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Child and parent characteristics as predictors of change in girls' body mass index

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Abstract

OBJECTIVE—This study assessed predictors of change in girls' body mass index (BMI) between ages 5 and 7 y and familial aggregation of risk factors associated with childhood overweight.

METHOD—Participants included 197 5-y-old girls and their parents, of whom 192 were reassessed when girls were 7-y-old. Three classes of predictors of girls' change in BMI were assessed including girls' and parents' weight status, dietary intake and physical activity. Girls' and parents' BMI and change in BMI were calculated based on height and weight measurements. Girls' dietary intake was assessed using three 24 h recalls; parents' intake was assessed using a food frequency questionnaire. Girls and mothers provided reports of girls' physical activity; parents' frequency and enjoyment of activity were assessed using a self-administered questionnaire.

RESULTS—The most effective model predicting girls' change in BMI between ages 5 and 7 included both child and parent characteristics, specifically girls' BMI at age 5, mothers' change in BMI, fathers' energy intake, fathers' enjoyment of activity, and girls' percentage of energy from fat. In addition, results showed substantial intra-familial associations in weight status and dietary intake and to a lesser extent physical activity, and the presence of multiple risk factors within families. Associations were also noted between girls' and parents' change in BMI.

CONCLUSIONS—Results from this study highlight the centrality of the family in the etiology of childhood overweight and the necessity of incorporating parents in the treatment of childhood overweight.

Keywords

children; overweight; predictors; family; parents; environment

Introduction

Rising rates of overweight among children[1–3] coupled with negative health and psychological outcomes[4] has resulted in a concerted effort to identify causal factors leading to the development of childhood overweight. Research has identified multiple factors that are associated with an increased risk of overweight among children including high fat intake,[5–7] low levels of activity,[8,9] and high levels of sedentary behavior[8,10,11] to mention a few. In addition, research suggests that risk factors co-occur; for example, a negative association has been identified between physical activity and sedentary behavior among children.[12,13] It is likely that the family plays an important role in the development of risk profiles and the emergence of overweight among children, as risk factors for overweight emerge in the context

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of the family and show a degree of tracking across time.[12,14–17] Surprisingly little research, however, has comprehensively assessed the influence of the familial context on the development of overweight among children. In an effort to build a comprehensive and context-based model of childhood overweight, this study assesses child and parent characteristics as predictors of girls' change in body mass index (BMI) between ages 5 and 7.

While a relatively large body of research has assessed factors associated with childhood overweight at any one point in time, less research has assessed predictors of change in BMI or overweight among children. Among young children, research has shown that higher daily energy intake[18] and higher percentage of energy from fat[18,19] are associated with greater increases in degree of overweight. In addition, lower levels of activity have been associated with greater increases in degree of overweight among preschool children[20] and greater participation in physical activity has been associated with decreases in degree of overweight among preadolescent children.[19,21,22] The present study will add to this small body of research by assessing parents' dietary intake and physical activity, in addition to children's intake and activity, as predictors of girls' change in BMI. Assessing predictors of change in BMI between ages 5 and 7 is of interest because adiposity rebound generally occurs during this time period and the timing of rebound, specifically early rebound, has been linked to risk of overweight in adolescence and adulthood.[23–25] Consequently, it has been suggested that change in BMI between ages 5 and 7 y marks a critical period for the subsequent development of overweight.[26]

Parents play a crucial role in shaping children's dietary and activity patterns, and ultimately the regulation of children's weight status, as shown by the fact that all risk factors for overweight co-occur within the family. Research shows significant positive correlations between children's and parents' weight status[10,27–30] dietary intake,[31–35] food preferences,[36] and activity patterns.[37–40] Research, however, has rarely considered the influence of parent physical activity and dietary intake on children's change in degree of overweight. One exception is a recent study by Hood *et al*,[41] who found that parent disinhibition, or the abandonment of control of food intake in the presence of external stimuli, was associated with greater increases in children's BMI and skinfold thickness across a period of 6 y, controlling for parent BMI. Hood *et al* suggested that parent disinhibition may influence children's risk of overweight as a result of the eating context that parents create for children by modeling inappropriate behaviors and by parents' child feeding practices.

