COVER SHEET

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Predicting obesity in early adulthood from childhood and parental obesity

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Abstract

Objective: To determine the degree of tracking of adiposity from childhood to early adulthood, and the risk of overweight in early adulthood associated with overweight in childhood and parental weight status in a cohort of children born in the mid 1970s.

Design: Longitudinal observational study.

Subjects: Approximately 155 healthy boys and girls born in Adelaide, South Australia 1975-6 and their parents.

Measurements: Height and weight of subjects at 2 years, annually from 4 to 8 years, biennially from 11 to 15 years and at 20 years, and of parents when subjects were aged 8 years. BMI of subjects converted to standard deviation scores and prevalence of overweight and obesity determined using worldwide definitions. Parents classified as overweight if BMI $\geq$ 25kg/m^2. Tracking estimated as Pearson correlation coefficient. Risk ratio used to describe the association between weight status at each age and parental weight status and weight status at 20 years and weight status at each earlier age, both unadjusted and adjusted for parental weight status.

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Results: The prevalence of overweight/obesity increased with age and was higher than that reported in international reference populations. Tracking of BMI was established from 6 years onwards to 20 years at r values > 0.6 suggesting that BMI from 6 years is a good indicator of later BMI. Tracking was stronger for shorter intervals and for those subjects with both parents overweight compared with those with only one or neither parent overweight. Weight status at an earlier age was a more important predictor of weight status at 20 years than parental weight status, and risk of overweight at 20 years increased further with increasing weight status of parents.

Conclusion: Strategies for prevention of overweight and targeted interventions for prevention of the progression of overweight to obesity are urgently required in school aged children in order to stem the epidemic of overweight in the adult population.

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Key words: body mass index, child to adult tracking, obesity, parent

Introduction

The prevalence of overweight and obesity in young people is increasing rapidly in both the developed and developing world and is a major global public health concern (1). The health consequences of obesity in childhood and adolescence are extensive and include dyslipidaemia, elevated blood pressure, insulin resistance, orthopaedic difficulties, accelerated growth and maturity and psychosocial problems (1-3). These have the potential to place considerable future burden on health costs and services. However the most important consequence of childhood overweight and obesity is a greater risk of obesity in adulthood (4, 5). A 1993 review of epidemiological studies in Europe and the United States of the relationship between obesity in childhood and subsequently in adulthood reported that the risk of adult obesity was at least twice as high for obese children as for non-obese children (6). A number of other studies also originating in Europe and North America have been published since that date (4, 5, 7-9). These studies support the findings of Serdula and colleagues on the degree of tracking of weight status from childhood to early and mid-adulthood and include additional information on the relationship with parental weight status (7, 8, 10) **.**

All but one of the studies (11) published to date have been of children born between 1930 and 1960 and the majority prior to 1950. It has been suggested that the degree of tracking in more recent cohorts may be greater as the prevalence of obesity in the last 30 years has increased as a result of exposure to an adverse environment (7) ie the risk of being an obese adult if obese as a child may be greater than previously estimated.

One of the problems of assessing the potential risk of adult overweight and obesity and associated morbidities has been the lack of an agreed definition for overweight and obesity in children and the absence of a definition that is related to measurable health outcomes. The agreement by the International Obesity Task Force (IOTF) that BMI, although not ideal, is a reasonable index of adiposity in children (1, 12) was followed by the publication of international definitions for overweight and obesity (13). However although these new definitions are extrapolated from the adult definitions based on health outcomes, they are still primarily statistical in derivation. Despite this, they do provide an opportunity to determine the degree of tracking at levels of fatness recognised internationally.

Estimates of the prevalence of overweight and obesity using the new worldwide definitions of overweight and obesity (13) are available from nationally representative samples of Australian children and adolescents surveyed in 1985 and 1995. These data indicate that the prevalence of overweight has increased by 65% and the prevalence of obesity by three to four-fold in the 10-year period and that in 1995 15% of 2 to 18-year-olds were overweight and a further 4.5% were obese (14). Only recently has an Australian study reported the degree of tracking of weight status in subjects aged 9 to 18 years (11). The Adelaide Nutrition Study (ANS) (15, 16) provides Australian data from aged 2 to 20 years on a birth cohort from 1975-6.

