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Prediction of Obesity in Children at 5 Years: A Cohort Study

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Abstract

Objective: To examine determinants of moderate and severe obesity in children at 5 years of age.

Methodology: A prospective cohort of mothers were enrolled at first antenatal visit, and interviewed shortly after delivery, at 6 months and 5 years. Detailed health, psychological and social questionnaires were completed at each phase by mothers, and child health questionnaires at 6 months and 5 years. At 5 years 4062 children were assessed physically, the Peabody Picture Vocabulary Test administered and mothers completed a modified Child Behaviour Checklist. Moderate obesity was defined as BMI between 85th and 94th percentiles inclusively, and severe obesity as a BMI greater than the 94th percentile.

Results: Independent predictors of severe obesity at 5 years were birthweight, female gender, maternal BMI and paternal BMI. Moderate obesity at 5 years was predicted by birthweight, paternal BMI and sleeplessness at 6 months, while small for gestational age (SGA) status and feeding problems at 6 months were protective factors for moderate obesity. Obesity was not associated with problems of language comprehension or behaviour.

Conclusions: Findings of this study suggest that biological rather than psychosocial factors are the major determinants of obesity at 5 years.

Keywords: obesity; prediction; children; weight; cohort studies.

Obesity in childhood is an important health issue. It is associated in children and adolescents with lowered fitness, hypertension, alteration of lipoprotein levels, [1,2] an increased prevalence of certain respiratory, skin and orthopaedic conditions, [3,4] possibly problems of psychological adjustment in childhood, [5] and later stigmatization and loss of self esteem in adolescence. [6] Childhood obesity is a risk factor for adolescent and adult obesity [7-9] which, in turn, are associated with increased morbidity and mortality from cardiovascular, diabetic and neoplastic disease. [10] In the USA the prevalence of obesity in childhood appears to be increasing. [11,12]

A number of theories have been suggested regarding the aetiology of obesity in childhood. These emphasize genetic [13] and metabolic factors, [14] early feeding practices, [15] activity level of the infant, [16] socioeconomic disadvantage, [17] temperament of the child,[18] and family neglect and maternal depression. [19] It is important to understand the origins and associations of childhood obesity if informed and effective intervention programmes are to be implemented.

The purpose of this study is to examine aspects of these theories as they relate to the aetiology of obesity in a large prospective cohort of children at 5 years.

METHODS

Subjects

The Mater-University Study of Pregnancy (MUSP) is a prospective longitudinal study initially of 8556 women enrolled between 1981 and 1984 at their first antenatal visit to the Mater Hospital, Brisbane. Details of the cohort have been described previously.[20] At the time of hospital discharge 7357 singleton children remained in the study. Mothers were interviewed at the time of the first pregnancy visit, shortly after delivery, at 6 months, and at 5 years when the child was also assessed. At the 5 year follow-up a total of 5627 mothers completed the questionnaires though not all their children were assessed clinically due to insufficient funds towards the latter part of the study. This report is confined to the 4062 children assessed clinically at the 5 year follow up, and where parental and child information was reasonably complete. The age range of the children at the 5 year follow-up was 4 years (*n*=147) to 6 years (*n*= 341), with the majority of children being assessed at 5 years. Of the 4062 children, 2133 were female and 1929 were male. Mothers lost to follow up at 5 years were likely to be younger, single, less educated, socially more disadvantaged and their children more premature and of lower birthweight.[21]

Measurement of obesity

Body mass index (BMI) (weight [kg]/height $[m]^2$) was calculated for all children at 5 years. Marked obesity was defined as a BMI greater than 94 percentile and moderate obesity as a BMI between the 85th and 94th percentiles inclusively within the study cohort. Height of the children was measured using a portable stadiometer (KaWe Personen-Messgerat 4440) and weight by a scale accurate to 0.2 kg. Research assistants were trained in measurement of height and weight by medical practitioners associated with the project.

Child predictors

Birth predictors were gestation, gender, ponderal index (weight [kg]/height $[m]^3$), birthweight, small for gestational age (SGA) status (i.e. less than the 10th percentile for gestation and gender within study cohort). At 6 months mothers completed a child health questionnaire including the child’s frequency of vomiting, diarrhoea, skin disease, cough, convulsions, feeding problems, colic, hyperactive behaviour and sleep disturbance. Also included were questions on the use of demand feeding and duration of breast feeding.

