AMERICAN COLLEGE of SPORTS MEDICINE℠

Roundtable Discussion

Physical activity, genetic, and nutritional considerations in childhood weight management

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Children's Exercise & Nutrition Centre, McMaster University, Hamilton, Ontario, CANADA; Departments of Medicine & Psychiatry, Baylor College of Medicine, Houston, TX; Physical Activity Science Laboratory, Universite Laval, Sainte-Foy, Quebec, CANADA; Yale Center for Eating and Weight Disorders, Yale University, New Haven, CT; Department of Pediatrics, Tuft's University, Boston, MA; Clinical Diabetes and Nutrition Section, National Institute of Diabetes and Digestive and Kidney Diseases, NIH, Phoenix, AZ; Nutrition Education & Research Program, University of Nevada, Reno, NV; Human Nutrition Unit, Institute of Nutrition of Central America and Panama, Guatemala City, GUATEMALA

ABSTRACT

BAR-OR, O., J. FOREYT, C. BOUCHARD, K. D. BROWNELL, W. H. DIETZ, E. RAVUSSIN, A. D. SALBE, S. SCHWENGER, S. ST. JEOR, and B. TORUN. Physical activity, genetic, and nutritional considerations in childhood weight management. *Med. Sci. Sports Exerc.*, Vol. 30, No. 1, pp. 2–10, 1998. Juvenile obesity is a serious, increasingly prevalent problem in technologically developed societies. Almost one-quarter of U.S. children are now obese, a dramatic increase of over 20% in the past decade. It is intriguing that the increase in prevalence has been occurring while overall fat consumption has been declining. Body mass and composition are influenced by genetic factors, but the actual heritability of juvenile obesity is not known. A low physical activity (PA) is characteristic of obese children and adolescents, and it may be one cause of juvenile obesity. There is little evidence, however, that overall energy expenditure is low among the obese. There is a strong association between the prevalence of obesity and the extent of TV viewing. Enhanced PA can reduce body fat and blood pressure and improve lipoprotein profile in obese individuals. Its effect on body composition, however, is slower than with low-calorie diets. The three main dietary approaches are: protein sparing modified fast, balanced hypocaloric diets, and comprehensive behavioral lifestyle programs. To achieve long-standing control of overweight, one should combine changes in eating and activity patterns, using behavior modification techniques. However, the onus is also on society to reduce incentives for a sedentary lifestyle and over-consumption of food. To address the key issues related to childhood weight management, the American College of Sports Medicine convened a Scientific Roundtable in Indianapolis.

BEHAVIOR MODIFICATION, DIET, ENERGY EXPENDITURE, EXERCISE, HEREDITY, OBESITY, PREVENTION, PUBLIC POLICY, TV VIEWING, UNDERNUTRITION

Childhood and adolescence obesity (henceforward, juvenile obesity) is a serious, increasingly prevalent problem. Almost one-quarter of children in the United States are currently obese, a dramatic increase of over 20% in the past decade (60). Dietary data from the United States suggest that this increased prevalence occurred despite a decrease in overall fat consumption and little change in caloric intake. It is therefore conceivable that energy expenditure has decreased during that period.

Juvenile obesity increases the risk of adult obesity. Forty percent of obese 7-yr-old children and 70% of obese adolescents become obese adults (35,41,54). The obese child is at increased risk for hypertension, hypercholesterolemia, hyperinsulinemia, decreased release of growth hormone, respiratory disorders, and orthopedic problems. The obese child suffers both psychologically and socially. Self-esteem and self-image are often damaged by ridicule and scorn.

The prevention and treatment of juvenile obesity through effective weight management are thus of enormous public health importance. Early identification of children at risk, prevention strategies, public policy and public health approaches, and early intervention may be the most effective means of addressing the primary causes of obesity, i.e., poor diet and a lack of physical activity.

National objectives for health promotion set forth by Healthy People 2000 (63) include seven initiatives which relate directly to improving weight management in children: 1) reduce or maintain the prevalence of overweight in the

U.S. at <15%; 2) increase the adoption of sound dietary practices and regular physical activity to 50% of overweight children; 3) increase to 90% the proportion of school lunch and breakfast service and child care food services with menus that are consistent with the Dietary Guidelines for Americans (61); 4) increase to 75% the proportion of schools that provide nutrition education as part of a comprehensive health education program from preschool to 12th grade; 5) increase to 30% those who engage regularly in light to moderate physical activity for at least 30 min·d^{-1}; 6) increase to 75% those children who engage in vigorous physical activity that promotes the development and maintenance of cardiorespiratory fitness three or more days per week for 20 or more minutes per occasion; and 7) reduce to 15% those who engage in no leisure-time physical activity. The major objective of these initiatives is to "increase the span of healthy life" most effectively and efficiently.

Unfortunately, few of these goals for the year 2000 will be attained at our current pace. The prevalence of obesity in children is on the rise, less than 50% of children engage in routine physical activity, less than 36% of schools offer physical education classes, sedentary activity has increased (TV watching averaging 24 h·wk^{-1}) and as many as 45% of children snack on high fat, caloric-dense foods at least twice per day (39). This, indeed, is a sad commentary on how the overall health and weight of our children are being directly affected by adverse practices, environmental influences, and lack of educational programming.

Likewise, in a recent report (64), the U.S. Surgeon-General states that "the prevalence of vigorous physical activity among young people falls short of the Healthy People 2000 goal of 75%" (p. 192). Nor have these goals been met for light to moderate physical activity (p. 196). The goals set for reduction of inactivity among young people have been "met for adolescents overall, but not for black females or young adults" (p.189).

The American College of Sports Medicine (ACSM) convened a Scientific Roundtable with the sponsorship of the National Dairy Council and the Sugar Association. The Roundtable met at the ACSM Center on July 16th and 17th, 1996. Its goals were to examine the roles of heredity, physical activity, and nutrition in juvenile obesity and weight management, and to suggest the most promising strategies for reversing the growing prevalence of obesity in our nation's youth. However, weight control programs should not compromise a person's health. Preoccupation with weight reduction may induce aberrant eating and activity behaviors, which may result in undernutrition. Another aim of the Roundtable was therefore to outline the effects of undernutrition on children's physical activity and fitness.