Using data from the Adelaide study the aim of this paper is to report (i) the degree of tracking of weight status from 2 to 20 years, (ii) the risk of overweight and obesity in early adulthood (20 years) conferred by childhood overweight and obesity, (iii) the proportion of overweight and obesity in early adulthood that can be accounted for by overweight and obesity in childhood, (iv) the relation between child and parent weight status with respect to the risk of overweight and obesity in childhood, adolescence and early adulthood, and (v) the degree of tracking according to parental weight status.

Subjects and Methods

The subjects (n=500) in the ANS were selected by birth order (every fourth child) from a cohort of 2000 healthy term infants born at Queen Victoria Hospital, Adelaide, South Australia between

November 1975 and June 1976. This ANS cohort participated in a longitudinal study that assessed growth and dietary intake annually or biennually from birth to 15 years of age (15-17). Considerable attrition occurred from n=500 at birth, to 198 at two years, to 141 at 8 years. At this time (1983-4), 118 children were recruited from the original birth cohort to join the ANS. Height and weight of all parents of children participating at 8 years were observer measured at this time. All subjects in the ANS (approximately 250) were then followed to 20 years of age. Details of the demographic status of participants and the reasons for cohort attrition have been published previously (15-17). The numbers of subjects at each age and the number of parents are shown in Table 1.

Anthropometric measurements

Anthropometric measurements of height and body mass were taken at age 2, annually from age 4 to 8 years, and at 11, 13, 15 and 20 years. All measurements were taken by the first author except at 2 and 20 years. Height and body mass of mothers and fathers were measured when children were aged 8 years. Body mass index (BMI) was calculated as body mass (kg)/height^2 (m^2) and children's values converted to standard deviation scores (BMI SD) using the BMI percentile curves derived by Cole et al (18). Use of SD scores accounts for variation of BMI by age and gender in childhood and adolescence and allows combination of data from boys and girls and comparison across age groups. Children aged 2 to 15 years were classified as acceptable weight, overweight or obese according to the international definitions for overweight and obesity based on BMI (13). The equivalent BMI classifications for subjects at 20 years and mothers and fathers were acceptable weight < 25 kg/m^2, overweight ≥ 25 and < 30 kg/m^2, and obese ≥ 30 kg/m^2.

Data analyses

Most analyses were performed using SPSS for Windows version 10.0. All variables were tested for normality. Parental BMIs were both log transformed and inverted to reduce skewness.

Analyses using the transformed variables were similar to those using the untransformed data, only the latter are reported here. Data are expressed as mean (standard deviation) and proportions of the sample unless otherwise specified. Associations between ages (tracking), and children and their parents are expressed as Pearson correlation coefficients. Significant differences between correlation coefficients were determined by t-test of the z-transformed coefficients.

Risk ratio was used to describe the association between weight status at each age and parental weight status, and the association between weight status at 20 years and weight status at each earlier age. Mother and father were classified as acceptable weight or overweight/obese and in all analyses acceptable weight was the reference category. The generalised linear model was used to describe the association between weight status at 20 years and weight status at each earlier age adjusted for parental weight status. These analyses was performed using Stata statistical software release 7.0

To simplify some of the tracking analyses and the risk ratio analyses data at ages 2, 8, 11, 15 and 20 years were selected, representing early childhood, pre-puberty, early puberty, puberty and early adulthood respectively.

Results

Weight status of subjects

Table 1 shows the number of boys and girls, mean (sd) BMI and BMI SD score, and the distribution to each weight status category at each age. In both boys and girls BMI initially decreased from 2 years to a low at about 6 years then increased at each subsequent age as expected. The BMI SD scores suggest that both boys and girls in this sample are slightly heavier than the reference population at most ages. There is no significant difference in BMI SD score between boys and girls at any age but BMI SD score is significantly greater at 20 years than at 8 and 6 years in boys ($p= 0.001$) and at every earlier age in girls (p range 0.01 to < 0.001). This increasing heaviness with age is also demonstrated by consideration of the proportion classified into each weight status category (Table 1). Overall the percent of boys classified as overweight and obese varied little through childhood and adolescence and remained around 12-15% up to 15 years but rose to 28% at 20 years. In girls the percent classified as overweight and obese varied little to 8 years (approximately 12%), increased to 19 – 23% for 11 to 15 years and increased again to 32% at 20 years.