At 5 years in addition to height and weight, language comprehension (Peabody Picture Vocabulary Test PPVT) [22] was also assessed. Because the maternal questionnaire was lengthy and covered a range of maternal health and psychosocial circumstances, a shortened form of the Child Behaviour Checklist [23] using second order grouping of the syndromes identified by Achenbach, was administered. This comprised an externalizing scale (11 items, Cronbach alpha 0.84); an internalizing scale (10 items, Cronbach alpha 0.77) and a social-attentional-thought (SAT) (10 items, Cronbach alpha 0.75). The shortening form of the CBCL was compared to the complete CBCL in 76 selected children. The correlations between the short and long forms of the CBCL were r=0.98 for the total behaviour problems, r =0.94 for externalizing, r =0.89 for internalizing and r =0.96 for the SAT scale. The extreme 10% of scores in each of the three scales were taken as indicating the presence of a behaviour problem, a similar process as with the complete CBCL.

Parental predictors

Maternal factors included were pre-pregnant BMI calculated from reported pre-pregnant weight and measures of maternal height, age at first visit and level of education. Level of income, marital status, and symptoms of anxiety and depression using the full subscales of the Delusions Symptoms-States inventory of Bedford *et al.* [24] at each phase of the study were also examined. The sole paternal factor was BMI calculated from maternal reports of the father’s height and weight.

For predictors divided according to percentiles (maternal BMI, paternal BMI, birthweight and SGA) rounding of the original data made it difficult to divide the distribution exactly at particular percentiles. This has lead to slight differences in actual percentages between the identified percentiles for these variables.

Statistics

The association between individual child and parental predictors and severe and moderate obesity at 5 years was examined. The strength of the association was measured by the relative risk, its precision by the 95% confidence interval and statistical significance by the Chi-squared test. Child and parental predictors significantly related to moderate and severe obesity in the univariate analysis were entered into separate logistic regression models with risk of severe or moderate obesity as the dependent variable. Adjusted odds ratios for predictor variables and their 95% confidence intervals were obtained from the logistic models. Calculations were performed using SAS [25] and Egret [26].

RESULTS

Child predictors significantly related to severe and moderate obesity at 5 years in the univariate analysis are shown in Table 1, together with their relative risk and the 95% confidence interval of the relative risk. Factors predictive of severe obesity were birthweight exceeding the 94th percentile (RR 1.8, 95% CI 1.1-2.9), birthweight between the 85th and 94th percentiles inclusively (RR 1.7, 95% CI 1.2-2.9), female gender (RR 1.4, 95% CI 1.1-1.9), and breast feeding. This later finding regarding breast feeding was only for duration of feeding between 7 weeks and 3 months (RR 1.6, 95% CI 1.0-2.4) and these results were generally not consistent with the overall trend of the relationship shown in Table 1.

Table 1 Child predictors at birth and 6 months of severe and moderate obesity at 5 years

			BMI ≥ 95%			85-94%	
	Total	*n*	RR	95% CI	*n*	RR	95% CI
Birthweight							
<5 percentile	164	7	1.0	0.5-2.0	11	0.7	0.4-1.3
5-14	378	18	1.1	0.7-1.7	29	0.8	0.6-1.2
15-84†	2851	126	1.0		274	1.0	
85-94	449	34	1.7	1.2-2.9*	55	1.3	1.0-1.7
>95	219	17	1.8	1.1-2.9*	38	1.8	1.3-2.5*
Sex							
Male†	2133	88	1.0		221	1.0	
Female	1929	114	1.4	1.1-1.9*	186	0.9	0.8-1.1
SGA							
Not	3683	189	1.0		338	1.0	
Yes	377	13	0.7	0.4-1.2	19	0.5	0.3-0.8*
Feeding problems (6 months)							
Never†	2140	109	1.0		234	1.0	
Rarely	1181	52	0.9	0.6-1.2	114	0.9	0.7-1.1
Few times/month	243	15	1.2	0.7-2.1	21	0.8	0.5-1.2
Few times/week	140	7	1.0	0.5-2.1	6	0.4	0.2-0.9*
Almost daily	152	7	0.9	0.4-1.9	10	0.6	0.3-1.1
Duration breast feeding							
>6 months†	1244	51	1.0		118	1.0	
4.6 months	408	16	1.0	0.6-1.7	46	1.2	0.9-1.6
7 weeks-3 months	561	36	1.6	1.0-2.4*	50	0.9	0.7-1.3
3 weeks-6 weeks	476	22	1.1	0.7-1.8	47	1.0	0.8-1.4
≤ weeks	430	22	1.3	0.8-2.0	53	1.3	1.0-1.8
Not at all	790	44	1.4	0.9-2.0	77	1.0	0.8-1.4
Sleeplessness (6 months)							
Never†	1063	63	1.0		97	1.0	
Rarely	1660	78	0.8	0.6-1.1	172	1.1	0.9-1.4
Few times/month	445	26	1.0	0.6-1.5	44	1.1	0.8-1.5
Few times/week	424	16	0.6	0.4-1.1	46	1.2	0.9-1.7
Almost daily	266	8	0.5	0.2-1.0	26	1.1	0.7-1.6

*$P < 0.05$; † reference category; numbers vary slightly because of missing data.

