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Health Consequences of Obesity in Youth: Childhood Predictors of Adult Disease

William H. Dietz, MD, PhD

ABSTRACT. Obesity now affects one in five children in the United States. Discrimination against overweight children begins early in childhood and becomes progressively institutionalized. Because obese children tend to be taller than their nonoverweight peers, they are apt to be viewed as more mature. The inappropriate expectations that result may have an adverse effect on their socialization. Many of the cardiovascular consequences that characterize adult-onset obesity are preceded by abnormalities that begin in childhood. Hyperlipidemia, hypertension, and abnormal glucose tolerance occur with increased frequency in obese children and adolescents. The relationship of cardiovascular risk factors to visceral fat independent of total body fat remains unclear. Sleep apnea, pseudotumor cerebri, and Blount's disease represent major sources of morbidity for which rapid and sustained weight reduction is essential. Although several periods of increased risk appear in childhood, it is not clear whether obesity with onset early in childhood carries a greater risk of adult morbidity and mortality.

Obesity is now the most prevalent nutritional disease of children and adolescents in the United States. Although obesity-associated morbidities occur more frequently in adults, significant consequences of obesity as well as the antecedents of adult disease occur in obese children and adolescents. In this review, I consider the adverse effects of obesity in children and adolescents and attempt to outline areas for future research. I refer to obesity as a body mass index greater than the 95th percentile for children of the same age and gender. *Pediatrics* **1998;101:518–525;** *obesity, children, adolescents, consequences, comorbidity.*

ABBREVIATIONS. SES, socioeconomic status; LDL, low-density lipoprotein; NIDDM, noninsulin-dependent diabetes mellitus; BMI, body mass index; PCOD, polycystic ovary disease.

The most widespread consequences of childhood obesity are psychosocial. Obese children become targets of early and systematic discrimination. As they mature, the effects of discrimination become more culture-bound and insidious. An important sequel of the widespread discrimination and cultural preoccupation with thinness is con-

cern about weight expressed at young ages. The concern becomes part of the culture and is most pronounced among female dancers and gymnasts.

Several studies have shown clearly that children at a young age are sensitized to obesity and have begun to incorporate cultural preferences for thinness. Preference tests have demonstrated that 10- to 11-year-old boys and girls prefer as friends other children with a wide variety of handicaps to children who are overweight.[1] Overweight children are ranked lowest as those with whom they would like to be friends. Furthermore, children ranging in age from 6 to 10 years already associate obesity with a variety of negative characteristics such as laziness and sloppiness.[2] One potential consequence of such discrimination is that overweight children may choose as friends other children who are younger than they and who may be less inclined to discriminate, less judgmental about the older child's weight, or more eager to play with the overweight child because he or she is older.

Despite the negative connotations of obesity, overweight young children do not have a negative self-image or low self-esteem.[3,4] However, obese adolescents develop a negative self-image that appears to persist into adulthood.[5] One explanation for this apparent discrepancy between children and adolescents is that self-image is derived from parental messages in young children and increasingly from the culture as children become adolescents.

The effect of psychosocial factors within the family on the origins of obesity and its psychosocial consequences has received limited attention in the United States. Several Swedish studies have demonstrated an association of parental neglect and obesity.[6] Furthermore, an increased prevalence of behavioral and learning difficulties has been observed among children who are gaining weight rapidly.[7] Whether learning difficulties reflect the subtle effects of sleep apnea or psychosocial problems within families requires additional studies. The psychological difficulties present in obese children may reflect maternal psychopathology or socioeconomic status (SES) rather than problems that result from the child's obesity.[8] Demonstration of the causal pathways that link obesity to psychosocial difficulties requires careful prospective studies.

EFFECT OF BODY SIZE ON SOCIALIZATION

Early maturation is associated with an increase in body fatness. Furthermore, children who mature early tend to have lower self-esteem.[9] To date, the effects of increased fatness on self-esteem have not been distinguished from the effects of early maturation. The effects of the two should be similar. White girls who develop a negative body image early in adolescence appear at greater risk for development of subsequent eating disorders.[10] No studies have examined these associations in other groups, such as black children.

