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PAPER

Overweight at age 21: the association with body mass index in childhood and adolescence and parents' body mass index. A cohort study of New Zealanders born in 1972–1973

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BACKGROUND: Obesity is an increasing problem so understanding the association between childhood and adolescent measures of body mass index (BMI) and being overweight at age 21 has implications for treatment or strategies to reduce its prevalence.
OBJECTIVE: To examine the association between measures of BMI in childhood and adolescence and parents' BMI and being overweight at age 21.
DESIGN: The study was based on a birth cohort born in Dunedin, New Zealand in 1972–1973.
RESULTS: BMI tracked from childhood to early adulthood. The point on the BMI distribution where the probability of being overweight at age 21 was 0.5 was close to the 75th centile for boys throughout childhood and adolescence. It was rather higher for girls in childhood but similar in adolescence. Boys with a BMI above the 75th centile at age 7 were more than 4.0 times more likely to be overweight at age 21 than those with a BMI below the median. The relative risk for girls was 3.2. By age 15 this increased to 9.8 for males and 6.8 for females. Having overweight parents, particularly a mother, increased the likelihood of being overweight. Only 40% of those who were overweight at age 21 could be identified by age 7 and 25% were not identified until they were at least 15.
CONCLUSION: Although a high BMI in childhood predicts being overweight at age 21, many of those who were overweight at age 21 had a BMI below the 75th centile or even the median in childhood and early adolescence. Population strategies, complemented by an individual approach for those above the 75th centile, are needed to reduce the average BMI of the population.
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Keywords: body mass index; longitudinal study; obesity; children; young adults; parents

Introduction

Obesity is an increasing problem with huge clinical consequences because of its association with cardiovascular disease, hypertension and diabetes in adults. Its onset is insidious and as successful treatment is known to be difficult it is generally agreed that the identification of potentially obese or overweight individuals before they become overweight is critically important. It has been argued that childhood or adolescent obesity are important in their own right because of the association with concurrent disease.[1,2] Others take a different view, asserting that obesity is rarely associated with other diseases in childhood but that its severity and age of onset are important determinants of its persistence into adulthood.[3]

The World Health Organization (WHO) guidelines define adults with a BMI of 25 kg/m^2 or more as overweight, and those with a BMI of 30 or more as obese.[4] Although being overweight in childhood is thought to be an important determinant of later obesity, the centile which should be used to delimit those regarded as at risk is difficult to define. A centile such as the 85th is sometimes used but its value

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depends upon the sample on which it is based. Increasing levels of obesity mean that the 85th centile has also increased, leading to different cut-offs for different time periods as well as different cut-offs for different populations.

This report uses data from the Dunedin Multidisciplinary Health and Development Study to describe the tracking of BMI from childhood to adulthood and to identify and evaluate cut-off points at various ages which could be useful in recognizing those likely to become overweight, according to the WHO guidelines for adults, by age 21. As weights and heights were also available for some of the parents, it was possible to examine the association between the parents' BMI and those of their children.

Methods

The sample was a birth cohort born in Queen Mary Hospital, Dunedin between 1st April 1972 and 31st March 1973. The mothers were resident in the Dunedin metropolitan area at the time of the birth. Consent was given for 1037 of the 1139 children who were traced and continued to be resident in the Otago area at the time of their third birthday to participate in the study. The cohort was seen again at two-yearly intervals to age 15 and then at ages 18, 21 and more recently at age 26 y. Compared with all New Zealand the cohort is under-representative of Maori and other Polynesian people. The study is described in detail elsewhere.[5]

Stature was measured to the nearest millimetre using a portable Harpenden Stadiometer. Weight was recorded to the nearest 0.1 kg using a Lindell Beam Balance, the participants being weighed in light clothing. Body mass index (BMI) was calculated as weight/height^2 with units kg/m^2. Overweight and obesity were defined according to body mass index as indicated.[4] Observations for women known to be pregnant at the time of their age 18 or 21 y assessments were excluded.