HEREDITY AND JUVENILE OBESITY

Obesity is a complex multifactorial trait that evolves under the interaction of influences from the social, behavioral, physiological, metabolic, cellular, and molecular domains. Segregation of the genes cannot be easily detected in familial or pedigree studies and whatever the influences of these genes, they are attenuated or exacerbated by nongenetic factors. In addition, it is likely that body fat content is also modulated over one's lifetime by various gene-environment interactions. The outcomes of these interactions may vary among individuals because their sensitivity to environmental exposures or to lifestyles varies because of genetic individuality. Among environmental factors one may include dietary fat, energy intake, level of habitual physical activity, smoking, alcohol intake, and others. Moreover, gene-gene interactions need to be considered, but little research bearing directly on this topic has been reported so far.

Heritability Level

The level of heritability has been considered in a large number of twin, adoption, and family studies. The level of heritability is simply the fraction of the population variation in a trait (e.g., BMI) that can be explained by genetic transmission. Results obtained by a good number of investigators indicate that the heritability level estimates depend on how the study was conducted and on the kinds of relatives upon which they were based. Recent studies incorporating individuals with a wide range of BMI together with information obtained on their parents, siblings, and spouses suggest that the genetic contribution to obesity may be ~25–40% of the individual differences in body mass or body fat (8). It has been suggested that the heritability level increases from birth to puberty and reaches its maximum at biological maturity. It seems also that the heritability of BMI decreases after middle age.

The Risk of Becoming Obese

A number of studies have reported that obese children frequently had obese parents. In about 30% of the cases, both parents of obese children are obese, with a range in frequency of about 5 to 45%. It has also been estimated that about 25–35% of the cases of obesity occur in families with normal weight parents despite the fact that the risk of becoming obese is higher if one has obese parents. The level of risk (the so-called "R value") for a first-degree relative of an overweight, a moderately obese or a severely obese person in comparison with the population prevalence of the condition reaches about 2 to 3 (1). However, obese children and adolescents who are in the upper decile of the distribution have a much greater risk of being obese as adults (35).

The Single Gene Hypothesis

It is commonly observed that severely or morbidly obese persons are, on the average, about 10–12 BMI units heavier than their parents, brothers, or sisters. Several studies have reported that a single major gene for high body mass was segregating from the parents to their children. However, a few studies did not find support for Mendelian transmission unless age and/or gender variations in the major gene were taken into account. From this small body of data, the trend seems to be for a major recessive gene accounting for about

20–25% of the variance, but with age-associated effects, with a gene frequency of about 0.2–0.3. These results must be viewed with great caution as they are based only on the unmeasured genotype approach and the gene(s) has(have) not been identified yet (8).

PHYSICAL ACTIVITY AND ENERGY EXPENDITURE IN JUVENILE OBESITY

Inactivity and Overweight

Interest in the relationship of reduced activity to obesity has been heightened by recent observations which suggest that, despite reductions in dietary fat, the prevalence of obesity in children and adolescents in the United States has continued to increase. Because 30% of the money spent on food is spent on items consumed outside the home, and because the fat and calorie contributions to the total intake of food consumed outside the home remain uncertain, the role of diet in the genesis of obesity cannot be entirely dismissed. Nonetheless, reduced activity remains a prominent potential source of energy imbalance. Although inactivity infers a level of energy expenditure close to resting metabolic rate, inactivity may induce obesity through its association with other behaviors that promote obesity rather than merely through a reduction in energy expenditure. In children (67) and adults (14), the effect of inactivity on the prevalence of obesity appears independent of the effects of more vigorous activity.

Television viewing constitutes the most prevalent sedentary behavior among children and adolescents in the United States. As shown over a decade ago (17), and more recently confirmed (34), obesity is directly related to the number of hours spent watching television. Although television viewing is associated with reduced energy expenditure, increased consumption of foods while watching television, and the increased consumption of foods advertised on television, may be as important as reduced activity in the genesis of obesity. These data are consistent with other observations that suggest that sedentary behavior covaries with other behaviors such as smoking, fat consumption, and alcohol consumption (22,37). They also suggest that the effects of inactivity on obesity may be related to the covariance of inactivity with other behaviors rather than the effects of reduced energy expenditure alone.

Limited opportunities for outdoor play and interaction may also contribute to inactivity. These factors include:

- Safety (including traffic)
- Reduced family size
- Children being driven to school
- Urbanization: fenced-in backyards
- Budget restraints in schools: elimination of physical education classes
- Limited funding of community (city, county, etc.) programs
- Liability and insurance issues in schools limit after-hours use of facilities by community
- Increased technology: computer games

Energy Expenditure and Overweight

Methods to assess energy expenditure in a free-living environment include heart rate monitoring, time-and-motion-techniques (direct observation, activity diaries, or recall interviews) with conversions for the energy cost of specific activities, and doubly labeled water ($^2H_2{}^{18}O$, DLW). The DLW method is based on the principle that whereas $^2H_2$ can only leave the body as water, ^{18}O can be eliminated as either water or $C^{18}O_2$ (48). A comparison of the disappearance rates of the two isotopes over a 7-d period allows for a determination of CO_2 production, which can then be used to calculate total energy expenditure (TEE) over this time period. If a measurement of resting metabolic rate (RMR) is also performed, then an estimate of activity energy expenditure may be obtained by difference (TEE − [RMR + 0.1 × TEE]), while the ratio TEE/RMR has been proposed as an indicator of physical activity level (PAL).

Although the DLW method is the most accurate of all methods for determining free-living energy expenditure, it is very expensive. In addition, no information is provided about the specific activities performed nor the behavioral aspects of activity. DLW combined with time-and-motion studies may give a more complete overview of the individual's activity, including the components of daily activity that contribute to obesity and may, thereby, improve our ability to make appropriate recommendations.