Child predictors of moderate obesity were birthweight exceeding the 94th percentile (RR 1.8, 95% CI 1.3-2.5), SGA (RR 0.5, 95% CI 0.3-0.8) and feeding problems a few times per week at 6 months (RR 0.4, 95% CI 0.2-0.9). Sleeplessness at 6 months (RR 1.2, 95% CI 0.9-1.7) was almost statistically significant and is included as it was statistically significant in the subsequent adjusted analysis. Age of the child was not related to mean BMI, and children in the severe (65.3 months) and moderate obesity (65.1 months) groups had a similar mean age to children in the reference BMI group 15-84%ile (65.8 months).

Significant parental predictors of severe and moderate obesity at 5 years are shown in Table 2. Maternal and paternal BMI are related to both moderate and severe obesity. A primary level of maternal education was a risk factor for severe obesity (RR 2.0, 95% CI 1.2-3.2). Income at 5 years was related to obesity with high income being associated with an increased prevalence of severe obesity (RR 1.7, 95% CI 1.0-2.7) and low income with a lower risk of moderate obesity (RR 0.7, 95% CI 0.5-1.0).

Table 2 Parental predictions of severe and moderate obesity in children at 5 years

		BMI ≥ 95%			BMI 85-94%		
	Total	*n*	RR	95% CI	*n*	RR	95% CI
Maternal							
<15 percentile	525	7	0.4	0.2-0.8*	25	0.5	6.3-0.7*
15-84†	2673	99	1.0		270	1.0	
85-94	371	38	2.6	1.8-3.8*	47	1.3	0.9-1.7
≥ 95	200	35	4.7	3.3-6.8*	26	1.3	0.9-1.9
Education							
Primary/special	177	16	2.0	1.2-3.2*	15	0.8	0.5-1.3
Started Secondary	527	29	1.2	0.8-1.8	47	0.9	0.6-1.1
Completed Grade 10†	2218	103	1.0		234	1.0	
Completed Grade 12	364	15	0.9	0.5-1.5	38	1.0	0.7-1.2
College/University	650	31	1.0	0.7-1.5	62	0.8	0.7-1.1
Income (5 years) (dollars)							
<100	1031	41	0.9	0.6-1.4	104	0.8	0.7-1.1
100-199	876	47	1.3	0.8-1.9	77	0.7	0.5-1.0*
200-299†	1071	43	1.0		122	1.0	
300-399	631	33	1.2	0.8-1.9	59	0.8	0.6-1.1
400	337	24	1.7	1.0-2.7*	33	0.8	0.6-1.2
Paternal							
BMI (percentiles)							
<15	515	16	0.8	0.5-1.3	34	0.6	0.5-0.9*
15-84†	2545	104	1.0		265	1.0	
85-94	343	35	2.5	1.7-3.6*	35	1.0	0.7-1.4
>95	192	23	2.9	1.9-4.5*	35	1.8	1.3-2.4*

* P<0.005; † reference category: numbers vary slightly because of missing data.

For all predictors discussed in Table 1 and Table 2, the sensitivity and positive predictive values for moderate or severe obesity were low. The highest positive predictive values for severe obesity was maternal BMI ≥ 95 percentile (17.5%) and paternal BMI ≥ 95 percentile (12%). For moderate obesity the two strongest predictors were BWt (95 percentile (17.3%) and paternal BMI ≥ 95 percentile (18.2%).

Adjusted odds ratios and their 95% CI for child predictors of severe and moderate obesity obtained from the logistic models are shown in Table 3. The separate models for severe and moderate obesity each included all child and parental factors shown in Tables 1 and 2. Birthweight and female gender remain predictors of severe obesity though duration of breast feeding was no longer significant in the adjusted analysis. For moderate obesity the results were very similar to the initial analysis. Birthweight > 94 percentile and sleeplessness at 6 months remained risk factors and SGA status and feeding problems at 6 months protective factors. The results for parental predictors from the adjusted analysis are shown in Table 4. For severe obesity maternal and paternal BMI remained strong predictors though the relationship with income at 5 years and level of maternal education were no longer statistically significant. For moderate obesity paternal BMI remained a risk factor and low income a protective factor. The strength of the association with maternal BMI was of similar strength though was no longer statistically significant in the adjusted analysis.