Parental weight status

For boys and girls the number of mothers and fathers, mean (sd) BMI, the number in each weight status category and percent with a BMI greater or equal to 25.0 are shown in Table 1. There were no significant differences in BMI between mothers or fathers of boys and girls. BMI of fathers was significantly greater than mothers ($p<0.05$) and significantly more fathers than mothers of both boys and girls were classified as overweight or obese ($p<0.01$).

Tracking

Table 2 shows a matrix of Pearson correlation coefficients of BMI SD scores for boys and girls between each age, and each age and father's and mother's BMI. Correlations were highly significant between all ages indicating a high degree of tracking. R values decreased as the age interval increased, and tracking from initial ages 2 and 4 appeared to be lower than for older initial ages. In most instances r values were no different between boys and girls but were greater in boys than girls between initial ages 2 and 4 years and later ages 8, 11 and 15.

The degree of tracking was also determined in sub-samples defined by parental weight status. Due to small numbers, for this analysis overweight and obese parents were included in a single overweight group. There were no significant differences between tracking coefficients according to whether mother/father were acceptable weight or overweight. Similarly although there was a tendency for tracking coefficients to increase with increasing weight of parents (eg 4 to 8 years r = 0.68 if both parents acceptable weight, r=0.82 if one parent overweight, r=0.87 if both parents overweight), in most cases these were not significantly different. However the tracking coefficient for the interval 8 to 15 years was significantly greater in those with both parents overweight (r=0.86) compared with those with one overweight parent (r=0.69) and those with both parents acceptable weight (r=0.72) (p= 0.05).

Degree of tracking may also be illustrated by the proportion of subjects who remain in the same weight status category from one age to another. Table 3a shows the number of subjects who remained at an acceptable weight and overweight and obese from 2 years to each subsequent age to 20 years, and similarly from 8, 11 and 15 years to 20 years. Between 2 and 20 years the proportion of those classified as overweight initially decreased but remained high at 20 years (82%) and greater than the proportion that remained at an acceptable weight (68%). For the other intervals similar proportions remained in the acceptable weight or overweight category with least change for the shortest interval 15 to 20 years ($\geq$ 80% remaining).

Also of interest is the proportion of subjects overweight in early adulthood that were overweight at earlier ages (Table 3b). About one-third of those overweight at 20 years were overweight at 2 8 or 11 years, a much smaller proportion than those who were acceptable weight at both times (95%). Almost half the subjects overweight at 20 years were overweight at 15 years but still a considerably smaller proportion than was acceptable weight at both times.

Relative risk of overweight

For these analyses overweight and obese subjects were classified into a single overweight group. Table 4 shows the risk of overweight at 20 years if overweight at 2, 8, 11 or 15 years relative to the risk if an acceptable weight at the specified earlier age. Relative risk increased as the interval decreased although there were no significant differences. There were no significant differences between the relative risk for boys and girls at any age (data not shown). Similar values were obtained for the sub-sample of those seen at every age (n=90) (data not shown).

Parental weight status and risk of overweight

Boys' BMI SD score was significantly but weakly correlated with both mother's (r= 0.26 – 0.40) and father's BMI (r = 0.20 – 0.42) at most ages (Table 1). Girls' BMI SD score was significantly correlated with father's BMI at every age except 2 years (r = 0.33 - 0.51) but only significantly associated with mother's BMI from 8 years (r= 0.25 – 0.40).

