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# Family and Early Life Factors Associated With Changes in Overweight Status Between Ages 5 and 14 Years: Findings From The Mater University Study Of Pregnancy and its Outcomes

**AA Mamun[1], DA Lawlor[2], MJ O'Callaghan[3], GM Williams[1] and JM Najman[1,4]**

[1]*Longitudinal Studies Unit, School of Population Health, The University of Queensland, Brisbane, Australia;*
[2]*Department of Social Medicine, University of Bristol, UK;*
[3]*Child Development and Rehabilitation Services, Mater Children's Hospital, Brisbane, Australia;*
[4] *School of Social Science, TheIUniversity of Queensland, Brisbane, Australia*

## Abstract

OBJECTIVE: To describe different patterns of overweight status between ages 5 and 14 y and examine the role of modifiable family and early life characteristics in explaining different patterns of change between these two ages.

DESIGN: A population-based prospective birth cohort.

SUBJECTS: A total of 2934 children (52% males) who were participants in the Mater-University study of pregnancy, Brisbane, and who were examined at ages 5 and 14 y.

MAIN OUTCOME MEASURES: Four patterns of change in overweight/obesity status between ages 5 and 14 y: (i) normal at both ages; (ii) normal at 5 y and overweight/obese at 14 y; (iii) overweight/obese at 5 y and normal at 14 y; (iv) overweight/ obese at both ages.

RESULTS: Of the 2934 participants, 2018 (68.8%) had a normal body mass index (BMI) at ages 5 and 14 y, 425 (14.5%) changed from a normal BMI at age 5 y to overweight or obese at age 14 y, 175 (6.0%) changed from being overweight or obese at age 5 y to normal weight at age 14 y and 316 (10.8%) were overweight or obese at both ages 5 and 14 y. Girls were more likely to make the transition from overweight or obese at age 5 y to normal at 14 y than their boy counterparts. Children whose parents were overweight or obese were more likely to change from having a normal BMI at age 5 y to being overweight at 14 y (fully adjusted RR: 6.17 (95% CI: 3.97, 9.59)) and were more likely to be overweight at both ages (7.44 (95% CI: 4.60, 12.02)). Birth weight and increase in weight over the first 6 months of life were both positively associated with being overweight at both ages. Other explanatory factors were not associated with the different overweight status transitions.

CONCLUSIONS: Parental overweight status is an important determinant of whether a child is overweight at either stage or changes from being not overweight at 5 y to becoming so at 14 y.

**Keywords:** childhood overweight or obesity; change with age-related trends; parental overweight or obesity; early life factors; sex

## Introduction

Overweight or obesity during childhood is an increasing problem throughout the world. The population prevalence of childhood overweight or obesity has increased by about three-fold in many countries, including Australia,[1] over the last 2 or 3 decades.[2] These trends are likely to have

major public health consequences since overweight or obesity status tracks from childhood to adulthood and there is emerging evidence that the precursors for diabetes and cardiovascular disease, some of which will be irreversible, already exist in overweight and obese children.[2–7]

With respect to the tracking of measures of obesity across time, most studies have assessed correlations between body mass index (BMI) at different ages and found moderate correlations,[8,9] or have assessed how well being overweight or obese at one stage of the life course predicts being overweight or obese at a later stage.[6,10–13] Few studies have examined the range of possibilities of patterns between two time points - that is what proportion of those who are not overweight at the first time point have become overweight by the second and what proportion have remained not overweight and what proportion of those who are overweight at the first time point remain so by the second time point. With respect to reducing the public health burden of childhood and adolescent obesity, it is important to know each of these proportions. Further, it is important to know what modifiable risk factors are causally associated with these different patterns of transition.

With respect to the occurrence of childhood obesity *per se,* parental obesity and family socio-economic position are two of the strongest predictors.[14–16] In addition, maternal mental health, birth weight, early weight gain, childhood behaviours and dietary and physical activity patterns are likely to be important, although evidence for their independent effects is inconsistent. Few studies have examined the independent role of these exposures as predictors of different patterns of change in overweight status between two time points in the life course.

The aim of this study is to describe different patterns of overweight status between ages 5 and 14 y and examine the role of modifiable family and early life characteristics in explaining different patterns of change between these two ages in a cohort of children born in Brisbane, Australia in the early 1980s.

## Methods

### *Participants*

The Mater-University of Queensland Study of Pregnancy (MUSP) is a longitudinal study of women and their offspring born during 1981–84 at one of the two major obstetric hospitals in Brisbane, Australia. The study was originally established to examine social and health factors associated with pregnancy outcome and then over the long term to determine the early life predictors of future social and health outcomes in both the mothers and their children. In total, 7223 mothers agreed to participate, delivered a live singleton baby who was not adopted prior to leaving hospital and completed both initial phases of data collection; these mothers and their offspring form the MUSP prospective cohort. The original study and subsequent follow-up received ethical approval from an ethics committee at the University of Queensland. Participants gave signed informed consent of their participation and that of their children. Full details of the MUSP study are described elsewhere.[17]

Mothers and children have been followed-up prospectively with maternal questionnaires being administered when they were at their first antenatal clinic visit, 3–5 days post-delivery, 6 months after birth, 5 and 14 y after birth. In addition, at ages 5 and 14 y, detailed physical, cognitive and developmental examinations of the children were undertaken, and at 14 y, the children completed health, welfare and lifestyle questionnaires. Of the original 7223 participants, BMI (weight in kg divided by height in metres squared) of 3989 (55%) children was measured at age 5 y, 3795 (53%) at 14 y and 2934 (41%) at both 5 and 14 y of follow-up.