The primary goal of this study is to develop a comprehensive model of girls' change in BMI. Predictors of girls' change in BMI that will be examined include girls' dietary intake and physical activity, and parents' change in BMI, parents' dietary intake, parents' physical activity, and familial risk of overweight (or the number of overweight parents). It is hypothesized that parent characteristics, in combination with child characteristics, will increase the ability to predict girls' change in BMI as a result of the information they provide on the context in which children's eating and activity patterns emerge. In addition to predictors of girls' change in BMI, familial aggregation of dietary and activity practices will be assessed to further explicate the role of familial factors in children's risk of overweight; that is, associations among all predictors of interest will be assessed for girls, mothers and fathers.

Methods

Participants

Participants were from central Pennsylvania and were part of a longitudinal study of the health and development of young girls. At entry into the study, participants included 197 5-y-old girls (mean age 5.4±0.4) and their parents; 192 families were reassessed 2 y later when girls were 7-y-old (mean age 7.3±0.3). Mothers' and fathers' mean ages were 35.4 (±4.7) and 37.4 (±5.4), respectively, when girls were 5 (time 1) and 37.4 (±4.7) and 39.4 (±5.4) when girls were 7 (time 2). At time 1, all families were seen during a 6-week period in the summer prior to girls' entry into kindergarten. At time 2, families were seen during the same 6-week period in the summer prior to girls' entry into second grade. Variability in age at each visit was small, as noted above, and the timing of visits across families differed by a maximum of 6 weeks across the two occasions of measurement.

Families were recruited for the study using flyers and newspaper advertisements. In addition, families with age-eligible girls within a five-county radius received letters inviting them to participate in the study and received follow-up phone calls. Eligibility criteria for girls' (and parents') enrollment in the project included, in addition to age, living with both biological parents, the absence of severe food allergies or chronic medical problems affecting food intake, and the absence of dietary restrictions involving animal products. Families were not recruited based on weight status. All families participating were non-Hispanic white. At time of entry into the study, two-thirds of parents reported a level of education higher than a high school diploma, all fathers and two-thirds of mothers were employed, and approximately equal proportions of families reported incomes below $35 000, between $35 000 and $50 000 and above $50 000.

Procedures

At both occasions of measurement (when girls were aged 5 and 7 y), girls were individually interviewed by a trained interviewer, parents completed a series of pencil and paper questionnaires, and height and weight measurements were obtained for girls, mothers and fathers. Three classes of risk factors for the development of overweight were examined for girls and parents including girls' and parents' weight status, dietary intake and physical activity. All measures were assessed when girls were 5, with the exception of girls' and parents' BMI which were assessed at both ages, and girls' tendency toward activity, which was assessed when girls were 7-y-old (see Table 1 for a summary). For ease of presentation, the label 'weight status' is used to collectively refer to height/weight measures for girls and parents as a variety of height/weight indices were obtained.

Girls' measures

Weight status—Three height and weight measurements were collected for girls at ages 5 and 7 y. Average weight and height were used to calculate girls' BMI (weight (kg)/height (m)^2) at each age and change in BMI from age 5 to 7 y. Girls were classified as overweight (BMI ≥ 17.2 at age 5 and BMI ≥ 18.0 at age 7) or obese (BMI ≥ 19.3 at age 5 and BMI ≥ 21.0 at age 7) based on recent international age- and sex-specific definitions of overweight.[42] Although BMI confounds fat mass and fat-free mass, BMI was considered an appropriate measure of weight status and change in weight status for this study for a number of reasons. First, research indicates that BMI is highly correlated with percentage body fat among children.[43–45] Second, overweight is associated with greater fat mass in addition to greater lean body mass;[46] thus BMI captures both aspects of the development of overweight. Third, children in this study were all girls, were all approximately the same age, and were assessed at roughly equal intervals. Consequently, expected developmental changes in BMI were similar for all girls and differences in change in BMI reflect the relative pace in the expected pattern of change.

