and infancy weight gain and BMI, fat mass, and fat distribution in young adulthood: a prospective cohort study in males and females born very preterm. *Am J Clin Nutr* 2005; **81**: 480–487.

22 The Infant Health and Development Program. Enhancing the outcomes of low birthweight, premature infants: a multisite, randomized trial. *JAMA* 1990; **263**: 3035–3042.

23 Casey PH, Bradley RH, Whiteside-Mansell L, Barrett K, Gossett JM, Simpson PM. The effect of early intervention on 8 year growth status of low birth weight preterm infants. *Arch Pediatric Adolesc Med* 2009; **163**: 1046–1053.

24 McCarton CM, Brooks-Gunn J, Wallace IF, Bauer CR, Bennett FC, Bernbaum JC *et al.* Results at 8 years of early intervention for low birth weight premature infants: the Infant Health and Development Program. *JAMA* 1997; **277**: 126–132.

25 Bradley RH. The HOME inventory: review and reflections. In: Reese H (ed). *Advances in Child Development and Behavior*. Academic: New York, 1994. pp 241–288.

26 Freedman DS, Srinivasan SR, Valdez RA, Williamson DF, Berenson GS. Secular Increases in relative weight and adiposity among children over two decades: the Bogalusa Heart Study. *Pediatrics* 1997; **99**: 420–426.

27 Strauss RS, Pollack HA. Epidemic increase in childhood overweight, 1986-1998. *JAMA* 2001; **286**: 2845–2848.

28 Sherry B, Zuguo M, Scanlon KS, Mokdad AH, Grummer-Strawn LM. Trends in state-specific prevalence of overweight and underweight in 2 through 4 year old children from low-income families from 1989 through 2000. *Arch Pediatr Adolesc Med* 2004; **158**: 1116–1124.

29 Benson L, Baer HJ, Kaelber DC. Trends in the diagnosis of overweight and obesity in children and adolescents: 1999-2007. *Pediatrics* 2009; **123**: e153–e158.

30 Centers for Disease Control and Prevention (CDC). Update: prevalence of overweight among children, adolescents, and adults-United States, 1988-1994. *MMWR* 1997; **46**: 199–202.

31 Troiano RP, Flegal K. Overweight children and adolescents: description, epidemiology, and demographics. *Pediatrics* 1998; **101**: 497–504.

32 Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA* 2006; **295**: 1549–1555.

33 Pylipow M, Spector LG, Puumala SE, Boys C, Cohen J, Georgieff MK. Early post natal weight gain, intellectual performance, and body mass index at 7 years of age in term infants with intrauterine growth retardation. *J Pediatr* 2009; **154**: 201–206.

34 Stettler N, Stallings VA, Troxel AB, Zhao J, Schinnar R, Nelson SE *et al.* Weight gain in the first week of life and overweight in adulthood: a cohort of European American subjects fed infant formulas. *Circulation* 2005; **111**: 1897–1903.

35 Hui LL, Schooling CM, Leung SSL, Mak KH, Ho LM, Lam TH *et al.* Birthweight, infant growth, and childhood body mass index. Hong Kong's Children of 1997 birth Cohort. *Arch Pediatr Adolesc Med* 2008; **162**: 212–218.

36 Botton J, Heude B, Maccario J, Ducimetière P, Charles MA. Postnatal weight gain and height growth velocities at different ages between birth at 5 years and body composition in adolescent boys and girls. *Am J Clin Nutr* 2008; **87**: 1760–1768.

37 Dennison BA, Edmunds LS, Stratton HH, Pruzek RM. Rapid infant weight gain predicts childhood overweight. *Obesity* 2006; **14**: 491–499.

38 Ekelund U, Ong K, Linné Y, Neovius M, Brage S, Dunger DB *et al.* Upward weight percentile crossing in infancy and early childhood independently predicts fat mass in young adults: the Stockholm Weight Development Study (SWEDES). *Am J Clin Nutr* 2006; **83**: 324–330.

39 Vogels N, Posthumus DL, Mariman EC, Bouwman F, Kester AD, Rump P *et al.* Determinants of overweight in a cohort of Dutch children. *Am J Clin Nutr* 2006; **84**: 717–724.

40 Sayer AA, Syddall HE, Dennison EM, Gilbody HJ, Duggleby SL, Cooper C *et al.* Birthweight, weight at 1 year of age, and body composition in older men: findings from the Hertfordshire Cohort Study. *Am J Clin Nutr* 2004; **80**: 199–203.

41 Ong KKL, Ahmed ML, Emmett PM, Preece MA, Dunger DB. Association between postnatal catch-up growth and obesity in childhood: prospective cohort study. *BMJ* 2000; **320**: 967–971.

42 Yliharsila H, Kajantie E, Osmond C, Forsén T, Barker DJ, Eriksson JG. Body mass index during childhood and adult body composition in men and women aged 56-70 years. *Am J Clin Nutr* 2008; **87**: 1769–1775.

43 McCarthy A, Hughes R, Tilling K, Davies D, Smith GD, Ben-Shlomo Y. Birth weight; postnatal, infant, and childhood growth; and obesity in young adulthood: evidence from the Barry Caerphilly Growth Study. *Am J Clin Nutr* 2007; **86**: 907–913.

44 Salsberry PJ, Reagan PB. Dynamics of early childhood overweight. *Pediatrics* 2005; **116**: 1329–1338.

45 Jouret B, Ahluwalia N, Cristini C, Dupuy M, Nègre-Pages L, Grandjean H *et al.* Factors associated with overweight in pre-school age children in southwestern France. *Am J Clin Nutr* 2007; **85**: 1643–1649.

46 Terry MB, Wei Y, Esserman D. Maternal, birth, and early-life influences on adult body size in women. *Am J Epidemiol* 2007; **116**: 5–13.