### *Measurement outcomes*

In this study, the main outcome in all analyses is the child's BMI at the 5- and 14-y follow-ups. In all assessments, the average of two measures of the child's weight when lightly clothed, with a scale accurate to 0.2 kg, was used. A portable stadiometer was used to measure the height. Overweight or obesity was defined according to standard definitions derived from international surveys by Cole *et al.*[18] Thus using the standard definition, in this study, a 5-y-old child was defined as overweight or obese if a child's BMI was greater than 17.42 kg/m$^2$ for a boy and 17.15 kg/m$^2$ for a girl. Similarly, overweight or obese was defined at age 14 y if BMI exceeded 22.62 kg/m$^2$ for a boy and 23.34 kg/m$^2$ for a girl. These values are equivalent to exceeding 25 kg/m$^2$ in adulthood.[18] At age 5 y, a participant was defined as obese if his or her BMI exceeded 19.30 kg/m$^2$ for a boy and 19.17 kg/m$^2$ for a girl and at age 14 if his or her

BMI exceeded 27.63 kg/m$^2$ for a boy and 28.57 kg/m$^2$ for a girl, which are equivalent to exceeding 30 kg/m$^2$ in adulthood.[18] Too few of the participants fell into the obese categories for meaningful analyses; therefore, we classified children as either overweight or obese (equal to or above the overweight threshold) or normal weight (below the overweight threshold).

*Risk factor and confounder measurements*

The main predictors considered in this study were parental BMI, birth weight (exact value in kg), gestational age (in weeks), rate of weight gain (nearest gram per day) during the first 6 months after birth, duration of breastfeeding, child-hood mental health, maternal depression, parental education and family income. Maternal height and pre-pregnancy weight, and paternal height and weight were obtained at the study initiation from obstetric records or maternal questionnaires. The mother reported paternal height and weight. A high degree of correlation was obtained between maternal estimate of her pre-pregnancy weight and her measured weight on the first antenatal visit (Pearson's correlation coefficient = 0.95). We defined three BMI categories both for mother and father based on the World Health Organization guidelines (1998).[19] Birth weight (exact value in kg), gestational age (in weeks), maternal age (y) at birth (three categories: 13–19; 20–34; and 35 or more), parity (categorised as 1, 2, 3 and more), maternal educational attainment (did not complete secondary school, completed secondary school, completed further/higher education) and racial origin (Caucasian, Asian and Abor-Islander) were obtained from questionnaires at the first clinic visit and obstetric records in the study. Rate of weight gain (g/day) and duration of breastfeeding were collected at a 6-month follow-up of the mothers. At the '6-month' follow-up time, some mothers were in fact between 4 and 6 months post-delivery (none were seen earlier than 4 months post delivery). The question concerned with the duration of breastfeeding gave the mothers the following response options: never, 2 weeks or less, 3–6 weeks, 7 weeks–3 months, 4–6 months, still breastfeeding. Because women were at least 4 months post-delivery when they responded to this question, there is a clear overlap between the last two categories; we therefore combined these into one category – breastfed for greater than 4 months. There were too few women in each of the categories 2 weeks or less, 3–6 weeks and 7 weeks–3 months for meaningful analyses and there-fore we have categorised breastfeeding as never, less than 4 months or 4 months or more in our analyses.

At the 5-y follow-up, mothers were asked about gross family income in the last week (0–99, 100–199, 200–299, 300–399, 400–499, 500–599, ≥600 Aus $). This was collapsed into two categories of low income (<$15 599/y) and high income ($15 600/y and more). When the children were aged 5 y, their mothers were asked about the general health status (excellent, good and fair) of their children. Child mental health was assessed from maternal reports of child behaviour using a modified child behaviour checklist (CBCL) at age 5 y.[20] Consistent with Achenbach, a case was defined as a participant scoring above the 90th percentile for the externalising (comprising delinquent and aggressive syndromes) or internalising (consisting of items measuring withdrawn behaviour, somatic complaints and symptoms of anxiety/depression) subscales.[20] Maternal depression was assessed at 5-y follow-up using the Delusions-Symptoms-States Inventory (DSSI). In this study, maternal depression when the child was aged 5 y was defined as having three or more symptoms out of the seven in the DSSI depression subscale.