Physical activity—Two measures of girls' physical activity were obtained. When girls were 5, mothers were asked to respond to the question 'How active is your daughter relative to other girls her age?' using the following response options: (1) much less active; (2) a little less active; (3) just as active; (4) a little more active; and (5) much more active. In addition, at age 7, girls completed the shortened version of the Children's Physical Activity Scale (CPA), which assesses children's preference for, or tendency toward, physical activity (eg 'I would rather watch TV or play in the house than play outside').[47] The CPA-short contains 10 items and uses a four-point response scale from **1** =completely true to 4 = completely false. To aid the interpretation of results, the CPA will be referred to as tendency toward activity. Research supports that validity of this scale; scores on the CPA were found to be significantly related to 1-mile run/walk time ($r = -0.43$, $P < 0.0001$), body fat percentage ($r = -0.41$, $P < 0.0001$), and BMI ($r = -0.32$, $P < 0.0001$).[47] In this sample, Cronbach's alpha was 0.58 for the CPA.

Dietary intake—When girls were 5, mothers provided three 24 h recalls of their daughters' food intake over the telephone. Girls were asked to be present during the phone interviews to ensure completeness of information. Two weekdays and one weekend day were randomly selected over a 2 – 3 week period during the summer. Portion-size posters were used as a visual aid for estimating amounts and portion sizes of foods eaten. Girls' daily nutrient intakes were estimated using a computer-assisted Nutrition Data System (NDS; Nutrition Coordinating Center, University of Minnesota, MN; Nutrient Database version 12A, Food Database version 27; Release date 1996). Nutrient data were averaged across 3 days to obtain an estimate of average daily energy intake. Total daily energy intake and percentage of energy from fat were used as indices of girls' dietary intake. Girls' energy intake was adjusted for body weight by regressing girls' energy intake onto their weight in kilograms and saving the residuals. Girls' adjusted energy intake was used in all analyses.

Parents' measures

Weight status—Three height and weight measurements were collected for mothers and fathers at each time of assessment. Average height and weight were used to calculate parents' BMI when girls were 5- and 7-y-old and change in BMI across this time period. BMI has been recommended as an appropriate measure of overweight among all age groups.[48] In addition, parents were classified as overweight (BMI $\geq$ 25) or obese (BMI $\geq$ 30) using criteria outlined by the World Health Organization.[3] Based on parents' classification of overweight, each family was assigned a value for familial risk of overweight: 1 = neither parent overweight; 2 = one parent overweight; 3 = both parents overweight.

Physical activity—Parents' participation in activity and parents' enjoyment of activity were assessed at time 1, when girls were 5-y-old. Parent participation in activity was assessed using the question 'How many days a week do you exercise or participate in sports?' Due to the substantial skewness present in this variable, with most parents reporting low levels of activity, responses were categorized into three groups: low activity = never exercise or participate in sports; medium activity = participate in sports or exercise 1 –3 days a week; high activity = participate in sports or exercise more than 3 days a week. Enjoyment of activity was assessed in addition to weekly frequency of activity, because parents who enjoy activity may be more likely to encourage their children to be active than parents who exercise for health or weight loss. Enjoyment of sports and exercise was assessed by asking parents to respond to the statement 'I exercise or play sports for fun' using a three point response option (1 = does not describe me; 2 = sort of describes me; 3 = really describes me).

Dietary intake—Mothers' and fathers' 'usual' dietary intake was assessed at time 1 using the semi-quantitative food frequency questionnaire (FFQ) developed by Kristal *et al*.[49] The FFQ is a standardized, comprehensive list of foods used for assessing dietary intake. Parents were asked to indicate the frequency with which they consumed each food within the past 3 months and the approximate serving size. Previous research supports the reliability and validity of the FFQ.[50] Parents' daily energy intake and percentage of energy from fat were used as indices of parents' dietary practices. Parents' energy intake was adjusted for body weight by regressing energy intake onto their weight in kilograms and saving the residuals. Adjusted energy intake was used in all analyses.