The parents, usually the mother, completed a comprehensive questionnaire at the age 11 assessment which included a section on the height and weight of both the natural mother and father. Their BMI was derived from this.

The analysis is presented in three parts. First all measures of BMI are treated as continuous variables, the results being reported in terms of means and standard deviations, and correlations. Logistic regression was then used to identify points on the BMI distribution at ages 7 – 18 y for various probabilities of having a BMI of 25 kg/m^2 or more at age 21 y. The cut-off points were derived from the following equation:

$$x = \left(\log\left(\frac{p}{1-p}\right) - a\right) \Big/ b$$

for values of p, where a and b were the parameters for the logistic regression model; $\log(p/1-p) = a+bx$ used to predict being over weight at age 21 from BMI at each age. These were linked to the values of the smoothed reference centiles, derived using the LMS method which uses curves for the median, the coefficient of variation and skewness to characterize the changing distribution of BMI.[6–8]

Of particular interest was the point on the BMI distribution where the participants were equally likely to be defined as overweight or of normal weight at age 21. This occurs when $p = 0.5$ and is equivalent to $a+bx = 0$. Finally, logistic regression was used to examine the association between groups defined by the cut-off points and being overweight at age 21.

Because this was a cohort study with a relatively common outcome, odds ratios derived from logistic regression were transformed to relative risks because their interpretation is more intuitive and less dependent on the prevalence.[9]

Results

The number of observations, the mean and standard deviation, as well as the smoothed values for the median and 75th centile, are shown for males and females in Table 1. These indicate that BMI declined between ages 3 and 7 and then increased, continuing to do so until the cohort reached adulthood. The correlations between BMI measurements at different ages are shown in Table 2. These are reported for all the available data so the number of observations included ranges from 308 to 467. All the correlations were statistically significant ($P < 0.05$). The weakest correlation for boys was 0.32 between BMI at ages 3 and 21 y. The correlation

Table 1 The mean, standard deviation, median and 75th centile of BMI for males and females from age 3 to age 21

	Males					*Females*				
Age (y)	n	*Mean*	*s.d.*	*Median*	*75th centile*	n	*Mean*	*s.d.*	*Median*	*75th centile*
3	467	16.5	1.27	16.4	17.2	458	16.2	1.33	16.2	17.1
5	457	16.0	1.24	15.9	16.7	435	15.8	1.25	15.7	16.6
7	450	15.9	1.33	15.8	16.7	418	15.8	1.39	15.7	16.7
9	427	16.3	1.57	16.2	17.2	383	16.4	1.76	16.3	17.4
11	372	17.5	2.15	17.3	18.6	339	17.6	2.22	17.5	19.0
13	381	19.3	2.34	18.6	20.2	355	20.0	2.64	19.3	21.1
15	500	20.0	2.85	19.8	21.5	465	21.0	2.86	20.7	22.6
18	450	22.7	3.19	22.0	24.0	417	22.9	3.19	22.3	24.4
21	482	23.9	3.34	23.5	25.7	442	23.8	3.60	23.2	25.5

Table 2 Correlations between measures of BMI from age 3 to age 21 for males above the diagonal and females below the diagonal

Age (y)	*3*	*5*	*7*	*9*	*11*	*13*	*15*	*18*	*21*	*Mother*	*Father*
3		0.64	0.60	0.54	0.39	0.40	0.43	0.34	0.32	0.15	0.07
5	0.63		0.81	0.71	0.61	0.62	0.53	0.53	0.46	0.26	0.19
7	0.58	0.78		0.89	0.81	0.77	0.69	0.70	0.62	0.30	0.24
9	0.48	0.70	0.87		0.91	0.84	0.79	0.73	0.67	0.30	0.21
11	0.37	0.54	0.75	0.85		0.86	0.82	0.75	0.68	0.26	0.21
13	0.35	0.51	0.69	0.74	0.82		0.86	0.77	0.71	0.28	0.21
15	0.24	0.42	0.57	0.64	0.74	0.84		0.85	0.76	0.32	0.26
18	0.24	0.43	0.56	0.59	0.68	0.72	0.80		0.86	0.31	0.28
21	0.27	0.39	0.52	0.55	0.60	0.62	0.69	0.84		0.24	0.30
Mother	0.13	0.15	0.19	0.22	0.22	0.25	0.24	0.24	0.23		0.25
Father	0.07	0.10	0.25	0.21	0.20	0.19	0.18	0.26	0.23	0.17	