The relationship of the effects of obesity in childhood on how adults relate to children and the consequent effects of such treatment on psychosocial development have not been examined carefully. As discussed in greater detail below, overweight children often are taller than their nonoverweight peers. Adults who do not know the age of overweight children often mistake them for older than their chronologic age and treat them accordingly. The expectation that a child can perform or converse at a level that is older than his or her chronologic age may lead to frustration on the part of the child or a sense of failure that such expectations cannot be fulfilled. No one has examined carefully the potential adverse effects of such treatment on the overweight child's capacity for interaction or socialization. One potential consequence is that the inadequacy the overweight child feels in response to inappropriate expectations of adults outside the family may lead the child to become less venturesome with respect to outside relationships with adults, increasingly dependent on family, and therefore increasingly isolated.

Social Consequences of Obesity in Young Adults Obese as Adolescents

At least one early study demonstrated that among girls who applied to an elite group of New England colleges, acceptance rates were lower among those who were overweight than among nonoverweight peers with comparable credentials.[11] The extent to which acceptance rates affect long-term achievement and income is not clear. Nonetheless, this study emphasizes the insidious expression of weight prejudice that is clearly operable when an overweight child reaches adolescence.

As early as 1960, Garn and Clark[12] demonstrated an association of obesity with SES. Among men, the relationship of obesity to SES was direct throughout the range of SES; in women, the association of SES with obesity was direct among young girls but inverse among women. Subsequent studies have replicated Garn and Clark's findings.[13] Because the early studies were cross-sectional, it was not possible to determine whether the inverse association between SES and obesity among women was a cause or a consequence of obesity.

The National Longitudinal Survey of Youth offered an opportunity to examine the effects of obesity in adolescence on social achievement in early adulthood.[14] The National Longitudinal Survey of Youth surveyed ~10 000 individuals 16 to 24 years of age. Among women who were obese in late adolescence and early adulthood, the number of years of advanced education completed, the family income, and the rates of marriage were significantly lower than rates among women who were not obese at the same ages. Furthermore, rates of poverty were higher. No such relationships were observed for men. The persistence of the effects of obesity on these areas of social performance, even when controlled for the income and education of the family of origin, suggested that obesity was a cause rather than a consequence of SES. Similar data have been published from a British cohort of 23-year-old men and women.[15] Interestingly, the magnitude of the effect of obesity on social indices was comparable.

Comparison of the performance of obese female adolescents and young adults with the performance

of women with a variety of other chronic conditions demonstrated that only obesity exerted an adverse effect on these indicators.[14] These data suggest that obesity may be the worst socioeconomic handicap that women who were obese adolescents can suffer.

Preoccupation With Weight

In adults, eating disorders such as binge-eating disorder occur with increased prevalence among overweight women and substantially reduce the response to therapy.[16] The prevalence of eating disorders in children or adolescents has received less intensive investigation. Nonetheless, the available evidence suggests that both eating disorders and weight preoccupation exist among white children and adolescents, particularly females, and may impair the normal regulation of food intake.

For example, a cross-sectional study of 7- to 13-year-old children demonstrated that almost half were concerned about their weight, more than one third had already tried to lose weight, and almost one tenth manifested responses consistent with anorexia nervosa.[17] As expected, more girls than boys were preoccupied with weight, and concerns about weight increased with age. Few studies of ethnic differences in weight preoccupation have been performed. Although obese adult black women are less preoccupied with the social consequences of their obesity,[18] more black than white preadolescent girls are chronic dieters.[19]

Among older morbidly obese girls, unequivocal binge-eating disorder occurred in ~30% of patients,[20] which is comparable to the prevalence of binge-eating disorder among obese adult women.[16] However, the prevalence of binge-eating disorder among obese adolescents has not been compared with its prevalence in the nonobese adolescent population. Whether abnormal eating behaviors in adolescents affect the outcome of weight-reduction therapy remains unclear.