The risk of a child being overweight at 8, 11 or 20 years if mother was overweight was twice that if mother was acceptable weight (RR 2.1 – 2.6 $p< 0.05$). At 2 and 15 years risk was not significantly greater than one. The risk of a child being overweight if mother was obese compared with mother being an acceptable weight ranged from 2.3 (CI 1.2 – 4.4) at 20 years to 5.1 (CI 2.8 – 9.3) at 11 years ($p< 0.001$) although not significantly greater than the risk if mother was overweight. Relative risk of a child being overweight if father was overweight varied between 2.6 (CI 1.2 – 5.7) and 4.7 (CI 1.6 – 5.7) at 8, 11 and 15 years but there was no significant increased risk at 2 or 20 years. If father was obese there was an increased risk of overweight at all ages ranging from 3.8 (CI 2.1 – 6.9) at 20 years to 7.3 (CI 2.4 – 22.8) at 11 years but this risk was not significantly greater than the risk if father was overweight.

Table 5 shows the risk of being overweight or obese at each age according to whether one or both parents are overweight/obese relative to the risk if both parents are acceptable weight. The widely varying risk values between ages reflect the small and varying percent of subjects overweight if both parents are acceptable weight. Relative risk was greater if both parents were overweight/obese than if only one parent was overweight/obese.

Risk of overweight at 20 years according to previous weight status and parental weight status

The relative importance of parental weight status and previous weight status of the subject on the risk of overweight at 20 years was determined using a generalized linear model. Table 6 shows the risk ratio for each variable in the model. Previous weight status at every age made the greatest contribution to the risk of overweight at 20 years. Mother’s weight status was significant at each age except 8 years and father’s weight status was significant at 2 and 11 years.

The probability of overweight at 20 years for the range of combinations of weight status at an earlier age and mother’s and father’s weight status was determined for each of the previous ages. The pattern was similar for each previous age. If acceptable weight at an earlier age the probability of overweight at 20 years varied between 16 and 27%. If either parent was overweight the probability was similar and slightly higher but not significantly greater if both parents were overweight. If the subject was overweight at a previous age the probability of overweight at 20 years if mother and father were acceptable weight ranged from 60 to 78% . If either or both parents were overweight as well as the subject the probability of overweight at 20 years was greater (78-100%) although not significantly different from both parents being acceptable weight.

Discussion

This paper describes the tracking of BMI from childhood to early adulthood in an Australian cohort born in 1975-6 and the relationship with parental BMI measured when the child was aged

8 years. Use of BMI SD score takes account of the variation in BMI due to age and gender and allows combination of data from boys and girls (19). BMI has been used as an index of adiposity in this paper based on its acceptance in 1997 by the International Obesity Task Force Childhood Obesity Working Group (12). However it is recognised that it is an imperfect measure as BMI reflects both lean and fat body mass.

Prevalence

The worldwide definitions of overweight and obesity in children and adolescents provide a standard against which international comparisons can be made (13) and estimates of prevalence in representative samples from Australia (14), Britain (19) and the US (20) have recently been published. All these studies report a considerable increase in prevalence of overweight and obesity from the 1980s to the 1990s, and comparisons between these countries indicate that in children aged 2 to 5 years prevalence is greatest in Australia followed by the US but in the older ages prevalence is greatest in the US. For all ages reported the prevalence was least in Britain (14, 21).

Comparison of the prevalence of overweight and obesity in the present sample with the Australian national surveys of 1985 (AHFS85) and 1995 (NNS95) (14) indicates that the prevalence rates for those up to 15 years of age (in 1991) are higher than those for the 1985 sample but similar to those for the 1995 sample. Thus this sample does not differ from a representative sample of Australian children and adolescents. The proportion of males who were overweight and obese at 20 years (28%) is less than that for 19-24 year olds in the NNS95 (38%) but the proportion of females is greater (32% versus 26%) (22).

Age-related changes in BMI

In this sample absolute BMI followed the expected trajectory of decreasing in early childhood to a minimum around the age of 6 years and then increasing steadily to age 20 (18). The age related increase in mean BMI SD score and proportion classified as overweight and obese indicate that this sample is getting fatter with increasing age. This may be a reflection of a decreasing energy expenditure in these children that is not matched by a relative decrease in energy intake, a worldwide phenomenon recognised as the major contributing factor to the increasing level of overweight and obesity (1). The mean BMI SD score (Table 1) also indicates that this sample is heavier than the reference population of British children surveyed between 1980 and 1990 (18).