between age 3 and both ages 15 and 18 was 0.24 for girls. Those between adjacent measures, particularly from age 7 onwards, were strong. The correlations between males and females and both the mothers' and fathers' BMI are shown for each age. In general the correlations between the boys' BMI and their parents' BMI were stronger than those for the girls. At age 11, the time when the parents' BMI was reported, the boys' BMI explained 46% of the variability at age 21, the mothers' BMI 7% and the fathers' 4%. The figures for girls were 36% for their own BMI, 5% for their mothers' and 4% for their fathers' BMI.

The prevalence of obesity and being overweight or obese at age 21

At age 21 y 28 (5.8%) men and 22 (5.0%) women were obese (BMI $\geq 30\,kg/m^2$), 119 (24.7%) men and 107 (24.2%) women were overweight (BMI 25–29) and 335 (69.5%) men and 314 (70.9%) women had a BMI below $25\,kg/m^2$.

Identifying thresholds or cut-off points for being overweight at age 21

Logistic regression was used to estimate the probability of becoming overweight or obese, that is having a BMI of $25\,kg/m^2$ or more at age 21 using earlier measures of BMI for males and females. The centiles for a probability of 0.75 of being overweight at age 21 were 92 for boys and 98 for girls at age 7 and 82 for both sexes at age 18. Those for a probability of 0.5 were between 72 and 77 for boys and declined from 87 at age 7 to 72 at age 18 for girls. The centile associated with a probability of 0.25 of being overweight increased from 48 to 53 for boys and 51 to 54 for girls between ages 7 and 15. At age 18 these were 62 and 60. On the basis of this, three groups were defined at each age using BMI at ages 7, 11 and 15, those with a BMI above the 75th centile, those with a BMI between the median and the 75th centile and those with a BMI below the median. The number and percentage in each of these groups as well the number and percentage who were overweight at age 21 are shown for men and women in Table 3 along with the associated relative risks and 95% confidence intervals. The relative risks for boys were of a similar magnitude at ages 7 and 11, increasing considerably between 11 and 15. Those for girls on the other hand increased between ages 7 and 15. The positive predictive value or percentage of those who were overweight at age 21 who came from the groups with a BMI above the 75th percentile at an earlier ages was between 50 and 70%. The sensitivity of the 75th percentile, however, ranged from 43.2% for 11-y-old girls to 51.4% for 15-y-old boys. The specificity of the 75th percentile was between 84.9% for 7-y-old girls to 91.7% for 15-y-old boys.

Persistence of being overweight

Complete data for all measurements between ages 7 and 21 were available for 522 people. Using the sex-specific centiles at each age, 271 (51.9%) had a BMI below the 75th centile at all ages up to age 18. Of these 26 (9.6%) had a BMI above $25\,kg/m^2$ at age 21. In contrast, the prevalence of being overweight was 64% among the 20% of the sample with BMI above the 75th centile at age 7 and on at least one later occasion. The relative risks for this group and those identified for the first time at a later age are shown in Table 4. It was not statistically significant for those identified once only at either age 7 or 9 y.