*Statistical analyses*

$\chi 2$ tests were used to assess differences between the participants, those with BMI measured at both ages 5 and 14 y and the remainder of the birth cohort, by sociodemographic background and parental BMI at birth. Multinomial logistic regression was used to estimate the exact age-(at the time of BMI assessments) adjusted prevalences of overweight or obesity at ages 5 and 14 y and the change in the patterns of overweight or obesity from ages 5 to 14 y. Four possible outcomes are considered: (a) normal BMI at ages 5 and 14 y; (b) normal BMI at age 5 y but overweight or obese at 14 y; (c) overweight or obese at ages 5 y but normal at 14 y and (d) overweight or obese at ages 5 and 14 y. Because the outcome variable involves four distinct transitions, a multinomial logistic regression model is used as the analytical technique[21] to assess the predictors of each of the transitions. Results are presented in relative risk (RR), which is similar to odds ratios. In the model, independent variables like birth weight, gestational age and rate of weight gain were taken as continuous and all other independent variables were taken as categorical.

In order to assess whether non-response biased our results, we used logistic regression (response vs non-response as outcome) to determine weights for each individual using the inverse probability of response. Response and non-response categories were defined based on the measured BMI at 5- and 14-y follow-ups. A child whose BMI was measured at 5- and 14-y follow-ups belonged to the response category and a child whose BMI was measured at 5 y but not at 14 y belonged to the non-response category. The inverse probability of response for each individual was estimated adjusting for the factors that predict non-response. Non-response was mainly predicted by mothers' age at birth, family income, maternal education and ethnic groups of the parents. The individual weighting factor was used as a sample weighting adjustment in the main analyses. All analyses were undertaken using Stata version 8.0 (Stata Inc., Texas).

Table 1. Prevalence and change in overweight or obesity between ages 5 and 14 y

| | *Males (%) (mean; s.d.)* N = *1534* | *Females (%) (mean; s.d.)* N = *1400* | *Total (%) (mean; s.d.)* N = *2934* |
|---|---|---|---|
| *BMI at age 5 y* | | | |
| Normal | 84.8 (15.6; 1.0) | 81.6 (15.4; 1.1) | 83.3 (15.5; 1.1) |
| Overweight or obese | 15.2 (18.5; 1.1) | 18.4 (18.6; 1.5) | 16.7 (18.6; 1.3) |
| *BMI at age 14 y* | | | |
| Normal | 76.5 (18.7; 1.9) | 72.8 (19.1; 2.0) | 74.7 (18.9; 1.9) |
| Overweight or obese | 23.5 (25.3; 2.8) | 27.2 (26.3; 3.3) | 25.3 (25.8; 3.1) |
| *BMI at ages 5 and 14 y* | | | |
| Normal both ages | 71.3 (17.0; 1.2) | 66.1 (17.1; 1.3) | 68.8 (17.1; 1.3) |
| Normal at 5 y, overweight or obese at 14 y | 13.6 (20.5; 1.3) | 15.5 (20.6; 1.3) | 14.5 (20.5; 1.3) |
| Overweight or obese at 5 y, normal at 14 y | 5.3 (19.2; 0.7) | 6.7 (19.3; 0.9) | 6.0 (19.2; 0.8) |
| Overweight or obese at 5 and 14 y | 9.9 (22.5; 1.9) | 11.7 (23.3; 2.4) | 10.8 (22.9; 2.2) |

## Results

Of the 7223 cohort participants, 2934 (41%) had BMI measurements at age 5 or 14 y. In the MUSP study, compared to responders, non-responders were more likely to have had teenage mothers, be from low-income families, have a mother who did not complete secondary education and to be from non-Caucasian ethnic groups.[22]

### *Prevalence and change in overweight/obesity between ages 5 and 14 y*

The exact age-adjusted prevalence of overweight or obesity at age 5 y was 16.7% (boys 15.2% and girls 18.4%) and at age 14 y was 25.3% (boys 23.5% and girls 27.2%) (Table 1). Of the 2934 participants, 2018 (68.8%) had a normal BMI at ages 5 and 14 y, 425 (14.5%) changed from a normal BMI at age 5 to overweight or obese at age 14 y, 175 (6.0%) changed from being overweight or obese at age 5 y to normal weight at age 14 y and 316 (10.8%) were overweight or obese at both ages 5 and 14 y.

For the children who changed from being overweight at age 5 y to being normal weight at age 14 y, their BMI increased between the two age points by 2.4 kg/m$^2$ (95% CI: 2.1, 2.6) on average, which compares to increases of 3.3 kg/ m$^2$ (95% CI: 3.2, 3.4) for the group who were normal at both ages, 8.9 kg/m$^2$ (95% CI: 8.5, 9.0) for the group who were normal at 5 y but overweight or obese at 14 y and 8.15 kg/m$^2$ (95% CI: 7.6, 8.4) for the group who were overweight at both ages. The change in BMI units per year was + 0.55 kg/m$^2$ between the ages 5 and 14 y.

### *Factors associated with different patterns of overweight status between ages 5 and 14 y*

Table 2 shows the four possible patterns of overweight status between ages 5 and 14 y by parental BMI, socio-demographic background, breastfeeding, and child and maternal mental status at age 5 y. In all, 36% of children whose fathers were overweight were overweight or obese at age 14 y (19% normal at age 5 y but overweight or obese at 14 and 17% persistent) and only 6% changed from being overweight or obese at age 5 y to a normal BMI at age 14 y. Similarly, half of the children whose mothers were overweight were over-weight or obese by age 14 y (28% normal at age 5 y but overweight or obese at age 14 y and 22% persistent). When both parents were overweight or obese, 59% of the children were overweight or obese by age 14 y (31% normal at age 5 y but overweight or obese at 14 y and 28% persistent). There was also some evidence of tracking of overweight or obesity associated with parental socio-economic status, duration of breastfeeding and child and maternal mental health, but none of these associations were statistically significant.

