Special Report

Modifiable Environmental and Behavioral Determinants of Overweight among Children and Adolescents: Report of a Workshop

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Abstract

JOHNSON-TAYLOR, WENDY L., JAMES E. EVERHART. Modifiable environmental and behavioral determinants of overweight among children and adolescents: report of a workshop. *Obesity.* 2006;14: 929–966.

The number of children at risk for overweight and the number of overweight children are increasing and have become a serious public health concern. Interventions that could be applied at the population level have not been proven effective. The development of effective strategies is thought to be hampered by the lack of understanding of which behavioral and environmental factors need to be modified. On June 14 and 15, 2004, the NIH held a meeting of experts to discuss the issue of modifiable determinants of obesity in children and adolescents. Included were presentations on interventions among children that have been proven effective, dietary and physical activity behavioral determinants, physical, social, and family environmental determinants, and the quality of measures of determinants and correlates of overweight.

Summary

Because of the long-term consequences of overweight and obesity, the great increase in the prevalence of childhood overweight over the last 30 years is of great concern. With millions of children overweight or at risk for overweight, a broad-based public health approach is the most practical way to address the problem. Yet, there is scant evidence for success by this approach. One significant reason for this lack of success may be the lack of identification of the overweight determinants and strategies for successfully modifying them. This workshop examined the evidence for such determinants, how researchers should approach their measurements, and how future studies might be conducted.

A thorough review of the many studies of the role of diet and nutrition on overweight concluded that there is strong suggestive data on breast-feeding for preventing overweight among offspring, although it may have a weak overall effect, as well as data on eating away from home, fast foods, and soft drink consumption as risk factors for childhood overweight. There is either no evidence, conflicting evidence, or insufficient evidence for other dietary factors. A review of physical activity found a consistent relationship between sedentary behavior, particularly television (TV)[1] watching, and overweight, although the absolute influence is probably small. Difficulties in accurate measurement of energy intake and energy expenditure and related behaviors are a significant obstacle in establishing relationships of diet and physical activity to overweight. The influence of the built environment is a promising avenue for research, but almost no study results for children have been published. A sophisticated body of literature exists on principles of family research and treatment, but these principles have not been applied to understanding or interventions of overweight among children. Non-familial social influences are

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[1] Nonstandard abbreviations: TV, television; NIDDK, National Institute of Diabetes and Digestive and Kidney Diseases; SES, socioeconomic status; AAP, American Academy of Pediatrics; NHANES, National Health and Nutrition Examination Survey; USDA, U.S. Department of Agriculture; CSFII, National Food Consumption Survey and Continuing Survey of Food Intake of Individuals; GUT, Growing Up Today; FFQ, food frequency questionnaire; MIT, Massachusetts Institute of Technology; SF, skinfold; PE, physical education; CDC, Centers for Disease Control and Prevention; ADP, air displacement plethysmography; BIA, bioelectric impedance analysis; BP, blood pressure; SD, standard deviation; OGTT, oral glucose tolerance test; TG, triglyceride; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

diverse and promising areas for interventions, but, again, little research specific to childhood overweight has been conducted.

Substantial time was devoted to issues of measurement. Dietary assessment tools commonly used in large studies are most appropriate for predicting health outcomes and assessing dietary patterns. They are valid for ranking people but are not sufficiently accurate for precisely estimating energy intake. Greater emphasis should be placed on dietary behavior. Tools for measuring physical activity have improved, particularly in the area of electronic monitoring devices. Future research in physical activity assessments among overweight children should focus on intensity, frequency, and patterns rather than just total activity. Much of the work on the influence of the built environment has been on what is termed "walkability." Measurement tools are being developed and refined to assess some built environment constructs, including land use mix, street connectivity, and residential density. Few measurement tools have been developed to measure the roles of family or social environment childhood overweight. Because parents and other caregivers so powerfully shape children's eating and activity environments during the first 5 years of life, attention to measurement during this period may have the greatest yield. One argument is that BMI should continue to be the main measurement of overweight in large studies, with the addition of body composition and metabolic measures when feasible. Although morbidity from overweight is uncommon during childhood, associated cardiovascular risk factors can become apparent during late childhood and adolescence. The psychosocial consequences of overweight are also important to measure.

In planning future studies, it is important to integrate dietary, activity, and environmental measurements. To gain a truer picture and limit biases, overlapping age cohorts should be followed for several years. Studies should be designed that will serve as a basis for advocating change, such as devising or justifying interventions regarding availability of food, food prices, or infrastructure for physical activity. Where a cohort approach would be unlikely to yield such information, for example, because of lack of variation among the participants, then alternative designs, including experimental interventions should be considered. Flexibility is needed to allow for rapid ascertainment of information when unpredictable natural experiments occur.

Part I: Introduction

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Shiriki Kumanyika, Ph.D., Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania, School of Medicine, Philadelphia, PA

On June 22 to 23, Dr. James Everhart and Dr. Shiriki Kumanyika chaired a meeting of invited experts who were charged with discussing the state of the science of modifiable environmental and behavioral determinants of overweight among children and adolescents and identifying the gaps and the research needed to move forward. Dr. Everhart defined a determinant as a factor that brings about change in a health condition or other desired characteristics (1). If that factor is changed or modified, then a quantifiable change in the health condition can be expected. A modifiable determinant was considered an environmental feature or a behavior that is susceptible to change through either broad-based individual choices or public policy choices. Consequently, this workshop focused on public policy and societal influences on the development of obesity rather than on individual clinical interventions or treatment of obesity, such as pharmacological or cognitive behavioral therapy. Importantly, determinant research will be useful only if it leads to successful change.

The workshop objectives were to review current knowledge of modifiable determinants of overweight in children and adolescents and to identify research opportunities and their priorities. Given that there has been limited success in identifying successful interventions in childhood overweight and in reducing its prevalence in the United States, it is reasonable to ask whether poor understanding of the determinants of childhood overweight contributes to that lack of success.

Speakers were asked to address the following questions in their areas of expertise:

- What are the major modifiable environmental and behavioral determinants of overweight?
- What is their relative importance?
- What is the correlation or interaction of modifiable determinants of overweight?
- Does a given determinant have the same effect in various age, sex, ethnicity, and socioeconomic status (SES) groups?

To answer these questions, additional research issues must be addressed. One regards measures of the determinants or risk factors themselves. Another is measures of outcomes, not only height and weight, but other features of overweight such as fat distribution and comorbidity. Third are the intermediates that are important to measure in terms of caloric consumption and energy expenditure. The fourth factor is the study design itself. The agenda for the workshop was built around presentations on the modifiable determinants and on these key factors. The purpose of this report is to disseminate the information and recommendations from this workshop.

What Behavioral and Environmental Interventions among Children Have Been Proven Effective?

Steve Gortmaker, Ph.D., Department of Society, Human Development, and Health, Harvard Prevention Research Center, Harvard University School of Public Health, Boston, MA

Dr. Gortmaker presented evidence from randomized behavioral and environmental trials, then offered his view of the most important factors influencing overweight among children and youth, and concluded with some questions to stimulate thinking about issues for future funded research.

Clinical Trials Directed at Dietary and Physical Activity Behavior

Only two clinical trials, conducted by the same investigator, could be identified that were successful in changing the physical activity and dietary behavior of children (2,3). These trials were expensive and, due to the intensive nature of the intervention, would have limited application on a population-based scale.

Clinical Trials Directed at Either Dietary or Physical Activity Behavior. Interventions that focus only on either physical activity behavior or dietary behavior have not been shown consistently to produce significant effects on overweight among children and youth (4,5). However, behavior changes that focus on modification of specific foods may hold promise. For example, a small, randomized control trial consisting of a 6-month intervention and a 6-month follow-up showed that a reduced glycemic load diet had greater effect on weight loss than a conventional low-fat diet (6). Another study that targeted schools was a small United Kingdom randomized controlled trial that used an educational intervention to persuade students to reduce their intake of carbonated beverages. The investigators reported a reduction in weight in the intervention school cluster when compared with the control cluster (7).

TV Viewing. There is increasing evidence that TV viewing is an important influence on overweight in childhood. As a behavioral target, TV seems to affect both inactivity and dietary intake, the latter through advertising and snacking. Children are particularly vulnerable to dietary manipulation. They tend to have primitive tastes, especially when they are young, preferring foods that are sugary or with a fatty or salty taste. Viewing ads that spotlight these types of food may increase their consumption. Robinson and colleagues (8) conducted a randomized controlled trial of a school-based intervention in the primary grades that assessed the effects of reducing TV, videotape, and video game use on changes in adiposity, physical activity, and dietary intake. Although there were no statistically significant changes in physical activity or the quality of meals consumed, there was a statistically significant reduction in the number of meals eaten in front of the TV and in the mean BMI.