Statistical analyses

Analyses were conducted using SAS software version 6.12 (Cary, NC). Before any analyses were conducted the data were checked for outliers, which can have a disproportionate affect on the group results, particularly when using correlation or regression analysis. Twelve families with outlying BMI values (ie greater than 3 standard deviations from the mean) were identified and removed from analyses. The total *n* when girls were 5-y-old was 185 (ie for the cross-sectional analyses at age 5). For longitudinal analyses (predicting girls change in BMI), only families with complete anthropometric data at both time points were used in analyses, resulting in an *n* of 168.

Predictors of girls' change in BMI—Hierarchical regression was used to identify the most comprehensive and parsimonious model of girls' change in BMI. The order of entry of the predictor variables in the regression analysis was established such that it reflected the developmental process leading to accelerated changes in children's BMI and the development of overweight. In this model, accelerated weight gain among children is influenced by their dietary and activity practices, which are shaped by their parents' dietary and activity practices. In turn, parents' diet and activity patterns reflect their weight status such that overweight parents display lower levels of activity and greater intake of total energy and percentage of energy from fat. Thus, the predictor variables hypothesized to be most *distal* to girls' change in BMI (ie parent weight status) were entered first into the model followed by predictors that were more *proximal* to girls' change in BMI (ie girls' physical activity and dietary intake). Predictor variables were entered in the following order: (1) background and confounding variables (ie family income; parent education status; girls' BMI at age 5); (2) parents' weight status (ie familial risk of overweight; parents' change in BMI); (3) parents' physical activity (ie frequency and enjoyment of activity); (4) parents' dietary intake (ie total energy and percentage fat intake); (5) girls' physical activity (ie relative activity and tendency toward activity); and (6) girls' dietary intake (ie total energy and percentage fat intake). At each step, all indicators for each predictor variable were entered simultaneously into the model. It was predicted that the addition of each set of predictor variables would *increase* the explanatory power of the model and that the final model would incorporate both parent and child characteristics. Background and confounding variables were entered first into the model to remove potential confounding effects of such variables on change in girls' BMI. At each step, the contribution to the model of (a) each individual indicator (shown by the individual *P*-value), and (b) the class of predictor as a whole (shown by the change in *r*-squared) was examined.

Familial aggregation of risk factors for overweight—Follow-up analyses assessed familial aggregation of risk factors for overweight. Specifically, correlations among all indicators of weight status, physical activity, and dietary intake at time 1 were calculated for girls, mothers and fathers. In addition, correlations were calculated between girls' and parents' change in BMI. For both girls and parents, all correlations involving change in BMI partialled out the effects of time 1 BMI.

Results

Sample characteristics: weight status, physical activity and dietary intake

Girls' mean BMI at ages 5 and 7 and girls' change in BMI reflect population-level patterns for white 5- and 7-y-old girls[51] (see Table 2)[*] A strong degree of tracking was noted in girls' BMI from ages 5 to 7 ($r = 0.87$, $P < 0.001$), and girls' change in BMI was correlated with BMI at age 5 ($r = 0.36$, $P < 0.001$) and BMI at age 7 ($r = 0.76$, $P < 0.001$). Tracking was also noted in girls' overweight classification such that 80% of girls who were overweight at age 5 were also

[*] No population estimates of overweight and obesity using criteria outlined by Cole *et al* [42] are available.

overweight at age 7. In contrast, only 9% of girls became overweight between ages 5 and 7. Approximately half of mothers were overweight (BMI ≥ 25), reflecting population estimates among women, and three-quarters of fathers were overweight, which is slightly higher than population estimates among men.[52] With respect to physical activity, girls' and mothers' reports of girls' activity indicated that girls were on average moderately active and parents' reports of their own activity indicated that mothers' exercised on average 1 – 3 days per week, whereas fathers tended not to exercise. In addition, both mothers and fathers reported an average liking for physical activity. Finally, mean energy intake (not controlling for body weight) was 1517 kcal (±311) for girls, 1807 kcal (±685) for mothers and 2058 kcal (±670) for fathers and mean percentage of energy from fat was 31% for girls and 36% for mothers and fathers.