Few estimates of these behaviors have been made in the general population. Among almost 2000 adolescent high school students, disordered eating appeared to occur in ~2% of all students, but 11% of girls were classified as emotional eaters. Bingeing and feeling out of control about food were the principal abnormalities described.[21] The relationship of early abnormal eating behaviors to subsequent changes in body weight or to development of frank binge-eating disorders has not been studied carefully.

Psychosocial consequences represent the most prevalent morbidity associated with obesity. As indicated above, psychosocial effects may both contribute to and result from obesity. Longitudinal studies are essential to distinguish cause and effect. Furthermore, the effects of psychosocial difficulties of either parents or children on the outcome of therapy suggest that early identification and specific treatment for this subset of patients may be required. Despite the widespread preoccupation with weight and the concurrent increase in the prevalence of obesity, no studies of children have linked restrictive eating in preadolescents either to obesity or to eating disorders in adolescence or adulthood, or compared the prevalence of eating disorders in overweight and nonoverweight children or adolescents. Valid and reliable measures of eating behaviors are essential to clarify this problem.

Because greater acceptance of increased body weight exists among black women, and because eating disorders occur less frequently among black women and girls, additional studies of black females may help identify cultural norms that will lead to interventions that do not heighten concern about weight.

COMMON MEDICAL CONSEQUENCES OF OBESITY

Growth

Overweight children tend to be taller, have advanced bone ages, and mature earlier than nonoverweight children.[12] Longitudinal studies of children who became overweight have shown that height gain accelerates or follows shortly after excessive weight gain.[22]

Early maturation, determined by bone age, peak height velocity, and age of menarche, is associated with increased fatness in adulthood[23,24] as well as with an increase in the truncal distribution of fat in women.[25] In these studies, early maturation was associated with an increase in fatness at the same chronologic age, suggesting that those individuals who mature early were already fatter at the time maturation began. Nonetheless, even when it was adjusted for greater fatness at the same chronologic age, early maturation was still associated with increased fatness[24] in later life. As indicated above,[10] early maturation also may increase the likelihood of eating disorders. However, in a study characterized by limited measurements, height velocity was not linked to subsequent mortality, although both prepubertal and postpubertal weights were related directly to death rates.[26]

These findings suggest that early maturation may represent an additional biologic determinant of obesity and perhaps its complications that operate at puberty. The determinants of the increased body fatness and the increased truncal deposition of fat remain uncertain. Furthermore, the long-term effects of early maturation on development of binge-eating disorder or on the comorbidity of obesity have not yet been evaluated carefully.

One of the most controversial suggestions was that the timing of menarche depended on a critical mass of body fat.[27] The suggestion that a critical level of fatness was necessary for both the onset and maintenance of menstruation provided an attractive explanation for the timing of the cessation and resumption of menses in women with anorexia nervosa before and after treatment.[28] The importance of a critical level of body fat for menstrual function was subsequently disputed.[29,30] However, the recent observation that mice treated with leptin appear fertile earlier than untreated mice suggests that fatness may affect fertility through an effect on leptin concentrations.[31] Additional studies that link maturational timing, leptin concentrations, and subsequent obesity

may offer insights into the potential mechanisms that link these phenomena.

Hyperlipidemia

Increased blood lipids occur among obese children and adolescents. The characteristic pattern observed consists of elevated serum low-density lipoprotein (LDL)–cholesterol and triglycerides and lowered high-density lipoprotein–cholesterol levels.[32] Central fat distribution, perhaps through its effect on insulin levels, appears to be an important mediating variable between lipid levels and obesity.[33–36] Potential mechanisms are similar to those operative in adults. Increased free fatty acids produced by increased lipolysis by visceral adipocytes and hyperinsulinemia may promote hepatic triglyceride and LDL–cholesterol synthesis. Weight reduction clearly has a beneficial effect on these cardiovascular risk factors and may have a greater effect among girls with abdominal obesity.[37]

These studies, like those summarized below that have examined glucose and insulin metabolism, rarely have included simultaneous sophisticated measures of body composition and fat distribution. Instead, most studies have relied on skinfolds to calculate total body fat or on waist-to-hip ratios or extremity-to-trunk skinfold ratios as indices of fat distribution. However, neither waist-to-hip ratios nor skinfold ratios provide valid measures of intra-abdominal fat.[38] The degree of imprecision associated with anthropometric estimates of total body or visceral fat is considerable and may confound many of the relationships sought. Misclassification or bias may produce spurious positive relationships, weaken significant associations, or lead to negative findings when significant associations exist. When visceral fat was measured directly by magnetic resonance imaging, an equally precise measure of body fat was not included.[32,36] Therefore, the associations of morbidity with visceral fat may not be independent of total body fat. Because hyperlipidemia is common among overweight children and adolescents, a fasting lipoprotein profile should be obtained routinely.