Successful clinical interventions in other randomized control trials have been directed at TV viewing and improved physical activity (3,9). A 2-year school-based intervention on TV viewing, physical activity, and diet known as Planet Health found a modest reduction in overweight in girls but not in boys (10). One small cross-over study assessed the relative effects of increased and decreased sedentary behavior (computer and TV use) of ~80 min/d among non-obese youth 8 to 12 years old. With increased TV viewing, there was an increase in energy intake of ~250 kcal/d and a decrease in activity of ~100 kcal/d. No effect on energy intake or activity was seen with decreased sedentary behavior (11).

Multiple studies have shown at best a weak correlation in decreased time spent in TV viewing (sedentary behavior) and increased time spent in physical activity (10,12,13). This apparent paradox might be explained by the disparity in time spent in such activities; although children spend ~15 minutes a day in vigorous activity, 10 or more hours are spent being sedentary (14). Therefore, TV viewing and moderate or vigorous physical activity should be viewed as distinct constructs, not as functional opposites. As an example, the Health Professionals Study showed independent relationships of TV viewing and physical activity to diabetes incidence among adults (15). Furthermore, vigorous activity may contribute so little to energy expenditure that it is not a major factor in a person's total physical activity (16).

Summary

According to Dr. Gortmaker, current interventions are creative but provide only a very small portion of the needed evidence required to counteract the epidemic of overweight among children and adolescents. He highlighted the powerful opposing forces driving the epidemic as food producers, the fast food industry, advertisers, and the media of TV, film, and games that have drawn and keep children inside and sedentary. For example, an advertised value meal at McDonald's (double cheeseburger, French fries, soft drink, dessert) can contain ~2200 kcal, which would require a full marathon to burn off. The large majority of the advertising budgets for fast food restaurants and of food manufacturers is spent on TV, with the most advertised foods being confectionaries, snacks, prepared convenience foods, and soft drinks. In addition, Dr. Gortmaker predicted that the growth of broadband and video screen industries (broadcast TV, cable TV, VCR, DVD, video games, computer games, the Internet) will continue to change the lives of children. In contrast, resources do not exist to perform the rigorous randomized trials needed to identify the many possible ways for attacking the obesity problem among children. Furthermore, randomized controlled trials are not necessarily well

Table 1. Protective association of breast-feeding and fatness

Study first author	Year	*n*	Age (years)	Adjusted odds ratio (confidence interval)
von Kries	1999	9357	5 to 6	0.75 (0.57 to 0.98)
Liese	2001	2108	9 to 10	0.66 (0.52 to 0.87)
Gillman	2001	15,341	9 to 14	0.78 (0.66 to 0.91)
Toschke	2002	33,768	6 to 14	0.80 (0.72 to 0.90)
Armstrong	2002	32,000	3 to 4	0.70 (0.61 to 0.80)
Bergmann	2003	918	6	0.53 (0.31 to 0.89)
Grummer-Straun	2004	12,587	4	0.70 (0.50 to 0.99) (Non-Hispanic whites only for 6 to 12 months vs. never)
Hediger	2001	2685	3 to 5	0.84 (0.62 to 1.13)
Li	2003	2631	4 to 18	Not significant
Victora	2003	2250	18	Not significant

suited to studying the changes that are affecting childhood obesity. Mechanisms are needed to link new research with what is happening in the real world. In conclusion, the following questions were proposed for future research activities:

- How can interventions be made more relevant to the corporate and institutional environmental forces that are driving this epidemic?
- How can we provide more interdisciplinary study of economic factors to influence profit-focused industries to change?
- If a researcher partners with industry, can this research be accepted by other scientists?
- Can quasi- and natural experimental designs be used effectively in place of randomized controlled trials to study the synergy between environmental contexts and behavioral intervention?

Part II, Session I: Behavioral Determinants

Review of Dietary Research on Overweight among Children and Adolescents

Mary Story, Ph.D., Epidemiology, University of Minnesota Twin Cities, Minneapolis, MN

Dr. Story reviewed the following as potential dietary determinants of overweight in children: breast-feeding and infant feeding; macronutrients and energy intake; eating away from home; meal patterns such as breakfast eating and snacking; other dietary patterns, including eating of fruits and vegetables, fiber, and calcium intake; and food insecurity.

Breast-Feeding

A meta-analysis has suggested that breast-feeding has a small protective effect against childhood obesity, with an odds ratio of 0.78 (17). However, results of several studies performed in the last 6 years have not consistently shown a relationship across all ethnic and racial groups (Table 1) (18,19,20–27). For example, a recent U.S. population-based study found that breast-feeding had a protective effect to 12 months of age for non-Hispanic whites only (24). Thus, there appears to be a protective effect of breast-feeding, but the effect may be weak relative to the potential dominant role of other dietary and physical activity in later childhood. Still, breast-feeding is an overweight prevention strategy for early in life.

Infant Feeding

The American Academy of Pediatrics (AAP) recommends introducing solid foods at 4 to 6 months of age. There has been some concern that earlier introduction of solid foods may be associated with an increased risk of overweight. In a 1999 review, three longitudinal studies were found that showed no relationship between early introduction of solids and increased risk of overweight and two found a negative relationship such that children who had an early introduction of solids were at decreased risk of becoming overweight (28). The authors concluded that early introduction of solid foods may displace energy intake from liquid sources, rather than supplying additional energy, thus producing no impact. No more recent literature was found on this topic. There is no evidence that early introduction of solid foods is a risk factor for overweight.

Dietary Intake

As described in subsequent talks, dietary studies are all hampered by dietary assessment methods that have high

measurement errors and many built-in biases, especially in assessing diet in children and adolescents. Sources of error and biases include under-reporting, underestimating portion sizes, and relying on caretakers (parents and teachers) to report on children's diets. This ubiquitous problem of collecting accurate and reliable dietary data may help explain why many studies do not show a relationship between diet and overweight.

Macronutrients

Protein. A 1995 French longitudinal study of 112 children found that a higher protein intake at age 2 was associated with an earlier adiposity rebound, which was then associated with increased weight at 8 years of age (29). The authors hypothesized that this high protein content of infant formula may have increased the level of insulin-like growth factors that triggered early adipocyte multiplication. A recent larger longitudinal study of 889 children in England found no association between dietary protein and the timing of the adiposity rebound (30). Based on the findings of several recent studies, despite some inconsistency in the results, there appears to be an association between high early protein intake and subsequent overweight (31–39).

Dietary Fat

Because dietary fat is the most energy dense of all of the macronutrients, it has long been thought to play a role in obesity. The data, however, show only a very weak relationship. The longitudinal Amsterdam Growth and Health Study, and several studies after that, found no association between percentage energy from fat and overweight in children (29,31,32,40–46) Of the more recent papers, there are only two showing a positive relationship between percentage energy from fat and overweight (39,47).

Energy Intake

The National Health and Nutrition Examination Survey (NHANES) found little difference in age-adjusted mean energy intake in boys between 1971 and 1994 despite the large increase in childhood overweight during this 20-year period (48). Similar results were found for girls, except for those ages 12 to 19, in whom there was an increase in energy intake. On the other hand, the U.S. Department of Agriculture (USDA) National Food Consumption Survey and Continuing Survey of Food Intake of Individuals (CSFII) showed an increase in caloric intake among children over time between 1977 and 1996 (49). Most of the studies in a systematic Parsons 1999 literature review either showed no relationship or showed a negative relationship between energy intake and subsequent adiposity (28). Among the children of nurses in the Growing Up Today (GUT) study, girls (9 to 14 years) who reported higher caloric intake on food frequency questionnaires (FFQs) had larger increases in self-reported BMI over a 1-year interval (45). Such an effect was not seen among boys. However, for both boys and girls, those with greater increases in caloric intake over a year's period had larger BMI increases. Thus, there is only limited evidence from longitudinal studies that absolute energy intake is positively related to overweight, but there are many methodological limitations in these studies.

As regards energy-dense foods, the Massachusetts Institute of Technology (MIT) Growth and Development Study followed 2000 premenarcheal, primarily white girls, age 8 to 12 years, all normal weight at baseline, until the girls were 4 years after menarche (50). Using a validated FFQ over the 10-year study period, researchers found that the only energy-dense snack food that was related to BMI z scores was soda, and that was not related to percentage body fat. Overall, energy-dense snack food consumption did not influence weight status or change in body fat. There was, however, a positive association of energy-dense snack food consumption and TV viewing. A 24-hour recall study of youth ages 8 to 18 based on NHANES III (1988 to 1994) data found that low-nutrient energy-dense foods such as sweeteners and desserts contributed >30% of daily energy to the diets of youth (51). However, consumption of these foods was not related to measured BMI.

Carbohydrates

Although total carbohydrate intake has increased in both absolute grams and as a proportion of total energy intake over time, none of the longitudinal studies with youth found a significant positive relationship between total carbohydrate intake and adiposity. In fact, a few found inverse relationships for children who consumed large amounts and were leaner, possibly due to physical activity. Few studies controlled for physical activity.