Predictors of girls' change in BMI from age 5 to 7 y

Results from the hierarchical regression assessing predictors of girls' change in BMI from age 5 to 7 are outlined in Table 3. At step 1, the control variables (girls' BMI at age 5, parent education, family income) were entered into the model. The resulting r^2 was significant, explaining 16% of the variance in girls' change in BMI. Of the variables entered, only girls' BMI at age 5 was significantly associated with girls' change in BMI. At step 2, parent weight status variables were entered into the equation resulting in a marginally significant increase in r^2, with all variables entered explaining 19% of variance. Mothers' change in BMI and familial risk of overweight were associated with change in girls' BMI, although the effect for mothers' change in BMI was a trend. At step 3, parent activity variables were entered. Although the change in r^2 was not significant, a trend was noted between fathers' enjoyment of activity and girls' change in BMI. Parent dietary intake variables were entered at step 4 resulting in a significant increase in r^2, with all variables in the model explaining 29% of the variance. Of the variables entered, a trend was noted for fathers' energy intake. Next, girls' physical activity variables were entered into the model. No change in r^2 was observed and none of the variables were individually associated with girls' change in BMI. Finally, at step 6, girls' dietary intake variables were entered into the model. A marginal increase in r^2 was identified, with all variables explaining 32% of the variance, and a significant effect was found for girls' percentage fat intake.

The final model was created by entering into a separate model all variables that were at least marginally (ie $P \leq 0.10$) associated with girls' change in BMI across steps 1 – 6 (see Table 3). Variables fulfilling this criterion included girls' BMI at age 5, familial risk of overweight, mothers' change in BMI, fathers' enjoyment of activity, fathers' total energy intake, and girls' percentage fat intake. The final model was significant and explained 26% of the variance in girls' change in BMI. All variables were significant at $P < 0.05$, with the exception of fathers' energy intake, which was marginally associated with girls' change in BMI. Girls with greater increases in BMI between ages 5 and 7 had a higher BMI at age 5, a higher percentage of energy from fat at age 5, a higher familial risk of overweight, and had fathers who enjoyed activity less and had higher energy intake (controlling for body weight). Although girls' BMI at age 5 explained a reasonable proportion of the variance in girls' change in BMI (ie 15% of the 26%), the remaining variables explained a further 11% of variance in the model. Analyses were also conducted using only families with complete data for all variables ($n = 142$); no meaningful changes in results were identified.

Familial aggregation of risk factors for overweight

Correlations among all risk variables, for parents and their daughters, when girls were 5-y-old are presented in Table 4. Over 25% of the correlations calculated were significant at $P < 0.05$ or less, illustrating the extent to which risk factors for overweight cluster within families. Looking first at associations within each of the risk factors, significant positive associations were noted between girls' and parents' weight status; No associations were found between girls' and parents' physical activity, although mothers' and fathers' frequency of activity were positively correlated. With respect to dietary intake, girls with higher BMI at age 5 had mothers and fathers with higher BMI and were more likely to come from families with a higher risk of overweight (ie one or more overweight parents). No associations were found between girls' and parents' physical activity, although mothers' and fathers' frequency of activity were positively correlated. With respect to dietary intake, girls with greater energy intake had mothers and fathers with greater energy intake and girls who consumed a greater percentage of energy from fat had mothers with a higher percentage fat intake. Similarly, mothers' and fathers' energy intake and percentage of energy from fat were positively correlated. Associations were also noted across the different risk factors. Mothers with higher BMI (column 3) were less active, enjoyed activity less, and reported a higher percentage fat intake than mothers with lower BMI. Fathers with higher BMI (column 4) were less active and had a higher percentage fat intake than fathers with lower BMI. Finally, mothers who exercised more frequently reported a lower percentage of energy from fat; mothers who enjoyed activity reported greater energy intake, but lower percentage fat intake; and fathers who were active or enjoyed activity reported lower energy intake and a lower percentage fat intake (see bottom of columns 7 – 10).