Glucose Intolerance

Because obesity is tightly linked to diabetes in animal models of obesity, it is not surprising that glucose intolerance and diabetes are among the most frequent morbid effects of adult obesity.[39] Although few data are available about the frequency of glucose intolerance among obese children and adolescents, the recent observation that noninsulin-dependent diabetes mellitus (NIDDM) accounted for one third of all new cases of diabetes in Cincinnati in 1994[40] suggests that the morbid effects of the recent increases in the prevalence of obesity have already begun. The incidence of NIDDM among adolescents in Cincinnati appears to have increased 10-fold since 1982. The mean body mass index (BMI) was 37 among the newly diagnosed NIDDM adolescent patients.

The mechanism by which obesity causes NIDDM in adolescents may be similar to that observed in adults. Visceral fat, measured by magnetic resonance imaging, appears related directly to basal insulin secretion, stimulated insulin secretion, and insulin resistance.[36] Unfortunately, in both this and other reports,[32,37] total body fat and visceral fat have not been measured simultaneously. Therefore, it is impossible to determine whether visceral fat has an effect on insulin and glucose metabolism that is independent of the effects of total body fat. The association of insulin resistance with puberty and the deposition of visceral fat may identify puberty as a relevant period in which to examine causal linkages between adiposity, the behaviors that lead to fat deposition, and insulin resistance.

Acanthosis nigricans describes increased thickness and pigmentation of skin in intertriginous folds; it is associated with glucose intolerance in children and adolescents.[41] The prevalence of acanthosis nigricans among obese patients may be as high as 25%,[42] consistent with my own consecutive estimates from observations of 100 obese children.

Based on the contribution of obesity to diabetes in adults and the prevalence of acanthosis nigricans in overweight children and adolescents, measures of fasting insulin and glucose should be included routinely as part of the medical examination.

Hepatic Steatosis and Cholelithiasis

High concentrations of liver enzymes represent a frequent obesity-associated finding in children and adolescents. In a large Japanese series, >10% of all obese children seen in a general obesity clinic setting had modest increases of liver enzymes, frequently associated with fatty liver, fatty hepatitis, fatty fibrosis, or cirrhosis.[43] Hyperinsulinemia also may play a role in the pathophysiology of steatohepatitis.[44] Weight reduction induces a normalization of hepatic enzymes.[45]

Cholelithiasis occurs with increased frequency among obese adults[46] and may occur even more frequently with weight reduction.[47] Increased cholesterol synthesis[48] and cholesterol saturation of bile[49] occurs in obesity. Although gallstones are a less frequent occurrence among obese children and adolescents, almost 50% of cases of cholecystitis in adolescents may be associated with obesity.[50] Furthermore, as in adults, cholecystitis in adolescents may be associated with weight reduction.[50]

LESS COMMON MEDICAL CONSEQUENCES OF OBESITY

Hypertension

Hypertension occurs with low frequency in children. In the best community-based study of this problem, only 1% of >6600 school children 5 to 18 years of age had persistently elevated blood pressure.[51] However, almost 60% of the children with persistently elevated blood pressure had relative weights >120% of the median for their sex, height, and age. Based on the estimated prevalence of obesity in this sample,[52] persistently elevated blood pressure occurred approximately nine times more frequently among the obese. Correlations of childhood systolic pressure with systolic pressure observed in