The striking increase in high fructose corn syrup consumption over the last 30 years has prompted examination of its association with the increase in childhood overweight over the same period. Although per capita consumption of added sugars increased ~20% between 1970 and 2000, high-fructose corn syrup increased ~4000% over the same period (52). Meanwhile, there was a 125% increase in soft drink consumption among youth from 1977 through 1998 (53). By 1996, youth ages 6 to 17 consumed ~20% of their calories from added sugar, most of it occurring at home (54). NHANES data found that overweight youth, especially adolescent boys, consumed a greater proportion of their daily energy (nearly 10%) from soft drinks compared with non-overweight youth (48). Also, adolescent nonconsumers of soft drinks were found to consume fewer calories per day compared with those who were drinking >26 ounces per day (55). Nevertheless, most U.S. population studies with children and adults have shown an inverse relationship between sugar intake and BMI. Three longitudinal studies have suggested a relationship between sugar-

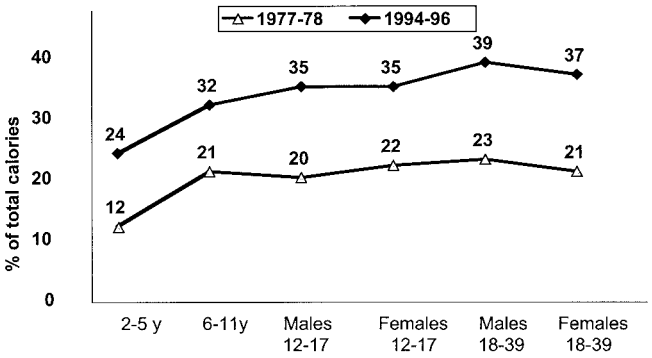

Figure 1: Percent of total calories obtained from away food, 1977 to 1978 vs. 1994 to 1996 in the CSFII. Reprinted with permission from Guthrie JF, Lin BH, Frazao E. Role of food prepared away from home in the American diet, 1977–78 versus 1994–96: changes and consequences. *J Nutr Educ Behav.* 2002;34:140–50.

sweetened drinks and childhood obesity (7,50,56). One limited study aimed at reducing consumption of carbonated beverage through randomization of six schools to an educational program. At the end of the school year, there was a modest reduction in soft drink consumption and decreased percentage of overweight children in the intervention group but no difference in BMI or *z* score between the control and intervention groups (7).

Eating away from Home: The Fast Food Issue

In the last 50 years, the share of the food dollar spent eating away from home rose from 25% to almost 50%. School-aged children obtain ~35% of their calories away from home (57). A study of adolescents 12 to 18 years of age found that from 1977 to 1996, energy intake from eating out in restaurants or fast food places tripled from 6% to 19% (58). Similar increases have been seen across the age range (Figure 1) (57). In considering the contributions of fast food to eating out, it must be noted that there is no consensus on what constitutes fast food, and surveys vary in how fast food is addressed. For the purpose of this discussion, fast food is consistent with the USDA definition as food obtained from self-service and carry-out eating places and cafeterias (59). Using this definition, there is no doubt that fast food sales have soared over the last 40 years so that today they are approximately equal to sales at full-service restaurants (places with waiter service) (60). USDA studies have shown that away-from-home foods, especially fast foods, contain more fat, sugar, and higher energy-dense foods and slightly lower fiber (59). A study based on USDA data of youth ages 4 to 19 found higher energy intake and higher fat, higher sugar, and higher energy-dense foods and slightly lower fiber among those who ate fast food compared with those who did not eat fast food that day (61). In Project EAT, a study designed to investigate factors influencing eating habits of adolescents to determine whether youth are meeting national dietary recommendations and to explore dieting and physical activity patterns among youth, both male and female adolescents who ate fast food three times a week or more had higher energy intake compared with those adolescents who reported they never had fast food, although there was no association with overweight among the >4000 surveyed youths (62). This study did not adjust for physical activity.

A study comparing eating behaviors of overweight and lean 13- to 17-year-olds found that the overweight adolescents consumed more energy when brought to a food court and told they could eat as much fast food as they wanted (63). Differences in energy consumption were also assessed among participants according to days they ate fast food and days they did not. The overweight youth consumed ~400 more calories on the fast food days than on the non-fast food days, whereas there was no difference among the lean participants. The MIT Growth and Development Study followed 100 non-obese, mostly white girls, over a 10-year period (64). Girls who ate what was called quick-service food two or more times a week had the greatest mean increases in BMI *z* scores; however, eating at other restaurants did not have an effect. Although there has been a lot of speculation on the role of the physical environment on increasing weight, a study by Burdette et al. (65) did not find an influence of geographic access to fast food restaurants on BMI among low-income preschool children.

Portion Size

Food portions have increased in all settings, but few studies have examined the effect of portion size on overall energy intake in children (66). Among 3- to 5-year-old children, energy intake increased ~15% at lunch when a portion size of an entrée doubled, but the response was not related to a child's BMI (67). It was also shown that increasing the portion size of lunch resulted in increased food intake among 5-year-olds but not among 3-year-olds (68). Meals from the rest of the day were not studied. More research is needed on how portion size affects energy intake.

Meal and Snack Patterns

Breakfast consumption among youth has decreased from 1965, especially among adolescents (69). Cross-sectional studies have consistently reported positive associations between breakfast skipping and overweight. Longitudinal studies are less consistent. The GUT study, a national, longitudinal cohort study of 16,862 adolescent girls and boys, found that children who never ate breakfast had lower energy intake than those who did eat breakfast (70). According to self-reported BMI, overweight children (9 to 14 years) who never ate breakfast actually had a decline in BMI over the 1-year period of the study relative to overweight children who ate breakfast. Normal-weight children who never ate breakfast gained weight compared with those who ate breakfast.

Sequential USDA surveys indicate that the number of snacks per day and the number of calories from snacks has increased in all age groups of children since 1977 (71). Numerous cross-sectional studies, however, have reported no association, negative association, or even an inverse association between snacking and obesity in children. One longitudinal study followed 173 white girls between the ages of 5 and 9 (72). In families where one or both parents were overweight, analysis found a joint association of TV viewing, snacking, and increasing BMI.

Other Dietary Relationships: Fruit and Vegetable Consumption

The GUT study found that in 9- to 14-year-old girls, there was no relationship between fruit juice and vegetable intake, alone or in combination, and changes in BMI *z* score (73). In boys, there was no relationship between fruit and vegetable consumption and overweight. There was an inverse relationship with vegetables, but after adjusting for calories, it was not significant. In the majority of eight cross-sectional studies, there was no relationship between fruit and vegetable consumption and overweight among children. These studies typically did not control for energy intake or physical activity, and classification varied, with some studies including potatoes and fried vegetables as vegetables and some including fruit with the juice. Some studies had an inadequate number of questions.

Despite concern that consumption of 100% fruit juice by children may increase weight, three longitudinal studies have not found a relationship between 100% fruit juice and overweight in children (33,74,75). In six cross-sectional studies, three found no relationship, and three found a positive relationship, one of which was to apple juice only.

Dietary Fiber

A World Health Organization report in 2003 indicated that in adults, dietary fiber is protective against weight gain and obesity. Far fewer similar studies have been conducted among children, although there is no physiological reason that the results should be different (76). Nevertheless, two longitudinal studies using 24-hour recall or FFQ found no association between fiber and overweight in children (45,46).

Calcium and Dairy

Longitudinal and cross-sectional studies with youth have mixed results regarding calcium and dairy intake. Methodological problems with these studies include classifying what are dairy foods and determining how much calcium is in a food, with so many foods, such as orange juice, being fortified today. A mixture of 24-hour recalls and food frequency surveys have been studied, most without adjustment for energy. The MIT Growth and Development Study found no association with BMI *z* score or percentage body fat for calcium or dairy intake (77). Another longitudinal study of 52 white, upper/middle SES boys and girls followed from 2 months of age for 8 years found that calcium intakes were negatively related to percentage body fat assessed by DXA (78).

Food Insecurity

Almost no studies have been conducted with either adults or children regarding food insecurity and overweight. Most of the studies with children have been limited by small sample sizes and parental reporting of children's height and weight. The few studies that have been done show no relationship or a negative relationship. In adults, cross-sectional studies have found a positive relationship between mild to moderate household food insecurity and overweight in U.S. women, after adjusting for SES.

Summary

There is strong suggestive data for breast-feeding being protective, although it may have a weak overall effect, and for eating away from home and fast foods and soft drink consumption as risk factors for childhood overweight. There is weak evidence for dietary fat, total energy, breakfast skipping, fruits and vegetables, and snacking. There is insufficient information to draw conclusions on fiber, portion sizes, calcium, meal patterns and eating frequency, and food insecurity. Studies of dietary determinants of obesity in youth have the following characteristics that limit the usefulness of the data:

- Most are limited in size and scope, and are generally inconclusive;
- Have confounding variables often not accounted for, such as parental BMI, SES, energy expenditure, and physical activity;
- Rely on different measures to assess diet (24-hour recall, 7-day records, food frequency) and adiposity, including reliance on self-reported BMI;
- Lack reliable assessment tools for dietary intake; and
- Lack capacity to identify the small daily imbalances in energy intake that are associated with development of obesity.