Table 2. Change (%) in overweight or obesity between ages 5 and 14 y by parental overweight or obesity, socio-demographic characteristics, breastfeeding, child health and maternal mental health status

| | | | | | | |
|---|---|---|---|---|---|---|
| *Father's BMI* | | | | | | |
| Normal | 73.5 | 12.4 | 5.7 | 8.3 | 1847 | |
| Overweight or obese | 57.2 | 19.0 | 6.4 | 17.4 | 769 | <0.001 |
| *Mother's BMI* | | | | | | |
| Normal | 74.1 | 11.8 | 5.9 | 8.2 | 2299 | |
| Overweight or obese | 45.0 | 28.2 | 5.0 | 21.8 | 458 | <0.001 |
| *Parental BMI* | | | | | | |
| Normal mother and father | 76.7 | 10.6 | 5.7 | 6.9 | 1534 | |
| Normal mother, overweight or obese father | 65.8 | 14.0 | 6.8 | 13.3 | 527 | |
| Overweight or obese mother, normal father | 50.9 | 26.8 | 5.4 | 17.0 | 224 | |
| Both mother and father overweight or obese | 36.5 | 31.3 | 4.7 | 27.6 | 192 | <0.001 |
| *Family income at 5-y FU* | | | | | | |
| Aus $15599 or less | 66.3 | 16.5 | 5.4 | 11.8 | 629 | |
| Aus $15600 or more | 69.4 | 14.1 | 6.2 | 10.4 | 2201 | 0.253 |
| *Maternal education at birth* | | | | | | |
| Did not complete secondary | 67.5 | 15.5 | 4.8 | 12.2 | 459 | |
| Completed secondary | 69.6 | 14.1 | 5.9 | 10.4 | 1868 | |
| Completed further or higher | 67.0 | 15.1 | 7.1 | 10.9 | 590 | 0.585 |
| *Racial origin* | | | | | | |
| Caucasian | 68.53 | 14.7 | 6.1 | 10.7 | 2634 | |
| Asian | 79.82 | 9.2 | 3.7 | 7.3 | 109 | |
| Abor-islander | 67.54 | 14.9 | 5.3 | 12.3 | 114 | 0.347 |
| *Mother's age at birth* | | | | | | |
| 13–19 y | 68.0 | 15.5 | 7.3 | 9.2 | 303 | |
| 20–34 y | 68.7 | 14.4 | 5.8 | 11.2 | 2471 | |
| 35+y | 71.9 | 14.4 | 6.3 | 7.5 | 160 | 0.661 |
| *Parity* | | | | | | |
| 1 | 67.5 | 14.5 | 6.3 | 11.8 | 1152 | |
| 2 | 71.4 | 12.2 | 6.2 | 10.2 | 901 | |
| 3+ | 68.0 | 16.7 | 5.4 | 9.9 | 876 | 0.120 |
| *Breastfeeding* | | | | | | |
| Never | 69.6 | 13.5 | 6.0 | 11.0 | 520 | |
| Less than 4 months | 65.6 | 16.5 | 5.8 | 12.1 | 1056 | |
| 4 months and more | 70.9 | 13.3 | 6.0 | 9.8 | 1284 | 0.135 |
| *Sex* | | | | | | |
| Males | 71.3 | 13.6 | 5.3 | 9.9 | 1534 | |
| Females | 66.1 | 15.5 | 6.7 | 11.7 | 1400 | 0.023 |
| *Child's general health at age 5 y* | | | | | | |
| Excellent | 68.5 | 14.2 | 5.8 | 11.6 | 1455 | |
| Good | 69.0 | 14.9 | 6.2 | 9.9 | 1304 | |
| Fair | 66.7 | 17.7 | 4.3 | 11.4 | 141 | 0.532 |
| *Any behavioural problem at age 5 y* | | | | | | |
| No | 68.9 | 14.3 | 6.2 | 10.7 | 2569 | |
| Yes | 65.9 | 17.2 | 4.8 | 12.1 | 331 | 0.319 |
| *Maternal depression at 5-y FU* | | | | | | |
| Not depressed | 68.5 | 15.0 | 5.9 | 10.8 | 2753 | |
| Depressed | 72.3 | 9.9 | 6.4 | 11.4 | 141 | 0.449 |

Table 3 shows the univariable and multivariable associations of parental BMI, birth weight, rate of weight gain, gestational age, breastfeeding, socio-demographic status and child and maternal mental health at age 5 y for the different patterns of overweight status between ages 5 and 14 y. These results are for the 2188 (76% of the 5- and 14-y-old respondents with measured BMI) children and adolescents with complete data on all variables included in the model. The widths of the confidence intervals for relative risk ratios do not differ markedly between the unadjusted and adjusted models, suggesting that collinearity is not an important problem in this final model. One might expect that the direction in relative risks between two transitions, normal to overweight or obese and overweight or obese to normal would be opposite. For most examples, this is not the case. For example, parental overweight status is positively associated with changing from being normal to overweight and from being overweight to normal. However, the magnitudes of the effect estimates are different such that if one's parents are overweight, the child is much more likely to change from normal to overweight than the opposite.