26- to 30-year-olds ranged from $r = .27$ to $r = .39$; correlations of childhood diastolic pressure with adult diastolic pressure ranged from $r = .24$ to $r = .31$.[53] Childhood blood pressure and change in BMI were consistently the two most powerful predictors of adult blood pressure across all ages and both genders.[53] Although only limited follow-up is available regarding the long-term consequences of obesity-associated hypertension, substantial morbidity has been observed less than a decade after the original assessment, such as hypertensive heart disease or cerebral hemorrhage.[54]

Hypertension appears to be another consequence of hyperinsulinemia.[55–57] Hyperinsulinemia produces a significant decrease in renal sodium retention in both obese and nonobese adolescents,[58] and dietary therapy, particularly when it is accompanied by exercise, effectively decreases blood pressure.[59]

Pseudotumor Cerebri

Pseudotumor cerebri is a rare disorder of childhood and adolescence. The disease is characterized by increased intracranial pressure. Pseudotumor cerebri presents with headaches and may lead to severe visual impairment or blindness.[60] Papilledema usually occurs at some time during the course of the illness. Most cases occur before adolescence.[60,61] Up to 50% of children who present with this syndrome may be obese, but the onset of symptoms does not appear to correlate with weight gain.[60] The potential for visual impairment indicates the need for aggressive treatment of obesity in patients with pseudotumor cerebri.

Sleep Apnea

Sleep apnea is another consequence of childhood obesity for which aggressive therapy is warranted. The only published estimate of the prevalence of sleep apnea among obese children and adolescents suggests that sleep apnea occurs in ~7% of obese children.[62] However, one third of children whose body weight was >150% of ideal body weight with a history of breathing difficulties during sleep were found to have apnea.[62] Neither the degree of obesity nor any question about a history of breathing difficulties during sleep predicted the severity of the obstruction. Neurocognitive deficits are common among obese children with sleep apnea.[63] In two of the more severe cases, a tonsillectomy and adenoidectomy in one case, and weight reduction in a second, improved the sleep apnea substantially. The relationship between sleep apnea and the obesity hypoventilation syndrome remains unclear. Hypoventilation may represent a long-term consequence as well as a cause of sleep apnea. The high mortality reported among published cases of the obesity hypoventilation syndrome[64] suggests that aggressive therapy is warranted for obese children with this syndrome.

Orthopedic Complications

Because the tensile strength of bone and cartilage did not evolve to carry substantial quantities of excess weight, a variety of orthopedic complications accompany childhood and adolescent obesity. Among young children, excess weight can lead to bowing of the tibia and femurs analogous to the bowing that occurs when downward pressure is exerted on a flexible stick. The resultant overgrowth of the medial aspect of the proximal tibial metaphysis is known as Blount disease. Although the prevalence of Blount disease is low, approximately two thirds of patients may be obese.[65] Slipped capital femoral epiphysis results from the effect of increased weight on the cartilaginous growth plate of the hip.[66] Between 30% and 50% of patients with slipped capital femoral epiphysis are overweight.[67,68] Because Blount disease may recur and because there is increased risk for development of bilateral slipped capital femoral epiphysis if the other has already slipped, prompt and sustained weight reduction is essential.

Polycystic Ovary Disease (PCOD)

Among adult women who considered themselves normal and who had not sought treatment for menstrual irregularities, infertility, or hirsutism, 14% had polycystic ovaries diagnosed by ultrasonography.[69] Up to 30% of women with PCOD may be obese.[70] Hyperandrogenism and hyperinsulinemia frequently accompany the syndrome.[70,71] Obesity is frequently associated with PCOD, but the pathophysiology is complex.[72,73] Menstrual abnormalities may begin at adolescence.[74] An association of obesity, acanthosis nigricans, insulin resistance, and hyperandrogenemia has been identified in adolescent patients.[41]

The process of adolescent maturation appears ideally suited for the study of the relative contribution of body fatness, fat distribution, hyperandrogenemia, hyperinsulinemia, and PCOD. Nonetheless, most studies of this problem have been cross-sectional rather than longitudinal. Furthermore, the contribution of obesity and hyperinsulinemia in adolescents to the prevalence of PCOD in adults has not been evaluated definitively.