Tracking: BMI

Tracking describes the consistency through time of a biological variable. The tracking coefficients reported here are similar to those of previous studies which spanned early childhood to mid-twenties but are generally at the higher end of the range of those studies (5, 6, 23). As also reported in these previous studies tracking was stronger for shorter age intervals. Tracking was weakest from early childhood (2 and 4 years) to early adulthood but from 6 years or older, to 20 years tracking was established at r values >0.6 suggesting that BMI from 6 years onwards is a good indicator of later BMI. The stronger tracking coefficients for those with both parents overweight compared with those with only one parent overweight or both parents normal (at child age 8 years), are supported by similar findings of Lake et al (1997) who reported tracking of BMI from 7 to 33 years was greatest in those with both parents obese (at child age 11 years) (defined as BMI > 27.7) (7). The small numbers of those measured at 20 years with both parents obese does not allow estimation of tracking for this subgroup. However the results of Lake et al (1997) and this study suggest that fat children of overweight parents are more likely to be fat adults than if their parents are normal weight.

Tracking: weight status categories

When subjects were tracked according to weight status categories over 75% remained in the same category (acceptable or overweight) from childhood or adolescence (2 to 15 years) to early adulthood (20 years). Of those overweight at 2 years only about 50% were overweight at 8,11 or 15 years but 82% were overweight at 20 years. Seventy-five to 86% of those overweight at 8 years or older were overweight at 20 years. In contrast, of those who were overweight at 20 years only a third were overweight at 2, 8 or 11 years and about half were overweight at 15 years but 95% of those acceptable weight at 20 years had been in the same category at earlier ages. It is difficult to make direct comparisons with and between earlier studies as the interval between measurements, the weight status measure and the definition of overweight and obesity varies. However our data on the tracking of weight status are similar to those previously reported to the extent that a greater proportion of obese subjects remained obese into early adulthood than the proportion of obese adults who were obese as children (5, 6) but for both scenarios the proportions are higher in our study. Serdula and colleagues in assessing data from several studies of children born before 1960 reported that 27 – 63% of obese children become obese adults and between 5 and 44% obese adults were obese as children (6). Power reported similar figures for a 1956 birth cohort namely 34 to 48% of those above 91st centile for BMI at 7 to 16 years were obese (BMI > 30) at 33 years of age and of those who were obese (BMI >30) at 33 years the proportion above the 91st centile at earlier ages ranged from 49% at 23 y to 27% at 7 years (5). These results suggest that the risk of being overweight in adulthood if overweight as a child or adolescent may be greater for subjects born in the 1970's than for subjects from earlier birth cohorts. Similarly a greater proportion of those who are overweight in early adulthood in the 1990s were overweight in adolescence or childhood than those who reached early adulthood in the 1970s (5). This suggests that as the population grows fatter it is more likely that the fatness

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originated earlier in life and may reflect interactions between decreasing physical activity and increasing energy density of food (1).

Risk of adult overweight: childhood overweight

We used relative risk to determine the likelihood of being overweight in adulthood if overweight at an earlier age compared with the likelihood of being overweight if normal weight at an earlier age. As overweight is a common disease relative risk rather than odds ratio is the appropriate measure to use (24). In the present sample relative risk increased with increasing age ie as the interval to early adulthood decreased, and at every age the risk was significantly greater than 1. Serdula et al report similar risk ratios which are higher when the interval to adulthood is less (6). Others have used an odds ratio which cannot be directly compared with the present results although similar patterns of increasing odds ratio as interval to adulthood decreased were reported (8).