Both maternal and paternal overweight status were positively associated with changing from having a normal BMI at age 5 y to being overweight at age 14 y and with being overweight at both ages. Having both parents in the overweight or obese category was particularly strongly associated with these transitions. Children whose mothers and fathers were overweight or obese were more likely to change from being not overweight at age 5 y to being overweight at 14 y (fully adjusted relative risk: 6.17 (95% CI: 3.97, 9.57)) and were more likely to be overweight at both ages (7.44 (4.60, 12.02)). Overall, the change in the offspring's overweight or obesity from age 5 to 14 y showed closer links with maternal than with paternal BMI (P for interaction with sex o0.001; Figure 1).

Table 3 Predictors of the change in overweight or obesity between ages 5 and 14 y

| | *Unadjusted relative risk (N = 2188) (reference: normal BMI at ages 5 and 14 y)* | | | *Adjusted relative risk (N = 2188) (reference: normal BMI at ages 5 and 14 y)* | | |
|---|---|---|---|---|---|---|
| | *Normal to overweight or obese* | *Overweight or obese to normal* | *Overweight or obese at 5 and 14 y* | *Normal to overweight or obese* | *Overweight or obese to normal* | *Overweight or obese at 5 and 14 y* |
| *Sex* | | | | | | |
| Males | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Females | 1.13 (0.84–1.45) | 1.46 (1.02–2.09) | 1.22 (0.93–1.61) | 1.27 (0.97–1.67) | 2.20 (1.49–3.25) | 1.70 (1.25–2.32) |
| *Parental BMI* | | | | | | |
| Normal mother and father | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Normal mother, overweight or obese father | 1.60 (1.16–2.20) | 1.27 (0.83–1.96) | 2.10 (1.49–2.96) | 1.59 (1.14–2.22) | 1.42 (0.90–2.24) | 2.14 (1.49–3.07) |
| Overweight or obese mother, normal father | 3.98 (2.71–5.84) | 1.38 (0.72–2.70) | 3.74 (2.41–5.82) | 4.19 (2.82–6.22) | 1.44 (0.72–2.86) | 3.02 (1.86–4.91) |
| Both mother and father overweight or obese | 6.27 (4.15–9.48) | 1.79 (0.86–3.74) | 7.08 (4.53–11.07) | 6.17 (3.97–9.59) | 2.05 (0.95–4.42) | 7.44 (4.60–12.02) |
| Birth weight (kg) | 1.13 (0.89–1.44) | 1.86 (1.31–2.64) | 1.60 (1.22–2.11) | 1.06 (0.78–1.43) | 2.63 (1.72–4.01) | 2.10 (1.50–2.94) |
| Rate of weight gain (1 g/day in first 6 months) | 1.02 (1.00–1.04) | 1.05 (1.02–1.08) | 1.05 (1.03–1.07) | 1.02 (1.00–1.05) | 1.07 (1.04–1.09) | 1.06 (1.04–1.08) |
| Gestational age (weeks) | 1.01 (0.93–1.08) | 1.04 (0.93–1.16) | 0.97 (0.89–1.04) | 0.99 (0.90–1.08) | 0.89 (0.78–1.02) | 0.88 (0.79–0.98) |
| *Breastfeeding* | | | | | | |
| Never | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Less than 4 months | 1.26 (0.87–1.84) | 1.12 (0.65–1.93) | 0.98 (0.66–1.45) | 1.35 (0.90–2.02) | 0.95 (0.54–1.58) | 0.99 (0.64–1.54) |
| 4 months or more | 0.96 (0.66–1.39) | 1.04 (0.62–1.76) | 0.74 (0.50–1.09) | 1.07 (0.71–1.61) | 0.90 (0.51–1.58) | 0.81 (0.52–1.25) |
| *Maternal education* | | | | | | |
| Did not complete secondary | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Completed secondary | 0.84 (0.66–1.35) | 1.27 (0.73–2.21) | 0.90 (0.61–1.32) | 1.22 (0.83–1.80) | 1.58 (0.86–2.93) | 1.09 (0.71–1.68) |
| Completed further or higher | 1.10 (0.73–1.66) | 1.34 (0.71–2.51) | 0.94 (0.59–1.48) | 1.51 (0.96–2.38) | 1.57 (0.77–3.18) | 1.23 (0.74–2.06) |
| *Family income at 5-y FU* | | | | | | |
| Aus $15599 or less | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Aus $15600 or more | 0.78 (0.56–1.06) | 0.82 (0.53–1.27) | 0.70 (0.50–0.97) | 0.81 (0.59–1.12) | 0.83 (0.52–1.32) | 0.77 (0.54–1.11) |
| *Racial origin* | | | | | | |
| White | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Asian | 0.57 (0.26–1.27) | 0.55 (0.17–1.78) | 0.76 (0.34–1.69) | 0.55 (0.24–1.25) | 0.59 (0.18–1.95) | 0.82 (0.36–1.87) |
| Abor-islander | 1.22 (0.64–2.34) | 0.68 (0.21–2.23) | 1.76 (0.93–3.31) | 0.90 (0.43–1.86) | 0.69 (0.21–2.28) | 1.51 (0.75–3.04) |
| *Mother's age at birth* | | | | | | |
| 13–19 y | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20–34 y | 1.01 (0.64–1.58) | 0.82 (0.45–1.50) | 1.18 (0.69–2.00) | 0.86 (0.52–1.41) | 0.75 (0.38–1.46) | 1.10 (0.61–1.97) |
| 35+ y | 0.82 (0.41–1.65) | 0.95 (0.39–2.32) | 0.56 (0.22–1.42) | 0.54 (0.24–1.20) | 1.09 (0.39–3.01) | 0.51 (0.18–1.40) |
| *Parity* | | | | | | |
| 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 0.83 (0.61–1.13) | 1.01 (0.67–1.52) | 0.85 (0.61–1.18) | 0.78 (0.56–1.09) | 0.95 (0.61–1.48) | 0.81 (0.56–1.16) |
| 3+ | 1.29 (0.96–1.72) | 0.83 (0.53–1.30) | 0.85 (0.61–1.19) | 1.18 (0.84–1.65) | 0.71 (0.42–1.18) | 0.66 (0.44–0.98) |
| *Any behavioural problems at age 5 y* | | | | | | |
| No | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Yes | 1.17 (0.80–1.70) | 0.80 (0.43–4.49) | 1.30 (0.86–1.95) | 1.11 (0.74–1.68) | 0.76 (0.39–1.48) | 1.17 (0.74–1.85) |
| *Child's general health at age 5 y* | | | | | | |
| Excellent | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Good | 1.10 (0.86–1.42) | 1.02 (0.71–1.47) | 0.91 (0.68–1.21) | 1.18 (0.90–1.54) | 1.12 (0.76–1.63) | 0.91 (0.67–1.24) |
| Fair | 1.23 (0.69–2.18) | 1.01 (0.42–2.41) | 1.20 (0.64–2.24) | 1.25 (0.67–2.32) | 0.98 (0.37–2.57) | 0.95 (0.46–1.97) |
| *Maternal depression* | | | | | | |
| Not depressed | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Depressed | 0.59 (0.29–1.20) | 1.10 (0.50–2.46) | 1.16 (0.63–2.13) | 0.58 (0.28–1.21) | 1.17 (0.51–2.71) | 0.80 (0.38–1.69) |