In addition to the major issues with regard to the measurement and assessment of dietary intake, there is also a need for data on ethnic differences and SES. Other reviews have also found limited evidence for dietary determinants of childhood overweight. A World Health Organization literature review indicated that high-fiber intake and probably breast-feeding protect against weight gain and obesity in adults and adolescents. Evidence for increased risk was convincing for high intake of energy-dense micronutrient-poor foods and probable for high intake of sugar-sweetened beverages. More recent data have indicated a positive relationship of risk of overweight with eating away from home.

A 2001 literature review by The Center for Weight and Health, University of California, Berkeley, found no consistent documented evidence for the association of various groups of food with childhood overweight. They listed weak evidence for consumption of fat, fruits and vegetables, fast foods and eating out, snack foods, sugar-sweetened beverages, and meal skipping. They listed mixed or very weak evidence for total calories, energy density, fruit juice, and food insecurity.

Review of Physical Activity, Sedentary Behavior, and Overweight among Youth

James F. Sallis, Ph.D., Department of Psychology, San Diego State University, San Diego, CA (with the assistance of Rodrigo S. Reis, Ph.D.)

Dr. Sallis described studies that focused on the impact of physical activity and sedentary behavior on overweight among children and adolescents. His discussion emphasized the need to examine physical activity and sedentary behavior separately.

Physical Activity Guidance

Although there is not consensus on physical activity guidelines for youth, most statements, including those from the International United Kingdom Consensus Group and the National Association for Sports and Physical Education and the Dietary Guidelines for Americans, recommend 60 min/d of moderate to vigorous activity irrespective of age. In addition, for youth, the AAP and Healthy People 2010 both propose TV restriction to 2 or fewer h/d (http://www.healthypeople.gov/).

The proportion of children reaching these goals declines dramatically with age. For example, a study based on 7 days of monitoring with accelerometers showed that although 100% of children in grades 1 to 3 met the guideline of 60 min/d of moderate to vigorous physical activity, this percentage rapidly declined, until in high school, <40% of youth met the guideline (79). Regardless of how activity is measured, boys at virtually every age get more activity than girls.

Modification of the Relationship between Physical Activity and Overweight by Physical Activity Measures

In a review of >100 studies of correlates of physical activity, about one-half of studies among children ages 3 to 12 and fewer than one-third of studies among adolescents found a relationship between activity and overweight (80). The relationship did not depend on the quality of the physical activity measures. Even in prospective studies of self-reported physical activity, only about one-half showed a significant relationship with overweight. One that did was the GUT study of 10,779 children 9 to 14 years old. In this study, based on parental reports of BMI and physical activity, there was a statistically significant association after a 1-year follow-up in girls at but not in boys (45). The same variability was found among studies that used more objective measures of physical activity. For example, among 106 predominantly white children starting at age 4 years using motion sensors, inactive children were nearly 4 times as likely to increase triceps skinfold (SF) thickness as active children (81). Another small study of 138 Pima Indians did not find a relationship between energy expenditure as measured by doubly labeled water at age 5 and weight or percentage body fat 5 years later (82).

In a cross-sectional study of 11- to 15-year-old girls and boys with a high representation of ethnic minority children, high levels of physical activity measured by accelerometry were associated with lower prevalence of being at or above the 85th percentile of BMI (83). A study in Montreal of over 2000 9- to 12-year-old children found that recreational activity significantly predicted subsequent BMI for girls at 1-year follow-up and for boys at 2-year follow-up (84). A European study of 8-year-old children followed for 4 years had no statistically significant findings (32). These mixed prospective results were all from studies with young children, not adolescents. The inconsistent results that occur across study types, age of children, and ethnicity may be attributable to the difficulties of measuring physical activity

Sedentary Behavior and Overweight

A review of studies related to sedentary behavior and overweight in youth found 21 significant and six non-significant associations in cross-sectional studies and five significant and one non-significant associations in prospective studies (85). Despite this generally consistent evidence, there were numerous inconsistencies across studies that used different measures of overweight and sedentary behaviors, and within studies, not all comparisons were significant across subgroups. Associations between overweight and sedentary behavior were strongest in the 8- to 12-year-old group, the peak years for watching TV. The findings were more often significant for boys, who also watch more TV than girls. Parental reports of sedentary behavior were more likely to be significant than child reports. Also, recent studies were more likely to have statistically significant associations. Efforts to reduce sedentary behavior in overweight youth have had some success in producing weight loss. One study showed that those who earned TV time by riding a stationary cycle lost weight (86). Setting goals for reducing sedentary behavior or for physical activity has been found effective for weight loss (3,9).

Changes in Physical Activity Rates and Sedentary Behavior among Children

The proportion of 8th to 12th graders who watched at least 4 hours of TV per day on weekdays declined modestly over the last decade but is still 25% (http://www.

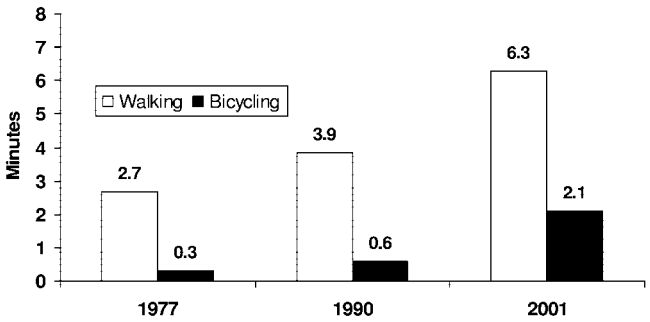

Figure 2: Average active travel time in minutes of children 5 to 15 years in 1977, 1990, and 2001. Source: Nationwide Personal Transportation Survey 1977, 1990 and National Household Travel Survey 2001.

childtrendsdatabank.org/indicators/55WatchingTV.cfm). In the last generation, the percentage of high school students attending physical education (PE) classes at least 1 d/wk has declined to about a one-third of students, although it has recently increased slightly (87). Over a 25-year period, the duration of walking or biking trips to school has increased by a few minutes but remains at <10 minutes per school day (Figure 2) (88). However, walking to school as a percentage of school trips fell from ~20% to 12% over a 25-year period. Meanwhile, the number of daily car trips outside the home for 5- to 15-year-old children increased by 60% to a mean of 3.5, suggesting that children are traveling more in cars (88). Preliminary results of a longitudinal study of elementary school students found that boys, but not girls, who walked or biked had significantly less increase in BMI and SF measures (Cain, Sallis, et al. Presentation at the Society of Behavioral Medicine, 2004).

Summary

Similar to dietary intake, objective measures of physical activity are generally not sensitive enough to identify sources of a daily 50 or 100 cal/d energy imbalance that can lead to obesity. There appears to be a consistent relationship between sedentary behavior, particularly TV watching, and overweight. However, a recent meta-analysis concluded that although a statistically significant relationship exists between TV viewing and body fatness among children, it was likely to be too small to be of substantial clinical relevance (89). There are not enough studies on other forms of sedentary behavior, such as playing computer and video games, to draw any conclusions. More studies are also needed on active commuting to school. There are not enough data on associations in specific subgroups; younger children have been studied more than adolescents. With regard to trends, unfortunately there are no good U.S. data on youth physical activity trends, although TV viewing has declined slightly. However, other forms of screen watching may be substituting for TV. Although time walking or biking to school has increased by a few minutes, the total activity is almost trivial. The quantity of PE in high school has declined somewhat, but there are no data on elementary schools and no data on the quality of PE or the amount of activity in that PE on a national basis.

Recommendations

Recommendations include:

- Prioritizing national surveillance of youth physical activity, using objective measures and sedentary behaviors to identify trends in youth activity, especially in population subgroups;
- Beginning a national surveillance of selected psychosocial and built environment correlates of physical activity and sedentary behavior because to prioritize intervention strategies, it is important to know whether the underlying influences on physical activity are moving in the right direction;
- Developing practical, objective measures of sedentary behaviors because low levels of counts in accelerometers are an indication of sedentary behavior, but they do not tell whether a person is watching TV, listening to music, sitting at a computer, or just being very quiet; and
- Examining separate interventions for physical activity and for sedentary activity because these are independent behaviors, not opposite ends of a spectrum, and they need to be investigated differently and have distinct interventions to improve them.