In adults, both TEE and RMR increase with increasing weight (43,50). RMR is elevated because of increased amounts of fat free mass (the major determinant of RMR); TEE is increased because of the increased cost of weight-bearing activities. Although absolute TEE may be similar, RMR may be lower and activity energy expenditure may be higher in lean than in obese individuals. This indicates an inverse relationship between the amount of physical activity and body size (43).

In young children, there is not much information about energy expenditure and risk of obesity. Decreased TEE in children as young as 6–9 months (45) and lower physical activity in preschool aged children (40) are reported to affect later-age obesity. However, conflicting reports show no relationship between TEE at 12 wk and indices of body fatness at 9 months or 2 yr (15). Cross-sectional data from our laboratory show no relationship between physical activity level and percent body fat; nor did we find a significant difference in TEE or activity energy expenditure between lean and obese children (46). Surprisingly, Mohawk children, who have a high prevalence of obesity, are reported to have higher TEE than Caucasian children (33). Data from time-and-motion questionnaires suggest an inverse relationship between time spent in activity and body fat mass (32); however, this observation is not supported by the DLW data. Longitudinal follow-up studies in a large cohort of children may help to clarify these incongruities in the future.

In most of the studies of energy expenditure in young children, one consistent observation stands out: children younger than 7 yr appear to expend approximately 20–30%

less energy in physical activity (31,46) than the level recommended by the World Health Organization (65). However, the recommendations for children from 1–10 yr of age were based on published intake data from developed countries. A review of the WHO recommendations has recently been undertaken by Torun et al. (57), resulting in the suggestion that habitual physical activity levels be classified as light, moderate, or heavy and that to prevent obesity, energy intakes which support the level of activity be recommended. However, a critical number of calories is necessary to ensure that all other nutrient requirements are met during this period of rapid growth in children. Perhaps targeting physical inactivity (by promoting less television viewing, less use of video games, and less automobile usage), as well as encouraging increased vigorous physical exercise, are reasonable alternatives to ensure good health and prevent obesity in these children (19).

MANAGEMENT OF JUVENILE OBESITY

Enhanced Physical Activity as an Intervention

Enhanced physical activity (EPA) is a major component in weight management of obese children and adolescents. Reduction in body fat is only one objective of EPA. Other reported benefits include improved selfesteem, increased aerobic fitness, a decrease in resting blood pressure, and an improved plasma lipoprotein profile (for review see (2)). Another potential benefit which has been documented for adults (49), but not yet for children, is the preservation of fat-free mass when a very-low-calorie diet is implemented. Likewise, training in obese adults can affect fat distribution, decrease insulin resistance, and increase glucose tolerance; but there are no similar data for children.

In healthy, nonobese young people EPA has a limited effect on body adiposity (66). Greater efficacy and effectiveness of such programs have been suggested for children and adolescents who are obese (3). There are no data available on the optimal dose of EPA in juvenile obesity. It seems, however, that prolonged programs (e.g., 1 yr or more) are more efficacious than shorter ones (47). Compared with a low-caloric diet, the effect of EPA on body fat and total body mass is considerably slower. The main reason is that the energy equivalent of EPA programs for children seldom exceeds 1–1.2 MJ (250–300 kcal) per activity session, compared with a reduction of 4–5 MJ (1,000–1250 kcal) per 24 h through a low-caloric diet. There are indications, however, that the overall increase in daily energy expenditure exceeds the amount expended in an activity session *per se*. Likewise, the increase in energy expenditure over a one-month program exceeds the expenditure added by the program itself (6).

Poor compliance with and adherence to EPA programs pose a major challenge to the therapist. It seems that the long-term effect of an intervention program is greater when lifestyle physical activities are promoted rather than a regimented exercise prescription (21). Furthermore, a mere reduction in the time spent on sedentary activities can induce a better and more sustainable weight control than does an exercise program (19). Furthermore, attitudes toward vigorous exercise among children reinforced for reductions in sedentary behavior seem more positive than attitudes among children reinforced for EPA (19).

Diets and Nutritional Considerations

Fat reduction phase. Diets used in the treatment of childhood obesity can be divided into three categories: First, very low calorie diets, which comprise a high-protein, low carbohydrate, and low-caloric content. These have been termed "protein sparing modified fast" (PSMF); Second, programs that emphasize balanced hypocaloric diets (BHD); and third, comprehensive, behavioral lifestyle programs that include both nutrition and activity components and set attainable goals for the entire family.

A loss of fat-free mass has been shown to occur during diet-induced weight reduction in obese subjects (18), particularly when diet is very low in energy (5). This is of particular concern in children and adolescents, who need to maintain a positive nitrogen balance during growth. It has been suggested (25) that PSMF is a suitable weight loss program for children. It allows for rapid weight loss (as much as L $kg \cdot wk^{-1}$), and seems to preserve fat-free mass. This is particularly so when exercise is added to the PSMF (24), which may induce an anabolic effect. Unfortunately, most intervention studies on this topic were based on small samples, did not have randomly allocated controls, and failed to prove long-term success. In a study with children, Figuera-Colon et al. (25) compared PSMF diet with a BHD diet. They found that patients on the PSMF diet had a significantly greater weight loss at 10 wk than did the BHD group and that both groups had minimal losses in fat-free mass. However, all the subjects in both groups regained most of their weight at 14.5 months. Indeed, the PSMF regimen should not be considered as a long-term approach. It should be limited to morbid obesity, when a fast reduction of adiposity is indicated, on clinical grounds, over a short period of time. More studies are needed to assess further the effectiveness of the PSMF method regarding the preservation of fat-free mass in children.

Epstein et al. (20) observed that behavioral family-based treatments are associated with sustained effects over a 10-yr period. In these treatments overweight children and parents were prescribed a 4.2–5 $mJ \cdot 24\ h^{-1}$ (1000–1200 calories·24 h^{-1}) BHD "traffic light" diet. This diet was used to maximize the nutrient density of food. Also included in the treatment is nutrition education for both the children and their families. It is difficult to tease out the efficacy and effectiveness of the 4.2–5 $mJ \cdot 24\ h^{-1}$ diet and nutrition education regarding weight loss in Epstein's program because of its combination with behavioral approaches and exercise prescription.