In the full-adjusted model, a girl was 2.20 (CI: 1.49–3.25) times more likely to make transition from overweight or obese at age 5 y to normal at 14 y and 1.70 (CI: 1.25–2.32) times more likely to remain overweight or obese during this age interval than her boy counterpart. Birth weight and rate of weight gain were positively associated with the transition from overweight or obese to normal as well as to the continuity of overweight or obesity, suggesting that these exposures were particularly associated with overweight status at age 5 y. When we repeated the analyses using weights for factors that predicted non-response, the results did not differ from those presented here.

## Discussion

We have found that 17% of children at age 5 y and 25% at age 14 y are overweight or obese. Of those children overweight or obese at age 5 y, nearly two-thirds were still overweight at age 14 y and among children who were not overweight at age 5 y, 17% had become overweight at age 14 y. Children whose parents were overweight or obese were more likely to change from being not overweight at age 5 y to being overweight at 14 y and were more likely to be overweight at both ages. Maternal overweight status in particular was associated with these transitions. Overweight or obesity in one or both parents probably affects the risk of overweight or obesity in their offspring due to the collective effect of genetic and environmental factors within families.[11]

A direct comparison of our results with those of other studies[1,23] is difficult because of differences in the birth years of the cohorts, the ages at which examinations were performed and the definition of overweight or obesity. However, our prevalence estimate of childhood and adolescence overweight or obesity using standard definitions derived from international surveys[18] is of the same magnitude as the prevalence of children and adolescents over-weight or obese, estimated at 20–25%, reported by the National Health and Medical Research Council (NHMRC)[24] and, in a prospective study of Australian children, proportions of overweight including obesity in boys and girls were 13 and 18% at 5 y[25] and in the age group 7–15 *y*, 20% boys and 20.5% girls[23] were overweight or obese. The associations of parental BMI and socio-economic factors with childhood overweight status are consistent with previous studies.[14–16] The change in offspring's overweight or obesity from one age to another age showed closer links with mothers than with fathers overweight or obesity, which is consistent with previous studies.[26]