Risk of overweight: parental weight status

BMI SD of sons was significantly correlated with both mothers BMI at every age and fathers BMI at every age but 20 years. BMI SD of daughters was significantly associated with mothers BMI from the age of 8 and with fathers BMI from the age of 4. Most correlation coefficients were around 0.35. One British and one Australian study have reported the correlation coefficients between BMI of children and their parents (7, 11). Subjects in the British study were a large (>11,000) cohort on whom height and weight were measured at 7, 11, 16 and 33 years. Parents' height and weight were self-reported when child was 11 years. The authors reported consistent correlation as in the present study between both mother and father and their sons and daughters from age 7 to 33 years although r values were around 0.2. The Australian sample comprised 219 18-year-olds and their parents from 169 families. R values between child and parent BMI (determined from measured height and weight) ranged from 0.2 between fathers and sons to 0.49 between mothers and daughters. Two previous studies have estimated the risk of overweight/obesity associated with parental weight status but as they used odds ratios, results cannot be directly compared with the present study (7, 8). Whitaker et al reported that risk of obesity (BMI $\geq$ 27.8 males, $\geq$ 27.1 females) in young adulthood (21 to 29 years of age) was increased three to four-fold if either mother was obese or father was obese compared with the parent not being obese (8), a finding similar to the present study for relative risk of overweight at any age if either parent was overweight (BMI >25). We found that the risk of overweight was even greater if mother or father was obese (BMI > 30) but the differences between the risk estimates were not statistically significant, possibly as a result of the small numbers. When the combined weight status of parents was considered relative risk of overweight at any age increased if one parent was overweight (BMI $\geq$ 25) and increased further if both parents were overweight. Both Lake et al and Whitaker et al reported similar increasing risk with increasing weight status of parents and risk was greatest if both parents were obese (7, 8). We did not estimate the risk associated with parental obesity separately from overweight due to the small numbers of subjects with obese parents.

A recent Australian study of 219 families reported significantly greater BMIs at 3 year intervals between 9 and 18 years in sons and daughters of fathers and mothers who were overweight or obese compared with those children of acceptable weight parents (11).

We also determined the relative importance of previous weight status and parental weight status in determining the risk of overweight at 20 years. Our results indicated that at every age previous weight status is the major determinant of weight status in early adulthood. In contrast Whitaker et al using odds ratios reported that before the age of three years parental weight status was the most important predictor, from 3 to 9 years child weight status had equal importance with parental weight status and in older children the child’s weight status became increasingly more important (8). These varying results may in part be due to the different analyses - odds ratios versus relative risk, and differences in definition of overweight. We determined the risk of overweight at 20 years for the range of scenarios from child, mother and father being acceptable weight to all being overweight. Overall the risk of overweight at 20 years was significantly greater if overweight at an earlier age and the weight status of parents did not make a significant difference to this risk. This lack of effect of parental weight status is most likely due to the small number of subjects in each of the groups. This analysis of combined risk from previous weight status and parental weight status has not been reported in other studies.

Conclusion

This paper is only the second to provide data on tracking of overweight from childhood to adulthood in a cohort born after 1960. The results reported here indicate that Australian children are getting fatter as they get older and an increasing proportion is classified as overweight and obese. The high prevalence of overweight and obesity, the strong tracking of BMI from childhood to early adulthood and the increased proportion of overweight children who remain overweight into adulthood compared with earlier studies have major consequences for the longer term health of the community with the expectation that a majority of overweight teenagers will remain overweight adults and potentially become obese adults. To what extent this stronger tracking reflects the increased prevalence of overweight and obesity in the adult population (ie the parents) is not clear but it is possible that the greater prevalence in the 1990s will result in a generation of children who display even stronger tracking. BMI is a good indicator of later BMI, more so if one or more parents are overweight.

These data strongly support intervention in early school-age children to prevent development of overweight and the progression of overweight to obesity. The WHO advocate that prevention and management of the global epidemic of obesity requires strategies that focus on environmental changes that will affect the weight status of the wider population as well as those that focus on individuals and groups who are at increased risk of obesity and its co-morbidities (1). The greater risk of overweight in those children with both parents overweight identifies a group for targetted intervention that promotes increased physical activity, decreased inactivity and decreased consumption of energy dense foods, in an environment which favours the opposite behaviour.

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Table 1. Number of subjects (N), mean (standard deviation) of body mass index (BMI), and distribution between weight status categories at each age and for parents measured when subjects aged 8 years.