It is critical that the composition of all diet formulations to be used in weight management of children include the required nutrients needed to provide for optimal growth as well as health maintenance. Low fat diets are not recom-

mended for children under the age of 2. Dietary recommendations for older children emphasize careful implementation of a low fat diet (not to exceed 30% total energy intake) by the age of 5. Further recommendations include a variety of foods with special emphasis on increasing intake of fruits, vegetables, and grains and an adequate amount of lower fat dairy products, as outlined in the Food Guide Pyramid (62). The quality as well as the quantity of energy consumed should be balanced such that nutrient needs are met. Consumer education is needed about the role of food high in calories and fat (e.g., chips), food high in calories but low in fat (low-fat brownies), and food high in calories but low in nutrients (soft drinks).

Weight management should be of life-long concern, beginning in childhood. Emphasis should be placed on total energy balance with the aim of maintaining healthy dietary patterns and choices. Long-term success involves setting realistic lifestyle goals and maintaining appropriate, small changes (deficits of approximately 800 $kJ \cdot d^{-1}$) which are achievable without compromising nutrient adequacy. A low fat dietary pattern can be achieved through decreasing intake of high-fat foods, fat used in cooking, or that added at the table, and avoiding visible fat whenever possible (trimming meats). A family-based approach should be emphasized. Normalization of eating patterns, with less emphasis on restriction and avoidance, decreases feelings of isolation and resentment, encouraging instead long-term positive eating patterns and enjoyment.

In addition to various dietary protocols in treating childhood obesity, there are various ways of providing the information. Group counseling is problem oriented and uses group dynamics to achieve desired outcomes, whereas individual counseling operates on the basis of individually specified problems and individual goals. Certainly, group counseling can reach a larger number of individuals. Research has shown the importance of treating both the child and the parents, with improved outcomes if the child and parents attend group treatment meetings separately (10).

Maintenance phase. Weight maintenance programs to prevent further weight gain and to allow children to "grow into their optimal weight" are receiving renewed attention. However, care must be taken to make appropriate nutrition and activity changes for children to achieve their optimal weight and body composition. Energy balance must be carefully maintained and challenges for arriving at the best recommendations for energy intake need further study. Recommendations for energy requirements at various ages, considering both median weight and height, have been established by the National Research Council and range from 450 $kJ \cdot kg^{-1}$ (2.7 $mJ \cdot d^{-1}$) for infants to 270$kJ \cdot kg^{-1}$ (1.3 $mJ \cdot d^{-1}$) for male adolescents. Although these recommendations have been helpful in determining approximate energy needs, individual variability and activity patterns must be taken into account.

Further considerations for growth have included comparisons between expected and observed height and weight changes in 6-month increments. These comparisons can be used to determine whether decreased energy intake is compatible with desired growth patterns.

Psychological and Social Considerations

Psychosocial consequences of obesity in children. The psychological and social consequences of being overweight in a society preoccupied with thinness can be both severe and enduring. Core aspects of psychological functioning such as self-esteem and body image can be affected, mood problems such as depression can occur, social discrimination is common, and long-term negative associations of overweight with college admission, employment opportunities, and income have been documented (29). Efforts at teaching body acceptance at the levels of both individuals and society should be enhanced, and health professionals working with obese children must be sensitive to psychosocial issues.

Dieting versus lifestyle changes. The typical response to excess weight is restrictive dieting. As calorie intake falls further from a person's "comfort" level, adherence becomes more difficult and binge eating becomes more likely. Replacing dieting with a focus on healthy eating and reasonable exercise broadens the scope of intervention and prevention beyond weight to the behaviors that affect weight and emphasizes health and well-being rather than physical appearance.

Weight preoccupation/body image. Modern culture overstates the degree to which the body can be shaped, molded, and sculpted, and presents highly unrealistic ideals for the perfect body (9). Eating disorders are the end product of this process in some people, but body dissatisfaction is so common that discontent with weight and shape is considered normative (55). The pressure to be thin is felt during childhood, with high rates of body concern and even dieting in children encountered in the third and fourth grades.

Those who seek to decrease the prevalence of childhood obesity must be sensitive to the possible negative consequences of producing an even greater emphasis on weight. The need for weight loss in overweight children and adolescents must be balanced against the need to encourage realistic body weight ideals and to minimize dissatisfaction with body image. This can be accomplished to some extent by helping individuals abolish weight and appearance as the center of self-esteem. In addition, children on weight control programs should be tracked for body image issues, self-esteem, and goals.

Reasonable weight goals. Because societal ideals for beauty hold out highly unrealistic goals, expectations of both the magnitude and rate of weight loss in both patients and families can often be unreasonable. It is essential that all concerned, including health professionals, have realistic expectations. In adults, this translates into a weight loss of approximately 10% of initial body weight (7). In children, it might mean even smaller losses or maintenance of weight until increased height creates more favorable body proportions. The health benefits of these modest weight changes have been documented, but the challenge is to help patients

to attain reasonable goals. The goals people establish for themselves are often, if not always, far in excess of the results to be expected from even the most effective programs. More work is needed to develop programs for acceptance of reasonable goals. Drawing on self-efficacy theory, relapse prevention theory, recent work on body image, and the behavioral principle of shaping, comprehensive efforts must be devised to deal with this important issue. Otherwise, the all-too-common phenomenon of a person despairing over what weight remains to be lost rather than celebrating what has been accomplished will persist.

Pathological eating. The problem of binge eating in adults has received considerable attention and is defined as eating what others would consider a large amount of food in a short period of time while feeling that the eating is out of control (23). Little work has been done with children, but interviews with adult binge eaters suggest that binge eating can begin in childhood and adolescence and, for some, precedes dieting and/or even a weight problem. Studies are needed to determine the degree to which binge eating contributes to childhood obesity; the psychological ramifications of binge eating independent of obesity; and whether the treatment of binge eating is necessary in at least some cases of childhood obesity.