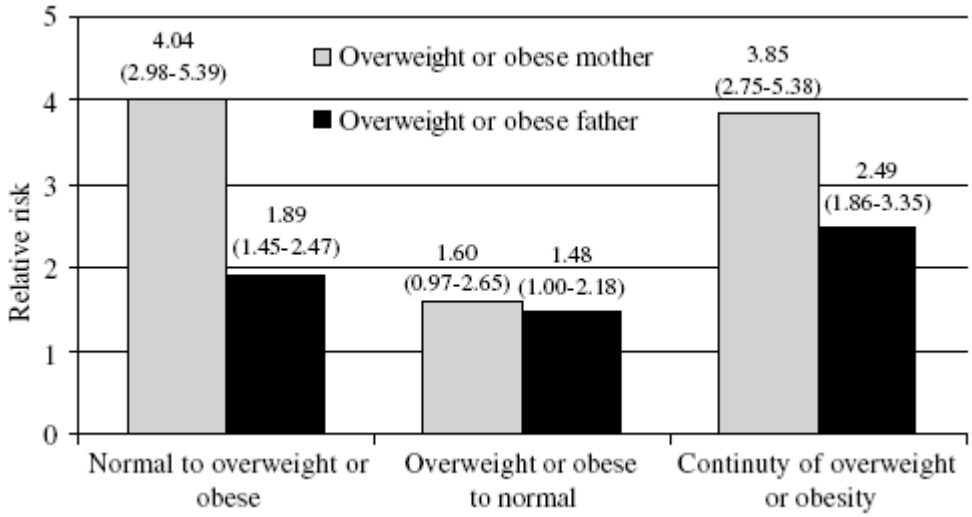


***Figure 1*** Relative risk for the change in overweight or obesity from age 5 to 14 y by father's and mother's overweight or obesity status.

### *Study limitations*

The strong association between parental overweight status and adverse changes in their children suggests that tackling adult obesity is likely to be important both for their own health benefit and for that of their offspring. There is evidence from randomised controlled trials that effective long-term weight control among obese children is associated with parental involvement in the intervention, including interventions that result in successful parental weight loss.[33–35] The effect of home-based/family-based interventions to prevent childhood obesity in the general population is unclear because of the poor quality, small size and short follow-up of most studies.[35,36] Although the associations The participation rate at both ages 5 and 14 y was 41% and the participants who did not attend were more likely to be from poorer backgrounds, with mothers likely to have had low education and be non-Caucasian. There was, however, no significant difference in participation by parental BMI. We expect results would only be biased if the associations we have assessed were nonexistent or in the opposite direction in non-participants, which is unlikely. Maternal pre-pregnancy height and weight and paternal height and weight were reported by the mothers and may be inaccurate. However, the correlation between maternal report of her pre-pregnancy weight and her actual weight at her first antenatal visit was very high (0.95). Any misclassification of these values would tend to dilute the associations.

Other important factors related to physical activity and diet are known to be important determinants of childhood BMI.[27–29] These are also likely to influence changes in overweight status over time. We were unable to assess the effects of these exposures since information on them was not available in this study before the age of 14 y. However, such exposures are themselves in part likely to be mediators of the parental BMI effects since childhood diet and physical activity patterns are known to be importantly determined by parental activities.[30–32]

*Implications*

We have found that the majority of those who were overweight or obese at age 5 y remain overweight or obese at age 14 y and an important proportion of those who were normal at age 5 y become overweight or obese. These findings suggest that to reduce the public health burden of childhood and adolescence overweight or obesity, early prevention of childhood obesity is important.

The strong association between parental overweight status and adverse changes in their children suggests that tackling adult obesity is likely to be important both for their own health benefit and for that of their offspring. There is evidence from randomised controlled trials that effective long-term weight control among obese children is associated with parental involvement in the intervention, including interventions that result in successful parental weight loss.[33–35] The effect of home-based/family-based interventions to prevent childhood obesity in the general population is unclear because of the poor quality, small size and short follow-up of most studies.[35,36] Although the associations between parental overweight status and childhood transitions in overweight status found in our study suggest that family-based interventions may be important for the prevention of childhood overweight or obesity, large, good quality trials are required to determine the effects of family-based interventions on the risk of becoming overweight or obese in childhood. Further, the study design needs to incorporate the ability to undertake long-term follow-up of the participants to determine the effects of such interventions on future health risks such as cardiovascular disease risk.

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**References**

1 Lazarus R, Wake M, Hesketh K, Waters E. Change in body mass index in Australian primary school children, 1985–1997. *Int* J *Obes Relat Metab Disord* 2000; 24: 679–684.

2 Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. *Lancet* 2002; 360: 473–482.

3 Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics* 1999; 103 (6 Part 1): 1175–1182.

4 Ferguson MA, Gutin B, Owens S, Litaker M, Tracy RP, Allison J. Fat distribution and hemostatic measures in obese children. *Am J Clin Nutr* 1998; 67: 1136–1140.

5 Ford ES, Galuska DA, Gillespie C, Will JC, Giles WH, Dietz WH. C-reactive protein and body mass index in children: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. *J Pediatr* 2001; 138: 486–492.

6 Tounian P, Aggoun Y, Dubern B, Varille V, Guy-Grand B, Sidi D, Girardet JP, Bonnet D. Presence of increased stiffness of the common carotid artery and endothelial dysfunction in severely obese children: a prospective study. *Lancet* 2001; 358: 1400–1404.

7 Srinivasan SR, Myers L, Berenson GS. Predictability of childhood adiposity and insulin for developing insulin resistance syndrome (syndrome X) in young adulthood: the Bogalusa Heart Study. *Diabetes* 2002; 51: 204–209.