Parent and childhood predictors of being overweight at age 21 y

Complete data for BMI for both parents and those in the sample for ages 11 and 21 were available for 558 people. The

Table 3 The number (percentage) of those with BMI centiles below the 50, between 50 and 75, and greater than 75 centile at ages 7, 11 and 15 with number (percentage) overweight at age 21 with relative risks and 95% confidence intervals

	Males			*Females*		
Cut-off centile	*Group* n *(%)*	*Number and percentage overweight at age 21* n *(%)*	*RR (95% CI)*	*Group* n *(%)*	*Number and percentage overweight at age 21* n *(%)*	*RR (95% CI)*
Age 7						
<50	233 (51.8)	32 (13.7)	1.0	209 (50.0)	33 (15.8)	1.0
50–75	113 (25.1)	42 (37.2)	2.7 (1.9, 3.7)	115 (27.5)	27 (23.5)	1.5 (0.9, 2.2)
75+	104 (23.1)	57 (54.8)	4.0 (3.0, 4.9)	94 (22.5)	47 (50.0)	3.2 (2.3, 4.0)
Age 11						
<50	201 (54.0)	31 (15.4)	1.0	183 (54.0)	23 (12.6)	1.0
50–75	86 (23.1)	31 (36.1)	2.3 (1.6, 3.3)	87 (25.7)	31 (35.6)	2.8 (1.8, 4.0)
75+	85 (22.9)	54 (63.5)	4.1 (3.2, 4.9)	69 (20.4)	41 (59.4)	4.7 (3.4, 5.9)
Age 15						
<50	255 (51.0)	18 (7.1)	1.0	229 (49.3)	20 (8.7)	1.0
50–75	138 (27.6)	52 (37.7)	5.3 (3.6, 7.4)	130 (28.0)	41 (31.5)	3.6 (2.3, 5.2)
75+	107 (21.4)	74 (69.2)	9.8 (7.7, 11.4)	106 (22.8)	63 (59.4)	6.8 (5.1, 8.3)

Table 4 Number (percentage) according to the first time identified as having a BMI above the 75th percentile with number (percentage) overweight at age 21 with relative risks and 95% confidence intervals

Age identified	*Group* n *(%)*	*Number and percentage overweight at age 21* n *(%)*	*RR*[a]* (95% CI)
Never	271 (51.9)	26 (9.6)	1.0
Ages 7 or 9 but not both	22 (4.2)	4 (18.2)	1.9 (0.7, 4.3)
Age 7 and later	102 (19.5)	65 (63.7)	6.8 (5.3, 8.0)
Age 9 and later	27 (5.2)	27 (66.7)	7.1 (4.8, 8.7)
Ages 11 or 13 but not both	26 (5.0)	7 (26.9)	2.9 (1.4, 5.3)
Age 11 and later	15 (2.9)	9 (60.0)	6.3 (3.5, 8.6)
Age 13 and later	27 (5.2)	17 (62.9)	6.3 (3.5, 8.6)
Ages 15 or 18 or both	32 (6.1)	20 (62.5)	6.6 (4.5, 8.4)

[a]Adjusted for sex.

mean (s.d.) BMI for the mothers was 23.1 (3.70) kg/m^2 and that for the fathers was 24.2 (2.76) kg/m^2. The sample was divided into three groups according to the BMI of each parent, those with a BMI of less than 25 kg/m^2 included 428 (76.7%) mothers and 329 (59.0%) fathers. Details of these are shown in Table 5. The associations between a BMI of 25 kg/m^2 or more at age 21 and BMI at age 11 and the BMI of the parents are presented in Table 5. Adjusting for the parents' BMI decreased the relative risk for the children with a BMI above the 75th centile or between the median and 75th centile at age 11 by a very modest amount. The relative risk for the group where the mothers had a BMI of 30 kg/m^2 or more was elevated, whereas that for the fathers after adjusting for the other terms in the model was not. Including the fathers' BMI in the logistic regression model which already included both the children's and the mothers' BMI did not add any explanatory power.