Common Issues for Dietary and Physical Activity Influences

During discussion, it was noted that research was expanding from trying to understand diet and physical activity based on personal characteristics—who people were and what they do and eat—to seeking greater understanding by looking at where and when people are more active and eat healthier. Place can inform interventions at the individual and certainly at the policy level, but timing might be of interest as well. Both discussants noted the limitations of the large majority of studies that have not examined physical activity and diet together. For example, when children are physically active, they tend to eat more. On a limited basis, the GUT Study has attempted to evaluate the joint effects of both (45). In such longitudinal studies, it is possible to create clusters of families with high activity, low energy intake, and low percentage fat and other clusters of families with low activity and high intake that would presumably be more prone to obesity.

The error in any of the current measurements is substantial but is much greater for exposures (diet and activity) than for outcomes (weight change and overweight). Specifically, children under 9 or 10 should not be asked to self-report height or weight or answer food frequency or phys-

ical activity questionnaires. Because these errors are so large, it is important to have more interventional research with randomized controlled designs to control for the various influences, as opposed to trying to disentangle or separately model the energy intake and the energy expenditure in observational studies. Assignment to interventions that widely separate intake and activity is more likely to overcome measurement error than is possible in observational studies. Observational measures could be improved if we could use, for example, daily accelerometers and multiple 24-hour dietary recalls.

Session II: Environmental Determinants

This session addressed an emerging paradigm on how the built environment, the family environment, and the social environment affect determinants of obesity.

Effect of Built Environment on Overweight among Children

Walker S. Carlos Poston, Ph.D., Mid-America Heart Institute and University of Missouri-Kansas City, Department of Clinical Health Psychology, Kansas City, MO

Review of the Literature

The study of the role of the built environment in obesity is relatively new. Because the poor and minorities share a greater obesity burden, an area of special interest is the role of socioeconomic disparities and trying to understand these disparities through studying the environment. The built environment has been defined as "comprising urban design, land use, transportation systems, and patterns of human activity" (90). To answer the question "What is the body of evidence with respect to the built environment and childhood obesity?" an OVID Medline search was conducted that cross-indexed BMI, body weight, obesity, overweight, and adipose tissue matched with children, childhood, or any derivatives thereof, and then crossed again with anything that resembles the built environment. Only two articles were found that satisfied this combination of terms, one of which was an editorial on the fact that playgrounds that are in poor areas often are in poorer condition than those in wealthier areas (91). The other was a review of the built environment and childhood health that concluded that "this issue has received little attention from researchers or policymakers" (92).

Going beyond a restricted literature search, only three studies were found that addressed the role of the built environment and obesity in children in any way. One focused on the issue of material deprivation as an indirect proxy for a poor environment, and two had direct measures and some interesting findings. In the indirect study that involved >20,000 children in the United Kingdom, an index of material deprivation known as the Townsend Score found that the greater the deprivation in both boys and girls, the greater the likelihood of obesity (93). Although not all of the findings were statistically significant, nevertheless, the pattern was consistent with some of the material deprivation studies with adults as described below. In one of the other studies of a population of about 7000 urban, low-income preschoolers in Cincinnati, overweight was not associated with proximity to playgrounds and fast food restaurants or with the level of neighborhood crime (65). A study among African-American Boy Scouts reported that consumption of juice and vegetables was associated with their availability (94).

A review prepared for the Institute of Medicine's report on "Preventing Childhood Obesity" found no consistent relationship between physical activity and the built environment (95). Part of the lack of a relationship may be due to inconsistency in how both the environment and physical activity are measured. Similar inconsistencies were also found for travel behavior. It is possible that as better measures are developed, the relationships may be more consistent. Because of the paucity of information on the influence of the built environment on childhood overweight, the remainder of this review examined studies among adults.

A number of studies have examined the indirect and direct measures of the built environment and obesity in adults (96–104). Most of these are cross-sectional studies because very few longitudinal studies exist. The four studies using indirect measures used proxies of the built environment such as SES or deprivation in an area or combined deprivation with some attempted measure of the environment. For example, business pages in a telephone directory have been used to locate the number of institutions in an area.

In the United Kingdom, in a study of four neighborhoods that were identified by level of material deprivation as measured by social class status, unemployment, car ownership, crowding, and a few other factors, a relationship was found between level of deprivation and BMI and obesity risk (104). Other studies have had similar results in a variety of settings (101–103). More generally, it has been shown in the U.S. that persons who live in poorer areas have poorer health (105,106). A problem with such studies is that we cannot tell why the relationship exists, e.g., what features of the environment led to the outcome.

Among six studies of adults that included direct measures of the built environment, in one neighborhood, weekly physical activity was 70 minutes longer and BMI was 2 kg/m^2 lower, on average, in the highly walkable area than in the lower walkability areas (100). A study in Perth, Australia, collected self-reported height and weight from a fairly large number of adults and looked at both direct and indirect measures of the built environment. After control-

ling for a number of factors, including SES, they found that a number of factors that discouraged walking, such as proximity to a highway or not having sidewalks, were associated with overweight (99). In a study in Kansas City, obesity prevalence was substantially higher in the lower income areas where the density of institutions that the authors considered possibly related to obesity (such as fast food, convenience stores, bars/liquor stores) was also substantially higher (107). Obesity prevalence was 34.6% in the low-income block groups vs. 19.3% in the high-income groups. A similar result was found according to density of institutions in units per 1000 people and units per square mile. Actual use of the institutions was not assessed. A study in Atlanta examined a number of features of the built environment with self-reported BMI among nearly 11,000 adults. A calculated measure of more diverse land use, meaning a greater mix of residential, commercial, office, and institutional use, was associated with decreased prevalence of obesity. This relationship was stronger among whites than blacks (98). A sprawl index based on density, land use mix, centering, and street accessibility was applied to 448 counties participating in the Behavioral Risk Factor Surveillance System in which higher scores on the index represented greater sprawl (97). Adult residents of counties with less sprawl walked more and had a lower prevalence of obesity.

A related area of research concerns how the physical availability of healthy foods affects diet. One study that examined the choices available for a wide range of communities found supermarkets, which offer a wide variety of foods at lower prices, to be less accessible by poor and minority communities (96).

Recommendations for Research

A behavioral ecologic model has been proposed that assumes that the physical and social environment explain and influence behavior. Rather than looking at proxies of the environment, as has predominantly been done until now, it is necessary to look at actual, real environmental markers, which require detailed measurements within communities. Such studies are necessary to work through the problem in epidemiological studies in which constructs such as SES can be shown to be related to obesity, but the direct causes cannot be shown. The model suggests that areas of socioeconomic factors influence the actual physical environment such as the densities of certain types of institutions, and these may affect caloric consumptions and physical activity levels and, ultimately, risk for obesity. The model also suggests that socioeconomic factors and the built environment may have biological effects, such as influencing the perinatal environment and physical stress, although this concept is more tenuous.

Although there are few studies on built environment and health, there are enough epidemiological studies with indirect measures that should encourage deeper investigation regarding what in the environment predisposes people to poor health and then what can be done about those elements of the environment. For example, studies have used census indicators of material deprivation or telephone books as a way of surveying and estimating what goes on in an environment. In a pilot study, the discussant learned that even in the most recent, up-to-date reverse telephone book directory, 70% of the phone numbers listed were inaccurate. Ultimately, if highly accurate information is needed on what is in an environment, then in-person examination is necessary.

A feature of the built environment may affect children differently from adults. For example, the density of fast food restaurants in an area may affect adult eating habits but may not have any effect on children's eating habits. Also, adults have substantial influence over children's behavior, particularly among young children. In addition, risk and protective factors may vary in complex and unexpected ways. The fact that people live in a more densely connected area does not necessarily mean that they will have improved health. For example, studies that have looked at SES and mortality in urban areas have found that the zip codes that had high mortality risk were also in urban corridors that presumably had fairly good street connectivity and probably less sprawl. Issues of institutional density apart from proximity and actual use of these institutions have not been measured. In other words, there are many interesting and important aspects of the built environment to be studied.

During discussion, it was suggested that other factors within the environment might modulate the effect of diet and physical activity on obesity. An animal model study suggested that if animals are put in very stressful environments, cortisol and other responses that promote obesity are induced. Do violent environments or other such stressful situations, beyond SES, have an effect? Are other measures of stress being developed that relate to obesity in these different environments? Dr. Poston replied that there are instruments for measuring perceived stress; potential stressors, such as crime rates, can be measured and plotted by census tract and incorporated into environmental studies.

The Role of Family Environments in Children's Overweight

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Effective efforts to prevent overweight among children must consider the family as a target of intervention and study the ways in which the family as a context for child development moderates the effects of interventions on children. Accordingly, Dr. McHale focused on principles un-

derlying effective family interventions. Four basic concepts of family therapy and research were discussed: families as systems, an ecological perspective on families, the role of parental socialization in children's self-regulation (e.g., self-regulation of diet; physical activity), and how parents' knowledge and beliefs about parenting affect their parental practices and, in turn, their children's development. As interventions are developed for prevention or treatment of overweight, the implications of each of these principles should be taken into account.