Partial correlations were also calculated between girls' and parents' change in BMI, controlling for girls' and parents' BMI when girls were 5. Results indicated that mothers' and fathers' change in BMI were positively correlated ($r = 0.20$, $P < 0.01$) and girls' change in BMI was positively and marginally correlated with mothers' ($r = 0.14$, $P < 0.10$) but not fathers' change in BMI.

Discussion

This study assessed child and parent characteristics as predictors of girls' change in BMI between ages 5 and 7 with the goal of developing a comprehensive and context-based model of girls' change in BMI. As hypothesized, the most effective model predicting girls' change in BMI incorporated child *and* parent characteristics. This finding is likely to reflect the extensive clustering of risk factors for overweight within families and suggests that measuring multiple aspects of the family environment increases the ability to explain the context in which childhood overweight occurs and as a result increases the ability to predict patterns of overweight among children.

The final model of girls' change in BMI incorporated girls' BMI at age 5, the number of overweight parents, mothers' change in BMI, fathers' enjoyment of activity, fathers' energy intake (controlling for body weight) and girls' percentage of energy from fat, collectively explaining 26% of the variance in girls' change in BMI. As was expected, girls' initial BMI explained a substantial proportion of this variance (ie. 15% of the 26%). Tracking was noted in girls' BMI across time; the correlation between girls' BMI at age 5 and (a) girls' BMI at age 7 and (b) girls' change in BMI was $r = 0.87$ and $r = 0.36$, respectively. Removing evidence of this tracking by controlling for girls' BMI at age 5 is necessary in order to separate predictors of BMI at a single point in time and change in BMI. This practice, however, is likely to attenuate the ability to predict change in BMI as parent and child dietary intake and physical activity are likely to be associated with both cross-sectional and longitudinal measures of girls' BMI. Yet given these drawbacks, parent weight status, parent physical activity, parent dietary intake, and girls' dietary intake significantly increased the ability to predict girls' change in BMI over girls' initial BMI, explaining a further 11% of variance in girls' change in BMI. In addition, currently used measures of dietary intake (including 24 h recall and FFQ) and physical activity (including questionnaires) are crude and susceptible to problems of reliability and validity[53–55] thus making it difficult to identify associations between dietary intake, physical activity and overweight. The measures in this study are no exception. In this context it is surprising that we were able to identify any significant predictors of girls' change in BMI and the results from this study are likely to underestimate the extent to which child and parent characteristics contribute to children's change in degree of overweight.

The finding that both child and parent characteristics predicted girls' change in BMI is likely to reflect the fact that childhood overweight occurs within a familial context. In this study, parent – child and parent – parent associations were noted within risk factors (eg familial links were identified in weight status and dietary intake), and across risk factors such that parents with higher BMI participated in less activity, enjoyed activity less, and consumed a greater percentage of energy from fat than parents with lower BMI. Although numerous correlations were calculated in this study, these findings cannot be attributed solely to type I error because more than a quarter of the correlations calculated were significant at $P < 0.05$ or $P < 0.01$. In addition, positive associations were identified between mothers' and fathers' and between mothers' and daughters' change in BMI across the same time period. Links between girls' and parents' BMI, and change in BMI, may be explained by a genetic predisposition for weight gain. However, the fact that mothers' and fathers' BMI, and change in BMI, were correlated to at least the same extent as girl – parent pairs highlights the importance of environmental factors. Likewise, it is likely that similarity in girls' and mothers' change in BMI at very different stages of development, when change in BMI is normative for girls but not for mothers, reflects environmental factors to a larger extent than genetic factors. These findings collectively suggest that overweight parents may place their children at particular risk of overweight due to their genetic predisposition for weight gain (which they may pass on to their children) and the eating and activity environment that they create.