When the sample was divided into four groups based on a combination of the parents' BMIs, the relative risk for the group where both parents had BMI of 25 kg/m^2 or more was 2.0 (95% CI 1.4, 2.5), that for the group where only the father had a BMI of 25 kg/m^2 or more was 1.1 (95% CI 0.7, 1.6) and where only the mother had a BMI of 25 kg/m^2 or more, it was 0.7 (95% CI 0.4, 1.2). The comparison group was that where both parents had BMIs of less than 25 kg/m^2. Adjustments were made for the sex and the BMI of the children at age 11.

Missing values

At age 21, 992 (97.3%) of the surviving 1020 members of the cohort had some form of assessment. BMI measurements were available for 938 (92%) participants. Those seen and not seen were not significantly different for birth weight, their mother's height, BMI at age 3 or for the available mothers' and fathers' BMI. At age 11, 925 (90%) of the surviving sample had some form of assessment but not all of them were seen at the study centre in Dunedin. BMI measurements were available for 711 or 77% of the surviving sample. Those not seen were lighter (10 g) at birth and had a lower BMI at age 3 (0.2 kg/m^2), and at age 21 (0.4 kg/m^2). These differences were statistically significant ($P < 0.05$).

Discussion

The correlations between BMI measurements in childhood and early adulthood reported in this study were similar to those reported across a 15 y interval in the Bogalusa and Muscatine Studies,[10,11] but rather lower than those reported in the 1958 British birth cohort across a time period of 17 y.[12] In general, the values were higher for boys, which was consistent with those reported in a review of the literature,[13] but in contrast to the results of the British study. These correlations indicate that BMI tracks between childhood and adulthood so that children with a high BMI are more likely to become overweight adults. The magnitude of the correlations in this study, however, suggests that up to age 11

Table 5 Relative risks (95% confidence intervals) for having a BMI of 25 kg/m^2 or more at age 21 given mothers' and fathers' and children's BMI at age 11

	n *(%)*	*Number and percentage overweight at age 21* n *(%)*	*Unadjusted RR*	*BMI > 25 RR[a] (95% CI)*
Mother's BMI				
Normal	428 (76.7)	124 (29.0)	1.0	1.00
Overweight	101 (18.1)	40 (40.0)	1.4	1.1 (0.8, 1.6)
Obese	29 (5.2)	18 (62.1)	2.1	1.9 (1.2, 2.5)
Father's BMI				
Normal	329 (59.0)	87 (26.4)	1.0	1.00
Overweight	204 (36.6)	83 (40.7)	1.5	1.2 (0.6, 2.0)
Obese	25 (4.5)	12 (48.0)	1.8	1.3 (1.0, 1.7)
Child's BMI				
< 50	305 (54.7)	48 (15.7)	1.0	1.0
50–75	135 (24.2)	56 (41.5)	2.6	2.5 (1.8, 3.2)
75+	118 (21.2)	78 (66.1)	4.2	4.1 (3.3, 4.8)

[a]Adjusted for sex and the other terms in the model.

for males and age 15 for females earlier measures of BMI explain less than half the variance of BMI at age 21.

This study shows that the point on the BMI distribution identifying boys with a probability of 0.5 or more of being overweight at age 21 was close to the 75th centile for ages 7 – 15. The value derived from the smoothed 75th centile was used as a cut-off at ages 7, 11 and 15 to identify those most at risk.[8] In the interests of simplicity the same threshold was used for girls, although it could be argued that slightly higher values were more appropriate at younger ages. The median was used as a further cut-off as it was close to points which identified those with a probability of 0.25 of being overweight. Although 50% or more of those whose BMI was above the 75th centile at ages 7, 11 or 15 were overweight at age 21, between 12 and 16% of those whose BMI was below the median at age 7 and 11 were also overweight. Thus, if the 75th centile for BMI up to age 15 were used to define the overweight, the positive predictive value would be in excess of 50% with a sensitivity of between 44% and 51% (Table 3). This suggests that earlier BMI was not an especially good prognostic test for being overweight in early adulthood. Nevertheless, those with a BMI above the 75th centile were between 4 and 10 times more likely to be overweight than those with a BMI below the median. The strong correlations between adjacent measurements suggest that little may be gained by using two measures rather than one. Table 4, however, shows that risk of being overweight at age 21 is much greater in those who have more than one measure above the 75th centile. Although this comparison was based on part of the original cohort, a comparison of the mean BMI for those included and those excluded showed that these were similar at each age. Table 4 also indicates that, even with the use of more than one measure, less than half of the overweight could be identified as early as age 7.