UNDERNUTRITION, PHYSICAL ACTIVITY, AND PHYSICAL FITNESS

Undernutrition and Physical Activity

There is a biological tendency to maintain energy balance, such that dietary energy intake equates total daily energy expenditure plus tissue accretion for normal growth. When dietary energy becomes a limiting factor, children respond initially by reducing spontaneous physical activity to conserve energy for growth and other biological functions. It is not until the restriction of energy intake becomes more severe that weight gain and growth velocity diminish or stop. In a study under controlled clinical conditions that mimicked the habitual dietary intake of preschool children from low socioeconomic conditions in a developing country (59), a reduction in daily energy intake from 90 to 82 kcal (375 to 345 kJ) per kg body mass produced a proportional decrease in daily energy expenditure without affecting weight gain of 2- to 3.5-yr-old children. When daily intake was further decreased to a population mean of 71 kcal (300 kJ)·kg^{-1}, energy expenditure did not diminish any more but weight gain was markedly reduced.

Few studies have compared the physical activity of mildly or moderately malnourished children with better nourished counterparts of the same ethnic, social, and cultural conditions (e.g., 12,30,53,56). All indicate that undernourished children are less active. This is especially evident among toddlers and preschoolers who are not influenced by social conventions nor peer pressure and among older children in environments that encourage discretionary physical activity, such as summer camp (53). This decrease in activity can be reversed when nutritional conditions improve, as shown in a study with 2- to 6-yr-old children living in their home environment (56).

Just as dietary and lifestyle habits can offset the biological tendency to maintain energy balance, thereby leading to obesity in some children, socioeconomic and cultural demands can override the tendency to compensate limited energy intake with a reduction in physical activity. Compared with boys and girls from industrialized relatively affluent societies, those who come from rural, poor environments where undernutrition is highly prevalent dedicate more time to moderate and heavy physical activities, such as domestic chores and productive work. Furthermore, their overall physical activity level is higher (57). This is not always accompanied by an increase in dietary intake, which partly explains the leanness and short stature of children and adolescents in those societies.

Undernutrition and Physical Fitness

Physical fitness of children is affected by mild or severe undernutrition. A study of preschool children with severe protein-energy malnutrition showed that as nutritional rehabilitation progressed, the regression coefficient of oxygen consumption on heart rate increased, as assessed through weekly tests on a treadmill (56,58). Mild degrees of chronic undernutrition also have a negative effect on fitness. Studies in 6- to 16-yr-old children showed that maximal oxygen consumption was lower in those with marginal undernutrition compared with children with better nutritional conditions (52). These differences disappear when maximal aerobic power is calculated per unit of lean body mass. It seems that while the physiological potential to perform heavy physical work is maintained in children with mild undernutrition, their smaller size limits their absolute maximal aerobic power.

In conclusion, undernutrition compromises physical activity and fitness of children from infancy through adolescence. A prolonged reduction in physical activity resulting from sustained low dietary intake may limit a child's social interactions and exploration of his/her surroundings. This, in turn, may contribute to slower cognitive development and suboptimal social performance (56). The smaller body size of children with chronic undernutrition limits their maximal aerobic power. In adults, this has been associated with lower productivity in performing heavy physical work. Thus, the effects of undernutrition on children's physical activity and fitness may have important biological, psychological, social, and economic implications.

POLICY CONSIDERATIONS: PRESENT AND FUTURE

Policies Regarding Prevention

Once established, obesity is difficult to treat. While the concept of prevention is appealing, little work has been done on the prevention of obesity in general and of childhood

obesity in particular. This lack of attention must be reversed and redressed immediately.

The goals of prevention may vary, from promoting no increase in the prevalence of obesity in targeted groups, to reduction of weight and body fat in those at medical risk. There are also many possible methods of prevention. Targeting nutrition education and physical activity in the schools is a logical beginning, particularly in light of the alarming decrease over the past several decades in the number of state and local school boards that mandate physical activity in the schools. A true prevention program, however, should move beyond general nutrition and physical education and must focus on issues specifically related to obesity. Examples might include buffering children against advertisements for poor foods, changing lifestyle patterns, focusing on decreasing sedentary behaviors such as watching television, as well as increasing activity and choosing a diet that is healthy but satisfying.

Public Policy Options

In areas such as smoking and alcohol abuse, professionals have long used policy as a means for affecting public health. Approaches such as smoking bans in public places, regulation of the advertising of cigarettes and alcohol to children, and drunk driving laws are generally accepted and have, to a greater or lesser extent, been evaluated. Despite the potentially powerful impact of similar actions that might affect great segments of the population, there has been virtually no such consideration in the field of obesity.

Issues influenced by policy decisions are likely to have substantial impact. Nutrition and exercise programs in the schools are examples, but at a broader level, it is important to consider the effect of policy on the cost and availability of healthy and less-healthy foods, on the content of food advertising, and the availability of exercise facilities around the country.

These issues appear to be of central importance in the health and well-being of adults and children alike. There is unprecedented access to high-calorie, high-fat food; the number of fast food restaurants has exploded and factors such as drive-in windows, packaged meals, and "supersize" servings have boosted intake of specific types of foods (4). The average American child sees 10,000 television advertisements for food each year, 95% of these are for fast foods, candy, sweetened cereals, and soft drinks (4). It has been argued that Americans are exposed to a "toxic food environment" and that the outcome is a predictable increase in diet-related diseases, including obesity. Similar arguments can be made for declining physical activity.

Several policy measures have been suggested, including subsidizing healthy foods, increasing the price of unhealthy foods, regulating advertising aimed at children, and devoting public funds to build exercise facilities. Since these have not been tested, their impact is uncertain. While it is premature to make specific policy recommendations, it is imperative that policy be studied as a means to determine its role in the genesis of obesity and that policy changes be considered seriously as a means of addressing the growing epidemic of obesity.