Limitations of this study include the measures of physical activity and dietary intake and the characteristics of the sample. The measures of physical activity and dietary intake adopted in this study reflect time and financial constraints, but are nonetheless susceptible to problems of reliability and validity: multiple measures of each risk factor were assessed in an effort to address such problems. While it is difficult to obtain a more appropriate measure of dietary intake, additional research could replicate the results of this study using more sophisticated measures of physical activity. The results for physical activity in particular should be interpreted with caution as girls' and parents' physical activity were assessed using single item questionnaires. Although girls also completed the Children's Physical Activity scale, which is a validated multi-item questionnaire, this measure was assessed at age 7 rather than at age 5. Thus, we direct the reader toward the general pattern of findings in this study rather than specific relationships. Participants in this study were non-Hispanic white girls and their well-educated, middle-income parents, which limits the ability to generalize findings to other income and racial/ethnic groups and to boys. Nevertheless, parents or primary caregivers are likely to be influential in the emergence of characteristics that place children at risk of overweight irrespective of child gender or ethnicity. The specific patterns of influence that place children more or less at risk of overweight, however, are likely to differ for boys and for other racial and ethnic groups and present an interesting possibility for future research. Finally, while this study highlights the importance of the familial context in the etiology of overweight among children, additional research is needed to assess the processes that explain the aggregation of risk factors within the family. Possible explanatory mechanisms may include shared access to the 'family diet', parental modeling of behavior, and family recreation patterns.

In conclusion, the most important finding of this study is the centrality of the familial context in the emergence of factors that place children at risk of overweight and accelerated weight gain. Previous research has identified similarities in parents' and children's BMI, dietary practices, and physical activity. Results from this study showed that risk factors tended to co-occur within the family such that parents who were overweight exercised less, enjoyed activity less, and consumed a greater percentage of their energy intake from fat, thus illustrating that such risk factors cannot be considered as independent risk variables. Likewise, the most effective model predicting change in girls' BMI incorporated not only characteristics particular to girls, but also characteristics of their parents. These results highlight the necessity of taking multiple factors within the familial environment into consideration when assessing predictors of childhood overweight and the futility of designing intervention programs that do not focus on all family members.

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Table 1

Timing and method of assessment of weight status, physical activity and dietary intake variables

Variable	Method of assessment	Assessed at time 1	Assessed at time 2
Weight Status			
Girls' BMI	Directly measured height and weight	X	X
Mothers' BMI	for girls, mothers and fathers	X	X
Fathers' BMI		X	X
Physical activity			
Girls' relative activity	Mothers' reports	X	
Girls' tendency toward activity	Girls' reports on CPA		X
Mothers' frequency of activity	Self-report	X	
Mothers' enjoyment of activity	Self-report	X	
Fathers' frequency of activity	Self-report	X	
Fathers' enjoyment of activity	Self-report	X	
Dietary intake			
Girls' total energy intake	Mothers provided 24 h recall	X	
Girls' percentage fat intake	Mothers provided 24 h recall	X	
Mothers' total energy intake	FFQ	X	
Mothers' percentage fat intake	FFQ	X	
Fathers' total energy intake	FFQ	X	
Fathers' percentage fat intake	FFQ	X	

Note: at time 1 girls were 5-y-old; at time 2 girls were 7-y-old. CPA = Children's Physical Activity questionnaire.

Table 2

Family weight status characteristics

	Time 1		Time 2
Girls			
Mean BMI	15.8 (1.4)		16.5 (2.1)
Mean change in BMI		0.7 (1.1)	
Percentage overweight	16%		19%
Percentage obese	3%		4%
Mothers			
Mean BMI	26.3 (5.6)		27.0 (6.0)
Mean change in BMI		0.7 (1.9)	
Percentage overweight	54%		57%
Percentage obese	18%		23%
Fathers			
Mean BMI	28.0 (4.2)		28.3 (4.2)
Mean change in BMI		0.31 (1.2)	
Percentage overweight	76%		79%
Percentage obese	27%		30%

Note: at time 1 girls were 5-y-old, at time 2 girls were 7-y-old.