Mean PPVT scores were similar in the severe obese (99.3) and moderate obese (99.9) children compared to the reference category of children with BMI 15-84 percentile (99.7). The prevalence of externalizing, internalizing or SAT behaviour problems was similar in the severely obese and moderately obese groups of children to that of children in the reference BMI category, with no differences being statistically significant.

DISCUSSION

Predictors of severe obesity in this study were birthweight, female gender, maternal BMI and paternal BMI. Birthweight, paternal BMI and sleeplessness at 6 months were associated with an elevated risk of moderate obesity, while SGA status and feeding problems at 6 months were associated with a lower risk of moderate obesity.

The BMI is a recommended measure of obesity for epidemiological studies [27,28] and it has a close relationship with more sophisticated laboratory measures. [29,30] Possible limitations of BMI are that it may not detect differences in fat distribution within a body; it may fail to differentiate muscle from fat; and the percentiles most predictive of adult obesity and morbidity are uncertain and may vary with age. The percentiles used in this study to define moderate and severe obesity are consistent with other studies. [31]

Table 3 Adjusted child predictors of severe and moderate obesity at 5 years

	BMI ≥ 95%		BMI 85-94%	
	Adj.OR	95% CI	Adj.OR	95% CI
Birthweight (percentiles)				
<15	1.2	0.6-2.2	1.3	0.9-2.1
15-84†	1.0		1.0	
85-94	1.8	1.1-2.9*	1.2	0.8-1.7
>95	1.7	0.9-3.3	2.0	1.3-3.2*
Gender				
Male†	1.0		1.0	
Female	1.4	1.0-2.0*	1.0	0.8-1.3
SGA				
Not	1.0		1.0	
Yes	0.8	0.4-1.6	0.5	0.3-0.9*
Feeding problems (5 months)				
Never†	1.0		1.0	
Rarely	0.8	0.5-1.2	0.8	0.6-1.1
Few times/month	1.2	0.6-2.5	0.9	0.6-1.5
Few times/week	1.6	0.7-3.6	0.3	0.1-0.8*
Almost daily	1.3	0.5-3.0	0.4	0.2-0.8*
Duration breast feeding				
>6 months†	1.0		1.0	
4-6 months	0.7	0.3-1.4	1.4	0.9-2.1
7 weeks-3 months	1.6	1.0-2.7	1.1	0.7-1.7
3 weeks-6 weeks	11	0.6-2.0	1.3	0.8-1.9
<2 weeks	1.1	0.6-2.0	1.5	1.0-2.2
Not at all	1.4	0.8-2.3	1.2	0.8-1.7
Sleeplessness (5 months)				
Never†	1.0		1.0	
Rarely	0.9	0.6-1.3	1.4	1.0-1.9
Few times/month	1.1	0.6-2.0	1.3	0.8-2.0
Few times/week	0.9	0.5-1.7	1.7	1.1-2.6*
Almost daily	0.6	0.3-1.4	1.5	0.9-2.6

*$P< 0.05$; † reference category.

From twin and adoption studies, the genetic contribution to obesity has been well established. [32] The findings in this study of a strong association between obesity at 5 years and maternal and paternal BMI may reflect genetic factors. Measures of parental height and weight were based on maternal report and these were not validated. Though we have no reason to believe these estimates to be biased, they may increase random error and reduce precision in the estimates of association involving paternal BMI. Though few psychosocial differences were evident in this study between parents of obese and non-obese children, there may be shared lifestyle and social factors that also contribute to the association between child and adult BMI that have not been addressed in the study.

The expression of genetic risk for obesity and adult mortality and morbidity may be influenced by nutritional programming in early life. [33] Though breast feeding has been suggested as a protective factor for obesity, no such association was present in this study. Other aspects of early feeding practices measured in this study were not associated with increased risk of obesity, though presence of feeding problems at 6 months was associated with a lower risk of moderate obesity. Little information was available on the timing and nature of early infant solid foods, though this is unlikely to be causally related to later obesity. [3] Level of activity in infancy may also be related to risk of later obesity. [17,34] There was no direct observation of infant activity in this study, though maternal rating of infant activity at 6 months was unrelated to later child obesity.

Females in this study were at increased risk for severe obesity. The reason for this is uncertain, though White *et a1.* [29] reported a similar finding in United Kingdom children, with the upper percentiles of the BMI being larger for females than males.