Mass media efforts can positively facilitate behavior change (13). For example, the "5 a Day-for Better Health" campaign of the National Cancer Institute has positively influenced the consumption of fruits and vegetables. Thus, important attitudinal changes can result from effective use of the media to reshape expectations and definitions of what constitutes desirable eating and activity behaviors. Proactive efforts to promote early and ongoing assessments, implementation of successful interventions and/or prevention strategies, and adoption of healthful behaviors (including healthy eating habits and an active lifestyle) are needed. Thus, to begin, public health efforts should focus on effectively changing the prevailing political, educational, and medical climate.

The Role of Schools

Since 95% of American children, ages 5–17 yr, are enrolled in school, school-based interventions offer important potential. Many children eat one to two meals a day at school and the cafeteria can serve as a laboratory. Social support from teachers and peers can also be generated (44). The Nutrition Education and Training Program (NET)sponsored by USDA (51) is an excellent example. The program encourages: 1) instruction of students; 2) training of school food-service personnel; and 3) the in-service education of teachers and other school staff (57). New federal regulations for school breakfast and lunch programs mandate compliance with the 1995 Dietary Guidelines. Programs should be developed to include school-based assessment for early diagnosis and tracking of weight and weight-related problems. The Comprehensive School Health Program developed by the DHHS and CDC which integrates nutrition, physical education, health education, and psychological and social services beyond the classroom will make an impact. However, for successful weight management to be achieved in children, interventions must be targeted to address special and changing needs, focus on life-long strategies, and be evaluated for effectiveness (36,40).

RECOMMENDED QUESTIONS FOR FUTURE RESEARCH

The following list is not meant to be comprehensive, nor is it in order of priority. It outlines topics that reflect the authors' experience and interests.

1. What is healthy weight in children?
2. Is the effect of inactivity on obesity related to reduced energy expenditure or to the covariance of inactivity with other behaviors that promote obesity?
3. Do other sedentary behaviors have an impact on childhood obesity comparable with the effects of television viewing?
4. Are there certain periods in childhood and adolescence critical to the establishment of active or sedentary behaviors?

5. Are children with low rates of energy expenditure at higher risk of becoming overweight in the future?
6. Is the increased prevalence of obesity among children living in westernized countries the result of decreased physical activity?
7. Is there an optimal dose of enhanced physical activity for the treatment of childhood obesity?
8. Should resistance training be added to high-caloric activities, if one wants to counteract the catabolic effect of very low-caloric diets?
9. What are the characteristics of "good responders" and "poor responders" to a program of enhanced physical activity and dietary modification?
10. Should studies of enhanced physical activity be conducted in isolation from other therapeutic modalities, or should they be included only within multidisciplinary intervention projects?
11. How can school-based programs be more fully utilized as mechanisms for life-long, comprehensive weight management program?
12. What are the optimal and maximal levels of activity recommended for children with chronic mild or moderate undernutrition?
13. Is the obese child destined to become an obese adult? What are the predictors of those cases who track well across decades and those who do not?
14. What are the most important factors influencing children's dietary habits?
15. At what level of obesity should PSMF be implemented?
16. What is the efficacy of dietary programs when administered without enhanced physical activity?
17. What is the optimal approach for promoting prevention of juvenile obesity in the community? Is it more effective to intervene at the level of the environment (e.g., building exercise facilities or bike paths) or the individual (educational efforts)?
18. What is the cost effectiveness of prevention efforts aimed at the general child population versus those aimed at high risk individuals (e.g., children of obese parents)?
19. How can important differences and similarities in weight management strategies for children and adults be best communicated?

This Roundtable was made possible through support by the National Dairy Council and the Sugar Association. The authors are indebted to Barbara Campaigne, Ph.D., for her guidance and constructive comments.