Families as Systems

Four aspects of family systems were discussed: family influences are reciprocal and interconnected, families are embedded in a larger ecology, families are open systems subject to outer and inner influences, and families are homeostatic, but modifiable.

Interconnectedness. Parents do not just impose socialization on children; they react to their children's characteristics, including their developmental characteristics. Parents cannot always treat children the way they would like to because children influence their parents' strategies for dealing with them. A second and very important family systems principle is that changes in one part of the family system have implications for other parts of the family system. Failure to pay attention to these indirect effects in developing interventions can result in consequences for families that were not intended.

Ecological Perspective of Families. Families are embedded in a larger ecology, including a physical environment (such as how far is it to the local grocery store and how easy is it to get there), an economic environment (that determines what people can afford to buy and what they can store in their place of residence, for example), and a cultural environment (including local ideas, especially about what is appropriate to feed children, who is responsible for deciding on a child's diet, and norms about how people use their leisure time). A paper on differences in social class and the ways in which parents socialize children's leisure time argued that middle class families use leisure time to foster positive development (108). Parents choose activities for their children, and leisure time is really a form of work. In contrast, poorer families use leisure time for relaxation and socializing. Such different concepts of the use of leisure time have implications for the types and levels of activity parents encourage their children to do during leisure hours.

Open Systems. Families are subject to change from outside environmental pressures, but they are also subject to change because of changes in their individual family members. Importantly, some families have more resources than others to change their environments and to pick the environments in which they live. From this perspective, affluence can be defined as the ability of families to exert control over their environments (109).

Modifiable Homeostasis. Families tend to be homeostatic (that is, to resist change), but they are modifiable. Both developmental and environmental pressures change families. An important principle from a family system perspective is that one should build on momentum from naturally occurring changes to foster a desired change.

Implications for Intervention

The complexity of families means that there is no single effecter of change, but the complexity also provides for multiple points of entry for interventions. Planned change needs to be multipronged and multidimensional. Individuals and relationships can be targeted; usually, the more targets the better. Interventions can be built on momentum from natural changes such as transitioning to parenthood, a child's entrance into school, or youth's transition to adolescence. Seemingly small changes can have reverberations throughout the family system. Optimistically, family systems are a good focus for intervention.

Ecological Perspective

This second perspective on how families work targets similar themes to those of a family systems perspective, but an ecological perspective has a different emphasis. Families are embedded in a larger, multilayered environment that affords opportunities and resources and sets constraints on choices. From an ecological perspective, the environment is not a place or physical entity but a source of possibilities for and constraints against engaging in certain activities or behaviors. The environment also varies depending on one's point of view. For example, one child may see a vacant lot as a place to play, whereas a child who has grown up believing that private property is non-transgressible or that soccer must be played where there are chalked and measured lines would only see a vacant lot. In other words, perceptions help to determine what people do in their environments.

An ecological model of childhood obesity suggests that children are affected by their parents' and more general family characteristics and also by the larger community, cultural, political, economic, and political contexts in which their families are embedded (110). This multilayered environment affords opportunities and places barriers on children's activities, including their eating behaviors and use of free time (Figure 3).

At the most basic level, environments define subsistence demands for families, that is, how families make their livings. Parents' child-rearing behaviors are grounded in their understanding of their environment's subsistence demands. Accordingly, parents' primary socialization activities are about helping their children develop skills and competencies that will allow them to survive and make a living in a particular environment. For example, one large-scale study showed that fathers in blue collar vs. white

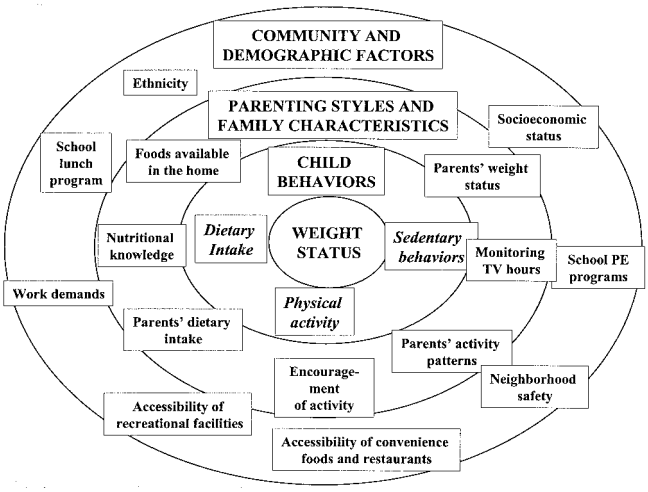

Figure 3: Ecological model of childhood obesity. Reprinted with permission from Davison KK, Birch LL. Childhood overweight: a contextual model and recommendations for future research. *Obes Rev.* 2001;2:159–71.

collar jobs used different child-rearing strategies with their children and suggested that fathers' strategies were based on their expectations about characteristics and competencies their children would need as adults in the world of work. Specifically, fathers in blue collar jobs promoted conformity in their children by using more authoritarian discipline given their expectation that obeying rules and deferring to authority figures (supervisors, bosses) would be important in their children's future jobs. In contrast, fathers in white collar jobs used more democratic discipline strategies to promote characteristics such as independence, initiative, and autonomy, characteristics they expected their children to need in their future work roles (111).

Implications for Intervention

Whether parents' ideas about their children's future are implicit or explicit, their ideas about what a child will need to make a living in the context of a particular cultural, economic, and political environment help to determine how they will treat their children. If parental behavior seems irrational or unhealthful and difficult to change, it is critical to understand where a parent is coming from (literally) and to recognize the way that the parent's behaviors represent adaptations to the needs and demands of a particular local setting.

Parental Socialization and Child Self-Regulation

Developmental research on child self-regulation and the transition from parental control of children's behavior to child self-control has important implications for child obesity and overweight. Studies show that if parents are fortunate, their child will move from complying with external influences (for example, obeying their parents) to internalization of parents' behavioral expectations and values to intrinsically motivated behavior (that is, behaving in ways consistent with their personal values). In the area of eating behavior, young children might not eat treats or junk food because parents are there to tell them not to. A child who has internalized parental values might not eat junk food because she feels guilty violating her parents' rules or because she wants to look beautiful in the minds of others. An intrinsically motivated behavior, in contrast, is self-satisfying, as when a person eats a healthful diet and exercises because he or she values those behaviors and feels best when doing so.

Research has shown that children's ability to regulate their own behavior is grounded in feelings of competence (that is, the knowledge and skills to accomplish their goals), autonomy (that is, choices provided within an adult-engineered environment that allows children to act on their own), and connectedness (i.e., feeling supported in their choices). Thus, parents can promote self-regulation in their children by providing structure, supporting autonomy, and establishing a socializing relationship, the last being, perhaps, the most important. Structuring includes providing clear guidelines and providing reasons behind the guidelines that promote compliance and internalization of parent values. In supporting autonomy, parents teach children that they are responsible for their own behavior and its consequences. Giving children the lead to be responsible for their own behavior is an important step in development. Although some parents can engineer the environment so that their children have good choices, it is important to remember that other parents may not have all of the resources they need to create safe and healthful choices for their children. Finally, having a socializing relationship, one in which children believe that the parents are on their side, makes a difference in how children respond to other parental practices. In an environment of warmth, support, and affirmation of their personal qualities and competencies, children are more accepting of parental values, motivated to comply with parents' rules and restrictions, and eager to model their parents' behavior.

Parental Beliefs and Child Development

A body of literature demonstrates that parents' beliefs, such as ideas about effective child-rearing strategies and the importance of particular child-rearing goals, affect how parents behave toward their children and, in turn, their children's development. A question for professionals concerned with childhood obesity is how to promote beliefs about the importance of healthful diet and exercise patterns for their children. Three principles relevant to such parent education efforts are that information conveyed to parents must be relevant to the family's circumstances, information

should come from a trusted source, and information should be both accessible and useable (112,113).

Information Relevance. The world views of parents affect how they understand and react to information provided by professionals. In other words, people interpret the facts based on their own experiences and their own points of view; thus, it is important for professionals to understand the potential disconnects between the messages they convey and the messages parents receive. It also important for professionals to understand that the many demands parents face in their everyday lives mean that parents must make trade-offs in their child-rearing practices. Thus, for example, when parents are stressed by a demanding environment and limited resources, professionals' ideas about what is best for children in the areas of fat content and exercise may be quite low on parents' hierarchy of concerns. Keeping children safe, quiet, or happy may be more important than taking them out for exercise or making sure they eat a healthful amount of fruits and vegetables.

Parents also have different ideas about how well they can influence their children. A parent who has grown up being overweight and has gone on many diets without success may feel that there is not much she can do to help with her child's weight. In some contexts, parents may believe, and accurately so, that a big child is better able to defend himself; therefore, growth and size are assets rather than deficits. For some parents who are unable to give their children opportunities to develop in other ways (e.g., special intellectual skills, artistic talents), watching a child grow bigger may be a source of gratification for them. In short, knowing where parents are coming from has strong implications for the kind of information they will listen to.