PERSISTENCE OF OBESITY AND ITS ASSOCIATED RISK FACTORS

Although critical periods appear to exist for the onset of obesity in childhood,[75] the relative contribution of obesity that begins in the prenatal period, the period of adiposity rebound, or in adolescence to the prevalence of adult obesity and its associated complications remains unclear. Odds ratios represent the most useful clinical expression of the likelihood that obesity will persist. In the Fels sample, the odds ratio for obesity at age 35 years increased from ~2 for males and females who were obese between the ages of 1 and 6 years to 5 to 10 for children who were obese at ages 10 to 14 years. The odds ratios for subsequent obesity at ages 15 to 18 years ranged from 8 to 57 for males and from 6 to 35 for females.[76] In other studies that tracked obesity, correlation coefficients have ranged from $r = .54$ to .72 depending on the group sampled.[77,78] However, these correlation coefficients may be low because of the inclusion of a broad age range.[78] Among the studies that have examined the effects of childhood-onset obesity on

adult obesity, at least one has shown that the prevalence of morbid obesity in adults appears to occur with a greater prevalence among individuals who were obese as adolescents.[79] However, only 15% to 30% of obesity in adults[80,81] is a result of obesity that was present in childhood or adolescence.

Studies of the tracking of obesity have rarely examined the effect of the first incidence of obesity on the likelihood that it will persist. Several studies in progress should clarify this problem. However, the finding that there was an increased likelihood of persistence of obesity into adulthood among individuals who first became obese at the time of adiposity rebound or at adolescence suggests that this approach may clarify the relative contribution of obesity at different ages of onset to the prevalence of adult obesity and its consequences.

Few studies have examined the long-term effects of childhood or adolescent obesity on adult morbidity or mortality. One long-term follow-up study demonstrated that mortality was increased among men but not women who were obese during adolescence.[82] All-cause mortality, deaths from coronary heart disease, atherosclerotic cerebrovascular disease, and colon cancer were increased. Among both men and women, the occurrence of coronary heart disease, atherosclerosis, and diabetes was also increased. Colorectal cancer and gout were increased among men, and arthritis was increased among women. Because no increase in mortality has been attributed to growth rates per se,[23] these findings suggest that adolescent obesity rather than the rapid growth rates that accompany it may be responsible for the excess mortality in adulthood. However, the study cited[23] included relatively few growth points. Therefore, growth velocity throughout childhood and growth velocity at specific intervals in childhood still may act as a contributing factor.

The change in body fat that occurs in adolescence appears a reasonable mediator that entrains the excess morbidity and mortality that occurs in later adulthood among obese adolescents. In girls, adolescence represents a time of rapid fat accretion. Likewise, body fat redistributes from the periphery to a more central distribution in both sexes, although abdominal fat accumulation is more pronounced in males than in females. Therefore, the increases in body fat that occur in adolescent girls may be compounded by the development of obesity at this time. Among boys, the development of obesity during adolescence may predispose to increased visceral fat accumulation.

Multiple studies of children and adolescents have demonstrated clearly that systolic blood pressure, total and LDL–cholesterol, plasma insulin, and obesity tend to cluster.[83,84] Furthermore, these variables tend to track with age. A high likelihood exists that cardiovascular risk factors present in obese children or adolescents will persist into young adulthood. Data from existing studies could be explored further to examine the relationship of age of onset to the development of later morbidity.

Several important problems remain. First, it is unclear whether the risk of obesity-associated morbidities varies with either the age of onset, severity of obesity, its duration, or factors responsible for its onset. Although early maturation appears related to the development of obesity at the period of adiposity rebound in both sexes and at the time of adolescence in girls, the biological or behavioral mechanisms that are responsible remain uncertain. Second, one long-term follow-up of individuals who were obese in adolescence demonstrated that the likelihood of cardiovascular disease appeared independent of the effect of adolescent obesity on adult weight status.[82] No long-term studies indicate that weight reduction after adolescence reduces the risk of adult morbidity. The development of the hyperinsulinemia that may constitute a pathophysiologic link between obesity and its several cardiovascular consequences remains unclear. As indicated previously, the independent effects of total body fat and visceral fat on cardiovascular risk have not been evaluated adequately. Furthermore, no prospective studies have linked the development of obesity and increased visceral adiposity to cardiovascular risk factors. Studies of this type appear to be essential.