Age	N	Boys					Girls				
		N	BMI	BMI SD[a]	Weight status[b] N (%)		N	BMI	BMI SD[a]	Weight status[b] N (%)	
					1	2				1	2
2	155	89	16.8 (1.7)	0.24 (1.31)	77 (87)	12 (13)	66	16.4 (1.4)	-0.15 (1.14)	58 (88)	8 (12)
4	155	89	16.1 (1.4)	0.35 (1.12)	74 (83)	15 (17)	66	15.8 (1.1)	-0.06 (0.83)	59 (89)	7 (11)
6	152	89	16.0 (1.7)	0.18 (1.22)	76 (85)	13 (15)	63	16.0 (1.4)	0.18 (0.89)	53 (84)	10 (16)
8	275	136	16.4 (1.9)	0.16 (1.03)	121 (89)	15 (11)	139	16.8 (2.4)	0.19 (0.95)	117 (84)	22 (16)
11	243	130	17.8 (2.3)	0.35 (0.98)	115 (88)	15 (12)	113	18.6 (3.1)	0.23 (1.09)	91 (81)	22 (19)
13	245	126	19.1 (2.8)	0.33 (1.06)	110 (88)	17 (12)	119	20.1 (3.7)	0.38 (1.19)	92 (77)	27 (23)
15	236	121	20.4 (2.8)	0.34 (1.00)	104 (86)	17 (14)	115	21.6 (4.1)	0.41 (1.21)	93 (81)	22 (19)
20	188	97	23.5 (3.0)	0.53 (0.96)	70 (72)	27 (28)	91	23.7 (4.4)	0.59 (1.23)	62 (68)	29 (32)
Mothers	267	137	23.8 (4.1)		96 (70)	41 (30)	130	24.0 (4.7)		93 (72)	37 (28)
Fathers	219	117	25.5 (3.5)		60 (51)	57 (49)	102	26.1 (3.3)		46 (45)	56 (55)

a: BMI standard deviation score based on data of Cole et al 1995.

b: weight status 1: acceptable weight, 2: overweight or obese (see methods for definition)

Table 2. Correlation matrix of BMI SD score at each age and mother's and father's BMI. Boys above the diagonal, girls below the diagonal, top line Pearson correlation coefficient, second line number of subjects. p < 0.001 unless otherwise indicated

child's age	2	4	6	8	11	13	15	20	Mother	Father
2		0.74	0.70	0.70	0.68	0.58	0.60	0.44	0.40	0.30[a]
		88	*88*	*76*	*73*	*69*	*71*	*55*	*77*	*69*
4	0.61		0.87	0.82	0.78	0.77	0.78	0.48	0.36[b]	0.34[b]
	65		*88*	*76*	*72*	*69*	*70*	*54*	*76*	*68*
6	0.58	0.79		0.92	0.86	0.80	0.78	0.61	0.33[b]	0.42
	62	*62*		*77*	*73*	*70*	*71*	*55*	*77*	*69*
8	0.48	0.70	0.87		0.87	0.79	0.77	0.65	0.34	0.35
	64	*64*	*62*		*126*	*121*	*115*	*95*	*130*	*111*
11	0.44	0.58	0.84	0.90		0.90	0.85	0.72	0.29	0.27[b]
	56	*56*	*54*	*112*		*120*	*115*	*94*	*125*	*107*
13	0.32[a]	0.48	0.80	0.84	0.91		0.89	0.70	0.26[b]	0.31
	51	*51*	*49*	*118*	*100*		*117*	*92*	*121*	*104*
15	0.30[a]	0.37[b]	0.71	0.81	0.84	0.86		0.80	0.37	0.25[a]
	51	*51*	*49*	*114*	*97*	*112*		*92*	*116*	*100*
20	0.39[b]	0.51	0.72	0.70	0.69	0.75	0.87		0.35	0.20[ns]
	42	*41*	*39*	*90*	*76*	*86*	*86*		*96*	*86*
Mother	0.11[ns]	0.02[ns]	0.16[ns]	0.37	0.40	0.32	0.25[b]	0.32[a]		0.19[a]
	55	*55*	*53*	*129*	*107*	*113*	*109*	*87*		*117*
Father	0.25[ns]	0.33[a]	0.45[b]	0.36	0.41	0.43	0.40	0.51	0.22[a]	
	48	*48*	*47*	*102*	*86*	*91*	*88*	*70*	*99*	

ns: not significant; a: p<0.05; b: p<0.01.