Table 3

Hierarchical regression predicting girls' change in BMI from age 5 to 7 y

Variables entered	*P*-value at entry	r^2	Δr^2	*F*-test for Δr^2	d.f.	*P*-value for Δr^2
Step 1: control variables		0.16	0.16	7.46	4	0.0001
Girls' BMI at age 5	0.0001					
Mothers' education	0.51					
Fathers' education	0.95					
Family income	0.77					
Step 2: parent weight status		0.19	0.03	6.53	3	0.09
Family risk of overweight	0.03					
Mothers' change in BMI	0.07					
Fathers' change in BMI	0.13					
Step 3: parent physical activity		0.23	0.04	5.96	4	0.25
Mothers' frequency of activity	0.34					
Fathers' frequency of activity	0.34					
Mothers' enjoyment of activity	0.99					
Fathers' enjoyment of activity	0.08					
Step 4: parent dietary intake		0.29	0.06	12.61	4	0.025
Mothers' energy intake[a]	0.52					
Fathers' energy intake[a]	0.08					
Mothers' percentage fat intake	0.72					
Fathers' percentage fat intake	0.85					
Step 5: girls' physical activity		0.29	0.00	0	2	NS
Girls' activity relative to others	0.81					
Girls' tendency toward activity	0.93					
Step 6: girls' dietary intake		0.32	0.03	4.66	2	0.10
Girls' energy intake[a]	0.70					
Girls' percentage fat intake	0.02					
Final model		0.26	NA	9.27	6	0.0001
Girls' BMI at age 5	0.0001					
Family risk of overweight	0.005					
Mothers' change in BMI	0.05					
Fathers' enjoyment of activity	0.01					
Fathers' energy intake[a]	0.09					
Girls' percentage fat intake	0.01					

[a] Energy intake controls for body weight.

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Table 4

Correlations between weight status, physical activity and dietary intake for girls and parents when girls were 5-y-old

Variable	Weight status 1	2	3	4	Physical activity 5	6	7	8	9	10	Dietary intake 11	12	13	14	15
Weight status															
1 Girls' BMI															
2 Family risk of overweight	0.19^{**}														
3 Moms' BMI	0.14^{*}	0.65^{**}													
4 Dads' BMI	0.21^{**}	0.49^{**}	0.22^{**}												
Physical activity															
5 Girls' relative activity	0.02	−0.09	−0.01	−0.03											
6 Girls' tendency toward activity[a]	−0.11	−0.06	−0.12	0.01	−0.03										
7 Moms' frequency of activity	−0.01	0.00	-0.15^{*}	−0.03	0.09	-0.16^{*}									
8 Moms' enjoyment of activity	−0.10	-0.16^{*}	-0.30^{**}	−0.02	−0.02	−0.03	0.31^{**}								
9 Dads' frequency of activity	−0.03	−0.15	0.08	-0.18^{**}	−0.03	−0.06	0.18^{*}	0.03							
10 Dads' enjoyment of activity	−0.08	−0.11	−0.08	−0.12	−0.02	0.12	0.07	−0.09	0.38^{**}						
Dietary intake															
11 Girls' energy intake[b]	0.00	−0.11	−0.11	0.04	0.04	0.14	−0.08	0.09	0.03	0.05					
12 Girls' percentage fat intake	0.00	0.06	0.06	0.04	−0.04	0.06	-0.20^{**}	-0.25^{**}	0.04	−0.09	0.12				
13 Moms' energy intake[b]	−0.02	−0.01	−0.04	−0.04	−0.01	0.11	0.03	0.24^{**}	0.04	0.02	0.19^{**}	−0.01			
14 Moms' percentage fat intake	0.15^{*}	0.10	0.19^{**}	0.06	0.02	−0.07	-0.20^{**}	-0.21^{**}	-0.18^{**}	−0.09	0.00	0.22^{**}	0.18^{**}		
15 Dads' energy intake[b]	0.03	−0.07	−0.03	−0.06	0.00	−0.07	0.00	−0.01	−0.13	-0.15^{*}	0.16^{*}	0.00	0.19^{**}	0.14	
16 Dads' percentage fat intake	0.07	0.18^{*}	0.08	0.20^{**}	−0.04	−0.07	−0.11	−0.08	-0.26^{**}	-0.16^{*}	−0.04	0.12	−0.08	0.41^{**}	0.02

* *Note: P* < 0.05;

** $P < 0.01$.

[a]Measured using the CPA.

[b]Energy intake controls for body weight.