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REFERENCES

1. Allison, D. B., M. S. Faith, and J. S. Nathan. Risch's lambda values for human obesity. *Int. J. Obes.* 20:990–999, 1996.
2. Bar-Or, O. Obesity. In: *Sports and Exercise for Children with Chronic Health Conditions*. B. Goldberg (Ed.). Champaign, IL: Human Kinetics, 1995, pp.335–353.
3. Bar-Or, O. and T. Baranowski. Physical activity, adiposity and obesity among adolescents. *Pediatr. Exerc. Sci.* 6:348–360, 1994.
4. Battle, E. K. and K. D. Brownell. Confronting a single tide of eating disorders and obesity: treatment vs. prevention and policy. *Addict. Behav.* 21:755–765, 1997.
5. Blaak, E. E., O. Bar-Or, K. R. Westerterp, and W. H. M. Saris. Effect of VLCD on daily energy expenditure and body composition in obese boys. *Int. J. Obes.* 14(Suppl 2):86, 1990.
6. Blaak, E. E., K. R. Westerterp, O. Bar-Or, L. J. M. Wouters, and W. H. M. Saris. Total energy expenditure and spontaneous activity in relation to training in obese boys. *Am. J. Clin. Nutr.* 55:777–782, 1992.
7. Blackburn, G. L. Effects of weight loss on weight-related risk factors. In: *Eating Disorders and Obesity: A Comprehensive Handbook*. K. D. Brownell and C. G. Fairburn (Eds.). NY: Guilford, 1995, pp. 406–410.
8. Bouchard, C. Genetics of obesity: overview and research directions. In: *The Genetics of Obesity*, C. Bouchard (Ed.). Boca Raton, FL: CRC Press, 1994, pp. 223–233.
9. Brownell, K. D. Dieting and the search for the perfect body: where physiology and culture collide. *Behav. Ther.* 22:1–2, 1991.
10. Brownell, K. A., S. H. Kelman, and A. J. Stunkard. Treatment of obese children with and without their mothers: changes in weight and blood pressure. *Pediatrics* 71:515–523, 1983.
11. Centers for Disease Control. Prevalence of sedentary lifestyle: Behavioral Risk Factor Surveillance System, United States. *Morbid. Mortal. Weekly Rep.* 42:576–579, 1993.
12. Chavez, A., C. Martinez, and H. Bourges. Nutrition and development of infants from poor rural areas: 2. Nutritional level and physical activity. *Nutr. Rep. Int.* 5:139–144, 1972.
13. Cheung, L. Do media influence childhood obesity? Prevention and treatment of childhood obesity. *Ann. N. Y. Acad. Sci.* 699:104–106, 1993.
14. Ching, P. L.Y. H., W. C. Willett, E. B. Rimm, G. A. Colditz, S. L. Gortmaker, and M. J. Stampfer. Activity level and risk of overweight in male health professionals. *Am. J. Pub. Health* 86: 25–30, 1996.
15. Davies, P. S. W., J. M. E. Day, and A. Lucas. Energy expenditure in early infancy and later body fatness. *Int. J. Obes.* 15:727–731, 1991.
16. Davies, P. S. W., J. Gregory, and A. White. Energy expenditure in children aged 1.5–4.5 years: a comparison with current recommendations for intake. *Eur. J. Clin. Nutr.* 49:360–364, 1995.
17. Dietz, W. H. and S. L. Gortmaker. Do we fatten our children at the TV set? television viewing and obesity in children and adolescents. *Pediatrics* 75:807–812, 1985.
18. Dietz, W. H. and D. A. Schoeller. Optimal dietary therapy for adolescents: comparison of protein plus glucose and protein plus fat. *J. Pediatr.* 100:636–644, 1982.
19. Epstein, L. H., A. M. Valoski, L. S. Vara, et al. Effects of decreasing sedentary behavior and increasing activity on weight changes in obese children. *Health Psychol.* 14:109–115, 1995.
20. Epstein, L. H., A. Valoski, R. R. Wing, and J. McCurley. Ten-year outcomes of behavioural family-based treatment for childhood obesity. *Health Psychol.* 13:373–383, 1994.
21. Epstein, L. H., R. R. Wing, R. Koeske, and A. Valoski. A comparison of lifestyle exercise, aerobic exercise, and calisthenics on weight loss in obese children. *Behav. Psychol.* 16:345–356, 1985.
22. Escobedo, L. G., S. E. Marcus, D. Holtzman, and G. A. Giovino. Sports participation, age at smoking initiation, and the risk of smoking among US high school students. *JAMA* 269:1391–1395, 1993.
23. Fairburn, C. G. and G. T. Wilson. *Binge Eating: Nature, Assessment, and Treatment*. New York: Guilford, 1993.
24. Figueroa-Colon, R., T. K. von Alman, and R. M. Suskind. Clinical considerations in the treatment of childhood obesity. In: *The Obese Child: Pediatric Adolescent Medicine*, P. L. Giorgi, R.M. Suskind, and C. Catassi (Eds.). Basel: Karger, 1992, pp. 181–196.
25. Figueroa-Colon, R., T. K. von Almen, F. A. Franklin, C.