Comfort in the familiar is another reason it is difficult to change families. Knowledge is constructed, reflecting self-identify and group belonging. Thus, asking people to change in ways that are not sanctioned by others who are important to them may lead to negative interpersonal dynamics and social ostracism. Another problem is that, when child-rearing strategies seem to be working, parents are likely to believe that their current knowledge is sufficient. One of the biggest challenges in the area of childhood overweight is that the future negative health implications of obesity and overweight are far down the road.

Trusted Source. A tenet of parental education is that information must come from a trusted source. Parents' history with professionals will affect their trust in the message; this may be a special issue with minority groups, given their history and social position in U.S. society. Parents have many sources of information and advice. Information from people they know already and trust is going to seem much more credible than information from a distant professional.

Accessible and useable information must include how the message can be acted on within the resources and constraints of the family environment. In addition, the modality of the message must match the parents' learning styles. Print media on the Web, in a pediatrician's pamphlet, or in a book about child development are fine for highly educated, older, affluent class parents. For others, text information by unknown professionals will receive less attention than information conveyed personally by a local, trusted source.

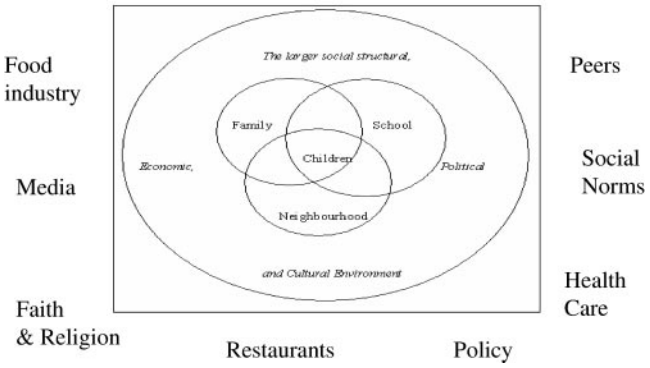

Figure 4: Constituents of a child's social environment.

Summary

In summary, the fields of family studies and child development have relevant information for those interested in preventing or intervening with childhood overweight. In particular, research in these fields has documented effective parenting strategies (structure, support, and a socializing relationship) that can be applied in the area of child health. Further, intervention research on families highlights important principles for effecting change, including building on the momentum of naturally occurring changes, using a multipronged approach to target several elements of the family system, relying on trusted sources to convey information in a modality that matches the parents' learning styles, and ensuring that the content of messages about child health is accessible and useable. Most importantly, an understanding of the family ecology is essential for crafting messages about health practices in a way that makes those messages credible to and useable by families.

Effect of Social Environment on Childhood Overweight

Lisa Klesges, Ph.D., Mayo Clinic, Rochester, MN

Children are embedded within a broad social environment (Figure 4). In addition to the child's family environment and the built environment of the child's school and neighborhood, the child lives within a larger social environment of economic, political, and cultural influences. This socioeconomic-cultural environment, with its food industry, media, faith, restaurants, peers, social norms, health care,

and policies, influences the obesity epidemic. Therefore, we need effective population-based approaches to modify the environment and influence children and adolescents. This review focused on ideas and interventions that showed success related to affecting the social environment. The evidence for social influences on a child includes non-familial social relationships, social community structures (in particular, schools, health care, faith/religion/spirituality, and eating patterns/restaurants), and the larger social system, including the media and advertising.

Non-Familial Social Relationships

Between 1979 and 1999, children became less concerned about overweight (114) Concern about overweight varies, of course, depending on race, age, etc., but this has been the trend, which is important to recognize when trying to develop risk perception, susceptibility, and motivation for change. Peers also influence beliefs and behaviors related to overweight. Physical activity is influenced by social support and other social influences, although there seem to be gender differences (80,115–117). Eating behaviors are influenced similarly (118–120).

A study of African-American girls found that when the need for social approval was greater, there was a greater discrepancy between measured and self-reported BMI, measured physical activity levels, and soft drink consumption (121). How social approval or influence and the perception of a social normative idea of overweight come together to influence an individual child's behavior has not been explored.

Social Community Structures: School Influences

Fat Content of School Meals. Reduction of fat content in school meals is achievable (122–124). How fat content is related to overweight is not clear, and some of the relationships to BMI have been inconsistent (122,125). It appears that it is easier to lower dietary fat intake for children (122,126) than it is for adolescents (125,127). Although the results have been mixed, school-level interventions have potential to reduce fat content and body mass.

A la Carte Foods and Beverages. A la carte foods and beverages generate revenue for schools and are widely used. A la carte foods are disproportionately high in fat and sugar, with candies and sweetened beverages tending to be highly available (128–130). Sweetened beverages, in particular, have shown a strong relationship to overweight and obesity (57,131,132). A school-wide, although individual level-based, educational intervention reduced the number of carbonated drinks children were consuming and resulted in a decrease in the number of overweight and obese children (7). Further research in these areas should evaluate children overcoming their environment.

Pricing in Vending Machines. Lowering the price of fruits and vegetables and low-fat snacks in schools and vending machines promoted purchases within schools and influenced eating behaviors, although it is unclear how this related to overweight (133,134). Only a 5% shift occurred in overall revenues when prices were raised on high-fat foods and reduced on lower fat foods (135). Further examination of the relationship of the price changes and purchases should include changes in weight or overall eating behaviors.

Physical Education (PE). This is probably the most developed area of social environmental interventions related to child overweight. The Community Guide to Preventive Services has cited strong evidence that offering PE and actually changing the PE environment increase activity during PE time and are related to reductions in BMI, particularly for boys (125,136–138) Unfortunately, barriers to implementation may limit the effectiveness of the approach (125,139,140). Nevertheless, the considerable evidence on the benefit of PE suggests that efforts should continue to translate and disseminate the discipline to obtain a public health impact. For example, among adults, observing activity in one's environment, such as seeing other walkers in the neighborhood, influenced women to walk. Whether this is also true for children's levels of physical activity has not been explored.

Community Structures

The influence of counseling and guidance on overweight in pediatrics has not been adequately evaluated, even though interventions and treatments are available. One study found that improvements in physical activity and dietary behaviors could be achieved with adolescents through primary care counseling (141). The Robert Wood Johnson Foundation is sponsoring a program at four pediatric primary care sites in North Carolina that includes assessments and counseling activities to help prevent excessive weight gain in children.

Because spirituality has a positive influence on risky health-related behaviors such as smoking, alcohol, and sexual promiscuity, this may also be a means to address health behaviors related to obesity. However, the influence of religion, faith, and spirituality is unknown with regard to eating and physical activity behaviors or to overweight among children. One study found that among other factors, spiritual beliefs influence fruit and vegetable intake among seventh graders (127). Among adult men, Protestant religious affiliation was associated with higher self-reported BMI (142). Others have reported the use of a faith-based setting for delivery of interventions in adults but not in children (143–146). These social environment settings present a potential opportunity for addressing child and adolescent overweight.

Larger Social Context

Eating Away from Home. The proportions of food consumed by children in restaurants and fast food outlets in-

creased nearly 300% between 1977 and 1996 (147), and it is known that fast food intake is related to greater intake of energy-dense foods, fats, and sweetened beverages (133,148). Frequency of eating fast food has been associated with increased BMI (64). Although a social environment intervention is unlikely to affect whether families eat away from home, it is possible to consider changing the foods offered in those environments to lower the energy intake. Because the restaurant industry responds to market demand, a number of chain restaurants are providing meals for children that have reduced fat and higher availability of fruits and vegetables included in them. However, offering healthier foods has been tried before with little success, and current efforts have not been evaluated.

Media and Food Marketing. Evidence of the pervasive exposure of media on childhood overweight is largely not available. Some studies have shown that children's requests and parent purchases of advertised foods on TV are related to the hours of TV viewing (149,150). One experiment manipulated exposure to advertisements of certain foods during a summer camp and showed an increase in Kool-Aid and candy consumption and reduced fruit selections (151). Given that greater TV exposure is associated with greater overweight, it is, perhaps, surprising how little content analysis there has been of food commercials to attempt to understand how they influence children's perceptions or eating behaviors. Other sources of advertising that have not been researched include counteradvertising, product placement, fast foods in schools, the popularity of logos, and the Internet.

Media and Physical Activity. Other than the studies showing that TV viewing tends to reduce physical activity and the large social marketing campaign of the Centers for Disease Control and Prevention (CDC), VERB It's What You Do, there is very little research available on physical activity and the media (www.cdc.gov/youthcampaign). An outcome evaluation will provide some surveillance data on the influence of the VERB media campaign on increasing physical activity.

Other Societal Approaches. Other potential approaches worth considering to change the social environment and influence childhood overweight include fostering community organizing and community action, especially around the structures mentioned above; providing economic incentives; consideration of preschool and after-school environments; design of all aspects of the built environment; working with the food industry and regulators on food choices, portion size, packaging, and labeling; and using food assistance programs to reach special populations (152–157).