It is difficult to compare these results with those of other longitudinal studies because different definitions of obesity were used in childhood or adolescence as well as in early adulthood.[10,14] It has, however, been suggested that the centile which identified the overweight in late adolescence or early adulthood could be extrapolated backwards to define the overweight in childhood.[15] This would mean using the 70th centile in this sample. Although the 70th centile would have better sensitivity than the 75th, it would have a poorer positive predictive value and would therefore identify more children or adolescents who would not turn out to be overweight as young adults. Using the 75th centile allows for some regression to the mean.

Although this study has used the WHO definitions for overweight and obesity for adults introduced in 1995 to define the parents as overweight or obese,[4] the results are consistent with those reported from the British 1958 birth cohort and a study carried out in Washington State.[16,17] All three studies showed an increased risk of the children being overweight as adults if both parents were overweight; the British and American studies also found an increased risk when only one parent was overweight. The American study, like the present study, showed a stronger effect for mothers than fathers when they were examined separately. Including the parents' and children's BMI in the same model in this study showed that the child's BMI was the strongest predictor of later overweight. This, too, was consistent with the American study, which showed that the children's BMI was the most important predictor for age groups older than 6. The magnitude of the correlations between the BMI of the parents and their offspring in the British study was similar to those reported in this study.[16] These suggest that the association between the parents' and children's BMI was weak in early childhood. The findings of this study support the belief that the risk of adult obesity depends on the overweight status of both the child and the parents, which is in turn consistent with the idea that familial or genetic factors may predominate in its persistence.[3]

At age 21 y, more than 30% of this sample were overweight and 5% were obese using the WHO cut-offs introduced in 1995.[4] Similar levels were found for 15 to 18-y-olds in the national survey of the New Zealand population carried out in 1989 – 1990[18] when the sample were aged 18 y and in a study carried out in England between 1995 and 1997.[19] The means for the sample and their parents were also similar to those reported in the New Zealand study. [18] Statistical comparisons of those included and those not included in the analysis at age 21 showed that they did not differ for earlier measures. There were, however, some differences at age 11. Using the smoothed centiles based on all available observations may have overcome these to some extent.

Conclusions

BMI tracked from childhood and adolescence to early adulthood, showing that in general those with a high BMI at an earlier age were more likely to be overweight at age 21. Dividing BMI into categories at ages 7, 11 and 15 using the median and 75th centile showed that up to 16% of those below the median at ages 7 or 11 were overweight at age 21. Those with a BMI above the 75th centile at one of these ages were between 4 and 10 times more likely to be overweight at age 21 than those with a BMI below the median.

Strategies for reducing the prevalence of being overweight at age 21 include identifying and providing interventions for those most at risk. The strong association between earlier measures, especially those from age 15, suggests that intervention strategies for individuals above the 75th centile may be appropriate. Although the 75th centile of the BMI distribution from age 7 onwards was useful for defining a group which was more likely to be overweight or obese at age 21, only 40% of those who were overweight or obese at age 21 were identified by age 7 and more than a quarter were not recognized until at least age 15. Because more than a quarter of those found to be overweight at age 21 had a BMI below the median at age 7, a population approach beginning in childhood is also necessary. Resources may be best utilized in

promoting exercise and better eating patterns in the general population.

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