SCHUFTAN, and R. M. SUSKIND. Comparison of two hypocalorie diets in obese children. *Am. J. Dis. Child.* 147:160–166, 1993.
26. FONTVIEILLE, A. M., I. T. HARPER, R. T. FERRARO, M. SPRAUL, and E. RAVUSSIN. Daily energy expenditure by five-year-old children, measured by doubly labeled water. *J. Pediatr.* 123:200–207, 1993.
27. FOREYT, J. P., and G. K. GOODRICK. Attributes of successful approaches to weight loss and control. *Appl. Prevent. Psychol.* 3:209–215, 1994.
28. FOREYT, J. P., W. S. C. POSTON, and G. K. GOODRICK. Future directions in obesity and eating disorders. *Addict. Behav.* 21:767–778, 1996.
29. FRIEDMAN, M. A. and K. D. BROWNELL. Psychological correlates of obesity: moving to the next research generation. *Psychol. Bull.* 117:3–20, 1995.
30. GARDNER, J. M. M., S. M. GRANTHAM-MCGREGOR, S. M. CHANG, and C. A. POWELL. Dietary intake and observed activity of stunted and non-stunted children in Kingston, Jamaica. Part II: observed activity. *Eur. J. Clin. Nutr.* 44:585–593, 1990.
31. GORAN, M. I., W. H. CARPENTER, and E. T. POEHLMAN. Total energy expenditure in 4- to 6-yr-old children. *Am. J. Physiol.* 264:E706–711, 1993.
32. GORAN, M. I., G. HUNTER, T. R. NAGY, and R. JOHNSON. Physical activity related energy expenditure and fat mass in young children. *Int. J. Obes.* 21:171–178, 1997.
33. GORAN M. I., M. KASKOUN, R. JOHNSON, C. MARTINEZ, B. KELLY, and V. HOOD. Energy expenditure and body fat distribution in Mohawk children. *Pediatrics* 95:89–95, 1995.
34. GORTMAKER S. L., A. MUST, A. M. SOBOL, et al. Television viewing as a cause of increasing obesity among children in the United States, 1986–1990. *Arch. Pediatr. Adolesc. Med.* 150:356–62, 1996.
35. GUO, S. S., A. F. ROCHE, W. CAMERON CHUMLEA, J. D. GARDNER, and R. M. SIERVOGEL.The predictive value of childhood body mass index values for overweight at age 35 yr. *Am. J. Clin. Nutr.* 59:810–819, 1994.
36. JAMES, W. P. T. A public health approach to the problem of obesity. *Int. J. Obes.* 19:S37–S45, 1995.
37. LYTLE, L. A., S. H. KELDER, C. L. PERRY, et al. Covariance of adolescent health behaviors: the Class of 1989 Study. *Health Ed. Res.* 10:133–146, 1995.
38. KRIEMLER, S., S. MIKAMI, B. AYUB, R. CALVERT, and O. BAR-OR. The impact of structured exercise on spontaneous physical activity, measured by tritrac, in obese adolescent boys. *Med. Sci. Sports Exerc.* 28:S12, 1996.
39. MCGINNIS, M. J. The public health burden of a sedentary lifestyle. *Med. Sci. Sports Exerc.* 24:S196–S200, 1995.
40. MOORE L. L., U.-S. D. T. NGUYEN, K. J. ROTHMAN, L. A. CUPPLES, and R. C. ELLISON. Preschool physical activity level and change in body fatness in young children. *Am. J. Epidemiol.* 142:982–988, 1995.
41. MOSSBERG, H.-O. 40-year follow-up of overweight children. *Lancet* 2:491–493, 1989.
42. PERRI, M. G. and P. R FULLER. Success and failure in the treatment of obesity: where do we go from here? *Med. Exerc. Nutr. Health* 4:255–272, 1995.
43. PRENTICE, A. M., A. E. BLACK, W. A. COWARD, and T. J. COLE. Energy expenditure in overweight and obese adults in affluent societies: an analysis of 319 doubly-labelled water measurements. *Eur. J. Clin. Nutr.* 50:93–97, 1996.
44. RESNICOW, K. School-based obesity prevention: prevention and treatment of childhood obesity. *Ann. N.Y. Acad. Sci.* 699:154–166, 1993.
45. ROBERTS, S. B., J. SAVAGE, W. A. COWARD, B. CHEW, and A. LUCAS. Energy expenditure and intake in infants born to lean and overweight mothers. *N. Engl. J. Med.* 318:461–466, 1988.
46. SALBE, A. D., A. M. FONTVIEILLE, I. T. HARPER, and E. RAVUSSIN. Low levels of physical activity in 5-year-old children. *J. Pediatr.*, in press.
47. SASAKI, J., M. SHINDO, H. TANAKA, M. ANDO, and K. ARAKAWA. A long-term aerobic exercise program decreases the obesity index and increases the high density lipoprotein cholesterol in obese children. *Int. J. Obes.* 11:339–345, 1987.
48. SCHOELLER, D. A. and E. VAN SANTEN. Measuremei expenditure in humans by doubly labeled water meth *Physiol.* 53:955–959, 1982.
49. SCHRUB, J.-C., L.-M. WOLF, and H. COURTOIS. Fastin cular exercise: changes in weight and nitrogen balance *Nouv. Press. Med.* 4:875–878, 1975.
50. SCHULZ, L. O. and D. A. SCHOELLER. A compilation o energy expenditure and body weights in healt *Am. J. Clin. Nutr.* 60:676–681, 1994.
51. SIMS, L. S. and J. VOICHICK. Our perspective: nutritio enhances food assistance programs. *J. Nutr. Ed.* 28:83
52. SPURR, G. B., M. BARAC-NIETO, and J. C. REINA. Grow tion, body composition and maximal aerobic power o ally normal and marginally malnourished school-aged children. In: *Human Growth, Physical Fitness and Nut* Shephard and J. Parizkova (Eds.). *Med. Sport Sci.* 31:41
53. SPURR, G. B. and J. C. REINA. Influence of dietary inter artificially increased activity in marginally undernour lombian boys. *Eur. J. Clin. Nutr.* 42:835–842, 1988.
54. STARK, O., E. ATKINS, O. H. WOLFF, and J. W. B. Longitudinal study of obesity in the National Survey of H Development. *Br. Med. J.* 283:13–17, 1981.
55. STRIEGEL-MOORE, R. H., L. R. SILBERSTEIN, and J. RODIN and understanding of risk factors for bulimia. *Am. Psy* 246–263, 1986.
56. TORUN, B. Short- and long-term effects of low or restricte intakes on the activity of infants and children. In: *Activity Expenditure and Energy Requirements of Infants and Chi* Schurch and N. S. Scrimshaw (Eds.). Lausanne: IDECG, 335–359.
57. TORUN, B., P. S. W. DAVIES, M. B. E. LIVINGSTONE, M. H R. SACKETT, and G. B. SPURR. Energy requirements and energy recommendations for children and adolescents years old. *Eur. J. Clin. Nutr.* 50:S37–S81, 1996.
58. TORUN, B., Y. SCHUTZ, F. E. VITERI, and R. B. BRADFIELD. body composition and heart rate/$\dot{V}O_2$ relationship change the nutritional recovery of children with two different activity levels. *Bibl. Nutr. Dieta* 27:55–56, 1979.
59. TORUN, B. and F. E. VITERI. Energy requirements of pr children and effects of varying energy intakes on protein olism. *Food Nutr. Bull.*, Suppl. 5:229–241, 1981.
60. TROIANO, R. P., K. M. FLEGAL, R. J. KUCZMARSKI, S. M. CA and JC. JOHNSON. Overweight prevalence and trends for c and adolescents. *Arch. Pediatr. Adolesc. Med.* 149:1085–91
61. U.S. DEPARTMENT OF AGRICULTURE, U.S. DEPARTMENT OF H AND HUMAN SERVICES. *Nutrition and Your Health: Dietary lines for Americans.* 4th Ed. Human and Garden Bulletin, N Washington, D.C. Department of Agriculture, 1995.
62. U.S. DEPARTMENT OF AGRICULTURE. *U. S. Department of Ag ture's Food Guide Pyramid.* Washington, D.C.: USDA H Nutrition Information Service, 1992.
63. U. S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, PUBLIC H SERVICE. *Healthy People 2000: Midcourse Review and 199 visions.* Maryland: National Center for Health Statistics, 19
64. U. S. DEPARTMENT OF HEALTH AND HUMAN SERVICES. *Physica tivity and Health: A Report of the Surgeon General.* Atlanta, U.S. Department of Heath and Human Services, Centers for ease Control and Prevention, National Center for Chronic Di Prevention and Health Promotion, 1996.
65. WHO (WORLD HEALTH ORGANIZATION). *Energy and Protein quirements.* Report of a joint FAO/WHO/UNU expert cons tion. Geneva: World Health Organization, Technical report s 734, 1985.
66. WILMORE, J. H. The C.H. McCloy research lecture: appetite body composition consequent to physical activity. *Res. Q. Ex Sport* 54:415–425, 1983.
67. WOLF, A. M., S. L. GORTMAKER, L. CHEUNG, et al. Activity, i tivity, and obesity: racial, ethnic, and age differences am schoolgirls. *Am. J. Public Health* 83:1625–1627, 1993.