8 Kelly JL, Stanton WR, McGee R, Silva PA. Tracking relative weight in subjects studied longitudinally from ages 3 to 13 years. *J Paediatr Child Health* 1992; 28: 158–161.

9 Guo SS, Huang C, Maynard LM, Demerath E, Towne B, Chumlea WC, Siervogel RM. Body mass index during childhood, adolescence and young adulthood in relation to adult overweight and adiposity: the Fels Longitudinal Study. *Int J Obes Relat Metab Disord* 2000; 24: 1628–1635.

10 Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *Am J Clin Nutr* 2002; 76: 653–658.

11 Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med* 1997; 337: 869–873.

12 Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T. Do obese children become obese adults? A review of the literature. *Prev Med* 1993; 22: 167–177.

13 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 to 1991. *Arch Pediatr Adolesc Med* 1995; 149: 1085–1091.

14 Parsons TJ, Power C, Logan S, Summerbell CD. Childhood predictors of adult obesity: a systematic review. *Int J Obes Relat Metab Disord* 1999; 23 (Suppl 8): S1–S107.

15 Langnase K, Mast M, Muller MJ. Social class differences in overweight of prepubertal children in northwest Germany. *Int J Obes Relat Metab Disord* 2002; 26: 566–572.

16 Langnase K, Mast M, Danielzik S, Spethmann C, Muller MJ. Socioeconomic gradients in body weight of German children reverse direction between the ages of 2 and 6 years. *J Nutr* 2003; 133: 789–796.

17 Keeping JD, Najman JM, Morrison J, Western JS, Andersen MJ, Williams GM. A prospective longitudinal study of social, psychological and obstetric factors in pregnancy: response rates and demographic characteristics of the 8556 respondents. *Br J Obstet Gynaecol* 1989; 96: 289–297.

18 Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; 320: 1240–1243.

19 World Health Organization. Obesity. *Preventing and managing the global epidemic*, Report of a WHO Consultation on Obesity, 3–5 June 1997. World Health Organization: Geneva, Switzerland; 1998.

20 Achenbach TM. *Integrative guide for the 1991* CBCL/4-18, YSR, and *TRF* profiles. University of Vermont Department of Psychiatry: Burlington; 1991.

21 Maddala GS. *Limited-dependent and qualitative* variables *in econometrics.* Cambridge University Press: Cambridge; 1983.

22 Lawlor D, Najman JM, Sterne J, Williams GM, Ebrahim S, Davey Smith G. Associations of parental, birth and early life characteristics with systolic blood pressure at age 5: findings from the Mater-University study of pregnancy and its outcomes. *Circulation*s 2004; 110: 2417–2423.

23 Burke V, Beilin L, Dunbar D, Kevan M. Associations between blood pressure and overweight defined by new standards for body mass index in childhood. *Prev Med* 2004; 38: 558–564.

24 National Health and Medical Research Council. *Clinical practice* guidelines - for *the management of overweight and obesity in children and adolescents.* Commonwealth of Australia: Canberra; 2003.

25 Burke V, Beilin LJ, Simmer K, Oddy WH, Blake KV, Doherty D, Kendall GE, Newnham JP, Landau LI, Stanley FJ. Predictors of body mass index and associations with cardiovascular risk factors in Australian children: a prospective cohort study. *Int J Obe Relat Metab Disord* 2005; 29: 15–23.

26 Danielzik S, Langnase K, Mast M, Spethmann C, Muller MJ. Impact of parental BMI on the manifestation of overweight 5–7 year old children. *Eur J Nutr* 2002; 41: 132–138.

27 Deheeger M, Rolland Cachera MF, Fontvieille AM. Physical activity and body composition in 10 year old French children: linkages with nutritional intake? *Int J Obes Relat Metab Disord* 1997; 21: 372–379.

28 Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998; 279: 938–942.

29 Scaglioni S, Agostoni C, Notaris RD, Radaelli G, Radice N, Valenti M, Giovannini M, Riva E. Early macronutrient intake and overweight at five years of age. *Int J Obes Relat Metab Disord* 2000; 24: 777–781.

30 Birch LL, Davison KK. Family environmental factors influencing the developing behavioral controls of food intake and childhood overweight. *Pediatric Clin N Am* 2001; 48: 893–907.

31 Kalakanis LE, Goldfield GS, Paluch RA, Epstein LH. Parental activity as a determinant of activity level and patterns of activity in obese children. *Res Quart Exerc Sport* 2001; *72:* 202–209.

32 Hodges EA. A primer on early childhood obesity. *Pediatric Nurs* 2003; 29: 13–16.

33 Golan M, Weizman A, Apter A, Fainaru M. Parents as the exclusive agents of change in the treatment of childhood obesity. *Am J Clin Nutr* 1998; 67: 1130–1135.

34 Epstein LH, Valoski A, Wing RR, McCurley J. Ten-year follow-up of behavioural, family-based treatment for obese children. *JAMA* 1990; 264: 2519–2523.

35 Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes Rev* 2004; 5 (Suppl 1): 4–85.

36 Campbell K, Waters E, O'Meara S, Kelly S, Summerbell C. Interventions for preventing obesity in children. *Cochrane Database Sys Rev* 2002; 2: CD001871.