CONCLUSION

Several of the obesity-associated morbidities in children and adolescents require urgent and aggressive therapy. Furthermore, as severely overweight children and adolescents become more common, the risks of weight-related complications in adulthood will increase. Nonetheless, no consensus exists to indicate how extreme overweight in children and adolescents should be treated.

Many of the complications associated with childhood and adolescent obesity would benefit from longitudinal studies to clarify cause and effect. These complications include psychosocial difficulties, eating disorders, and the effect of inappropriate expectations of obese children whose growth is increased. Longitudinal studies that include simultaneous measures of ethnicity, cardiovascular risk factors, visceral fat, and the factors that control the quantity and location of fat deposition throughout childhood and adolescence are essential to distinguish the effects of total and regional fat deposition on cardiovascular risk. The latter is particularly important to determine whether age of onset of obesity has differential effects on the persistence, morbidity, and mortality of obesity. The same studies might also help clarify the importance of a variety of behaviors that covary with obesity, such as smoking, alcohol use, or inactivity, and influence the central deposition of body fat independent of their influence on total body fat. Based on the studies performed to date, it is not clear whether obesity alone or the behaviors that generate obesity are more important determinants of obesity and its complications.

Finally, as more decisions about the allocation of resources are based on cost-effectiveness, outcome studies of the treatment of childhood and adolescent obesity that examine the effect of treatment on adult disease should be accorded a high priority. The outcome of greatest interest is weight adjusted for height. The success of therapy instituted at different

ages among children with and without sequelae of obesity has not been evaluated. Most of the adverse effects of obesity are rare in children but common in adults. No study has yet examined the future morbidity of overweight children who lose weight and subsequently gain weight in adulthood. Whether obesity present in childhood or whether treatment of obesity in childhood independent of its effects on weight has an effect on health or psychosocial function therefore remains uncertain.

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The Physiology of Body Weight Regulation: Relevance to the Etiology of Obesity in Children

Michael Rosenbaum, MD, and Rudolph L. Leibel, MD

ABSTRACT. The prevalence of obesity in children and adults in the United States has increased by more than 30% over the past decade. Recent studies of the physiology and molecular genetics of obesity in humans have provided evidence that body weight (fat) is regulated. Some of the genes encoding the molecular components of this regulatory system have been isolated from rodents. The increasing prevalence of obesity in the United States apparently represents the interaction of these genes with an environment that encourages a sedentary lifestyle and consumption of calories. The rapid increase in the prevalence of obesity emphasizes the role of environmental factors, because genetic changes could not occur at this rate. Thus, understanding of the relevant genes and how their effects are mediated by environment and development should lead to more effective prophylaxis and therapy of obesity. Although no clear environmental factors have been identified as causative of obesity, the rapid increases in the prevalence of obesity and the seeming voluntary immutability of adult body fatness can be taken as tacit evidence that the pediatric environment can be altered in a way that affects adult body weight. *Pediatrics* 1998;101:525–539; *obesity, genetics, energy metabolism, body weight regulation.*

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ABBREVIATIONS. NHANES, National Health and Nutrition Examination Surveys; C/EBP, CCAAT-enhancer binding protein; BMI, body mass index; CNS, central nervous system; ASP, agouti signaling protein; MCH, melanin-concentrating hormone; VMH, ventromedial hypothalamus; LH, lateral hypothalamus; NPY, neuropeptide Y; PVN, paraventricular nucleus.

Storage of excess calories as fat must ultimately result from a net positive energy balance (energy intake greater than energy expenditure) over time. Thus, the physiologic determinants of body composition are 1) energy intake, 2) energy output, and 3) partitioning of energy stores as fat, carbohydrate, and protein. Many physiologic systems (endocrine, gastrointestinal, central nervous, peripheral nervous, and cardiovascular) affect these functions. Small changes in any of these determinants can, over time, result in substantial changes in body weight.

Health Consequences of Obesity in Youth: Childhood Predictors of Adult Disease
William H. Dietz
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