Table 3a Number of subjects[a] in each weight status category at initial age (2, 8, 11 or 15 years) and the number (%) of these subjects remaining in the same category at subsequent ages

	2	8	11	15	20 (%)
acceptable	79	70	69	69	54 (68)
overweight and obese	11	5	6	7	9 (82)
acceptable		135	126	128	105 (78)
overweight and obese		22	17	17	17 (77)
acceptable			136	130	105 (77)
overweight and obese			24	19	18 (75)
acceptable				149	119 (80)
overweight and obese				29	25 (86)

a: only subjects on whom data available at initial and every subsequent age

Table 3b Number of subjects[a] in each weight status category at 20 years and the number (%) of these subjects in the same weight status category at earlier years

	20	15	11	8	2
acceptable	56	55	53	54	54 (96)
overweight and obese	34	16	13	12	9 (26)
acceptable	110	108	104	105 (95)	
overweight and obese	47	22	18	17 (36)	
acceptable	111	109	105 (95)		
overweight and obese	49	23	18 (37)		
acceptable	123	119 (97)			
overweight and obese	55	23 (45)			

a: only subjects on whom data available at every age shown

Table 4. Relative risk of overweight and obesity (owt) at 20 years if owt at specified age in childhood or adolescence.

Specified age	N	No owt at 20/ total owt previous age (%)	No owt at 20/ total normal previous age(%)	Relative Risk (95% confidence interval)
2	97	10/12 (83.3)	26/85 (30.6)	2.72 (1.81 – 4.10)
8	185	19/25 (76.0)	35/160 (21.9)	3.47 (2.41 – 5.01)
11	170	19/25 (76.0)	31/145 (21.4)	3.55 (2.43 – 5.21)
15	178	25/29 (86.2)	30/149 (20.1)	4.28 (3.01 – 6.08)

Table 5 Relative risk of overweight and obesity (owt) at each age according to parental weight status[a]

Age		No. subjects owt/total no.	%	RR	95% confidence interval
2	both parents acceptable weight	4/50	8.0		
	one parent overweight[b]	3/41	7.3	0.91	0.2-3.9
	both parents overweight[b]	9/23	39.0	4.9	1.7-4.3
8	both parents acceptable weight	3/81	3.7		
	one parent overweight[b]	13/85	15.3	4.1	1.2-14.0
	both parents overweight[b]	13/42	31.0	8.4	2.5-27.7
11	both parents acceptable weight	1/74	1.4		
	one parent overweight[b]	13/79	16.5	12.2	1.6-91.8
	both parents overweight[b]	13/36	36.1	26.7	3.6-196.4
15	both parents acceptable weight	4/75	5.3		
	one parent overweight[b]	16/75	21.3	4.0	1.4-11.4
	both parents overweight[b]	12/34	35.3	6.6	2.3-19.0
20	both parents acceptable weight	8/60	13.3		
	one parent overweight[b]	19/67	28.4	2.1	1.0-4.5
	both parents overweight[b]	15/26	57.7	4.3	2.1-8.9

a: only includes subjects for whom data on both parents available
b: overweight and obese, BMI $\geq$ 25.0kg/m^2

Table 6

Risk ratio (95% confidence interval) for each variable in the model[a] to determine the relative risk of overweight at 20 years according to weight status at an earlier age (2, 8, 11 or 15 years) and mother's and father's weight status[b]

weight status	2 y	8 y	11 y	15 y
previous age	5.1 (2.4-10.9)	3.0 (1.8-5.2)	3.5 (2.4-5.0)	6.7 (3.6-12.5)
mother	1.6 (1.0-2.7)	1.4 (0.9-2.3)	2.2 (1.4-3.4)	3.8 (2.0-6.9)
father	2.8 (1.3-5.8)	1.4 (0.9-2.8)	2.0 (1.3-3.2)	1.1 (0.6-1.8)

a: generalised linear model
b: weight status overweight v acceptable