Table 4 Adjusted parental predictors of severe and moderate obesity in the child at 5 years

	BMI ≥ 95%		BMI 85-94%	
	Adj.OR	95% CI	Adj.OR	95% CI
Maternal				
BMI (percentiles)				
<15	0.3	0.1-0.7*	0.5	0.9-2.1
15-84†	1.0		1.0	
85-94	2.4	1.6-3.8*	1.2	0.8-1.8
≥ 95	3.9	2.3-6.4*	1.4	0.9-2.3
Education				
Primary/special	1.9	1.0-3.6	0.7	0.4-1.4
Started secondary	1.0	0.6-17	0.8	0.5-1.2
Completed grade 10†	1.0		1.0	
Completed grade 12	0.7	0.3-1.4	1.1	0.7-1.6
College/university	1.0	0.6-1.6	0.9	0.7-1.3
Income (5 years)				
<100	1.2	0.7-2.1	0.7	0.5-1.0
100-199	1.6	1.0-2.6	0.7	0.5-0.9*
200-299†	1.0		1.0	
300-399	1.4	0.8-2.5	0.9	0.6-1.3
>400	1.5	0.7-3.2	0.8	0.5-1.3
Paternal				
BMI (percentiles)				
<15	0.8	0.4-1.4	0.7	0.4-1.0
15-84†	1.0		1.0	
85-94	2.8	1.8-4.5*	1.0	0.6-1.5
≥95	2.0	1.1-3.6*	2.1	1.4-3.3*

* *P* <0.05; † reference category.

Prevalence of obesity has been inversely associated with socioeconomic status in economically developed countries.[17] In this study, however, high income at 5 years was associated with an increased risk of severe obesity and lower income with a reduced risk of moderate obesity. This protective effect of low income on moderate obesity was also present in the adjusted analysis. Though not the subject of this paper, lower income was not associated with sub-optimal growth in this cohort at 5 years, making it unlikely that the association with lower risk of moderate obesity is due directly to poverty. The association between lower level of maternal education and severe obesity involved relatively few children and was not significant in the adjusted analysis. No association was present in this study between risk of obesity at 5 years and maternal age, marital status, or maternal symptoms of depression and anxiety.

At 5 years children who were moderately or severely obese had neither an increased prevalence of behavioural difficulty nor impairment of language comprehension. Other authors have reported similar behavioural findings. [34] Carey *et al.* and Mellbin [36] reported an association between rapid weight gain and behaviour disorder in middle childhood. Information on rapidity of weight gain prior to 5 years was not available in this study. Inconsistent findings between obesity and child behaviour may reflect selection factors in clinical samples, [6] or that such associations only become apparent in later childhood and adolescence. [6] The association in this study between infant sleeplessness at 6 months and increased risk of moderate obesity at 5 years may reflect a tendency to feed infants who wake at night. Information on this or on the presence of symptoms of obstructive sleep apnoea which may be associated with both obesity and frequent night time waking is not available on children in this study. The reason for the lack of association between sleeplessness and severe obesity is uncertain though may indicate that genetic factors are more important in the severe obesity group.

The correlation between childhood and adult obesity increases during childhood, though by 5 years the strength of the association is substantial. [9,7,37] Serdula *et al.* [38] concluded from a review of the literature that obese children have at least twice the risk of non-obese children for later obesity. Approximately 26-41% of obese pre-schoolers become obese adults. Because of the relative lack of success of intervention programmes in adults, [39] intervention programmes in childhood have been proposed. [40] Although the four predictors of severe obesity in this study, birthweight, female gender, maternal and paternal BMI, are identifiable at birth, the relative risk associated with each of the four factors in this study is only moderate and the sensitivity and positive predictive value for obesity at 5 years are low. There is also uncertainty regarding a risk predictive definition of obesity in childhood in relation to subsequent adult morbidity and mortality. [2] Finally, caution is required as though elevate lipid levels have been demonstrated in Australian children of 6-11 years, [41] there was no apparent adverse physical, psychological or behavioural consequences of obesity on the children in this study.

Weaknesses in this study include loss to follow-up at 5 years, with mothers lost to follow up being more socially disadvantaged. The extent to which the relationships reported would also apply to those children not assessed at 5 years is uncertain, though Boyle *et al.* [42] argue that losses of this extent would be unlikely to substantially alter estimates of relative risk. Because a shortened form of the CBCL was used it is possible that associations specific to a particular behaviour scale may have been missed. Measures of maternal estimates of paternal height and weight were not independently validated, and will be imprecise though the error in the estimate is likely overall to be random rather than systematic. Finally, a number of possible factors such as dietary fat intake, level of watching television and exercise have not been considered. These factors are, however, included in the current 13 year follow up of children in this cohort.

Follow up of this and similar cohorts of children should provide further information on the origins and continuity of childhood obesity into adult life, and its associations with problems of health, development and behaviour.

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