Social Moderators

Moderators of effects in the social environment include social capital, SES, race, gender, ethnicity, and all of the variability in perceptions and influences of the overall social environment on the child. A number of targeted interventions related to child weight are considering these influences, some within the family and some within the larger social structure of schools, housing developments, community centers, etc. Interventions that are using the social environment to influence individuals have included Pathways, Girls Health Enrichment Multisite Studies, Hip-Hop to Health Jr., and GO GIRLS.

Summary

Further research should pursue faith-based, primary care, and policy approaches. Much more information is needed on both the efficacy and effectiveness of interventions to prevent and reduce childhood overweight and how they can be translated into the larger social environment.

Session III: Measures of Determinants of Overweight among Children

Dietary Intake Measurement

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Information collected on dietary intake includes the prevalence of meeting healthy patterns such as eating at least five servings a day of fruits and vegetables or unhealthy patterns such as eating a high-fat diet, estimates of daily nutrient intake, and an emerging area on exposure to unhealthy eating influences such as fast foods and vending machines. Four major methods for assessing dietary intake are 24-hour recall; dietary records or food diaries; short diet screeners, which have gained in popularity recently; and FFQs. The values and limitations of each method were reviewed. All of the methods share one major limitation, which is the reliance on a participant's ability and willingness to recall dietary intake. This problem is particularly true in obesity research, where demand characteristics tend to be a significant issue. A demand characteristic is a potential bias in which subjects under- or over-report their behaviors so that they seem more favorable to the study investigators.

24-Hour Recall

Twenty-four-hour recalls are one of the most widely used methods and are considered a criterion standard in many studies. They are conducted by trained interviewers who use visual cues, such as food models, to estimate portion sizes. Major strengths include their accuracy and the ability to collect information on portion size, which can be estimated for all foods. In addition, information can be collected on the context in which the food was eaten, which can be an important item in trying to answer questions such as why TV viewing is associated with obesity and how this affects

children's eating patterns. An experienced interviewer can probe during the interview to ensure that foods are not forgotten.

One limitation is the requirement for a highly skilled interviewer who knows how to use memory aids and probing questions. It requires face-to-face or telephone interviews, which may make it difficult to achieve a necessary sample size, especially with adolescents who tend to change their schedules and plans repeatedly and suddenly. This method also is highly labor-intensive and, thus, expensive because of the need to conduct multiple interviews to capture the 24-hour variability of dietary intake, which tends to differ considerably on weekdays and weekend days. Unless at least several interviews are conducted, this method is not a good measure of long-term dietary intake.

Food Diary

Study subjects are asked to keep a diary of all of the foods and beverages they consume. Mixed dishes (such as a cheeseburger or a stir fry) must be broken down into their components (such as a bun, mayonnaise, ketchup, pickles, onions, meat, cheese, etc.), and portion sizes are recorded. Sometimes subjects are asked to report on the context in which the food was eaten. Diaries are kept for 3 to 4 days or longer, which provides a better indicator of usual dietary intake than a single 24-hour recall does. The records also can be used in weight-loss programs to increase subjects' awareness of what they are eating and as a useful teaching tool.

This method places a large burden on the respondent and can be expensive because subjects, especially adolescents, may expect to be compensated for the time and effort being asked of them. Data must be coded and entered into a database, which is labor-intensive. Another problem, particularly in studies of adolescents, is changing eating patterns to make intake easier to report. For example, eating a lot of mixed dishes means listing all those components and their respective amounts. The method also is susceptible to demand characteristics. For example, a person may write down "three cookies" and then later think, "That's a lot," erase it, and put down "one or two cookies." Also, although subjects are instructed to report the food immediately after they have eaten, frequently they delay doing so, thus increasing recall errors.

Short Diet Screeners

In this popular method, a brief set of questions is used to assess one or more components of diet, such as fruits and vegetables and high-fat foods. The method has been used frequently in large studies where diet was not the primary focus, such as the Youth Risk Behavior Surveillance System and the Add Health study. Screeners may be as valid as longer assessments for fruits and vegetables but not for high-fat foods (158–159). Because fat is contained in so many foods, this method probably results in a poor estimate of both total fat consumption and types of fat. The largest problem is in interpretation, in which spurious associations may be found because measurement error may be nonrandom.

FFQs

FFQs are less expensive than recalls or diaries but are more substantial than a brief screener. They consist of checklists of foods that measure long-term intake, typically over a week, month, or year. Contributing to their limitations in children is the fact that FFQs were developed in the context of nutritional epidemiology of adults, looking at the development of chronic diseases such as cancer and cardiovascular disease. The original purpose was to rank subjects in consumption of nutrients of interest. Original criteria in the development of FFQs included a need for a sufficient quantity of the nutrient in the food, and the foods assessed should be the ones that discriminate among individuals, rather than those that contribute the most to absolute intake (160). If everybody in the sample ate the same food, there would be no variation and, therefore, no point in including the foods on the FFQ. On the other hand, researchers studying obesity want this information for accurate estimates of caloric intake.

Portion size is included on some FFQs but not on others because, as the literature from adults suggests, inaccurate estimates of portion size seriously limit the utility of the information. People are best at estimating portion sizes for commonly recognized servings such as a can of soft drink or a bottle of beer. People do not estimate well portion sizes they do not think about in their everyday lives, such as 4 or 8 ounces of milk. For this reason, some FFQs collect no information on portion size. Semiquantitative food frequencies specify a portion size as part of the question, such as listing milk (8-ounce glass) or bacon (two slices). Quantitative FFQs ask for the frequency of consuming the food and the portion size. The Block instrument may be the best known quantitative FFQ (161).

Mixed dishes are an area of contention in FFQs. When the Youth Adolescent Questionnaire was developed for the children in the GUT study, who are offspring of participants in the Nurses' Health Study II, it was thought unlikely that adolescents were going to remember all of the components of, for example, a stir fry and record them correctly (such as rice in one section, red pepper and mushrooms in another section, chicken in the main dish section, and so forth). The Youth Adolescent Questionnaire included some mixed dishes, with the assumption that the components and the sizes of those mixed dishes did not vary across subjects. This assumption is, of course, questionable and a possible area for further study. A larger problem with including mixed dishes is that there is such a wide variety of such dishes, no questionnaire could include them all and still be

a manageable length. It is difficult to decide which ones really need to be on the FFQ. Consumption among some ethnic groups, such as Asians, is poorly measured. Also, food courts offer numerous popular mixed dishes, none of which would be included on most FFQs.

Strengths of FFQs include that they are self-administered and relatively inexpensive, making them easy to use in large studies. For example, in the GUT study of 17,000 children, any other method would have been too expensive. FFQs also provide a good estimate of long-term intake and have an adequate to good ability to rank subjects in terms of macro- and micronutrients, including variations on a nutrient of interest. Because FFQs are usually the only viable option for large epidemiological studies, it would be valuable to determine how they can be improved. Errors in estimation or measurement of portion size are more important issues in studying children than in studying adults. For example, the difference between portion sizes for an 8-year-old girl and a 16-year-old boy is significant. In addition to portion size issues, FFQs are better at ranking subjects than at assessing absolute intake. More validation work is needed before using them as predictors of the effects of dietary intake of specific foods on weight. Correlation between FFQs and 24-hour recalls or diet records is only modest for total caloric intake.

Challenges in Assessing Dietary Intake

Portion Size. Current methods to assess dietary intake have potential problems due to having to rely on participants' accuracy of their memory and/or willingness to report intake. Moreover, the increased use of prepared foods, whose portion sizes vary widely, is a new challenge that future assessment methods should address. Rapid changes in food intake trends (such as low-fat giving way to low-carbohydrate) can make questionnaires and databases out of date. Food prepared away from home has an increasing impact. Again, people are unaware of the food content, and serving sizes eaten away from home are usually larger. Actual portion sizes and USDA default sizes have shown that estimates of default sizes of chocolate chip cookies are off by 700% and for bagels, by 200% (162). Nutrient estimates will be inaccurate without knowing the source of foods. The same variation in portion size is true for servings in fast food restaurants (Figure 5) (163). Determining a default serving size is difficult. If a mean is used, how well does it represent all of the children in the sample? One solution might be to include questions on where the food was purchased: a bag of cookies from a grocery store? A chocolate chip cookie in its own bag? Or a cookie from a bakery? The latter two are usually, but not always, larger than cookies in a package purchased at the store.

No study has addressed the important question: If children and adolescents cannot estimate portion size, would a quantitative FFQ add more error than using default portion sizes? Preliminary data from a pilot study suggest that adolescents are confused when a question has a specified portion size when that is not what they usually eat. If asked about number of portions of large fries, and the student always orders medium fries, the student may give the number of medium fries as a response or may take the question literally and respond with a zero. Studies are needed to assess how well children can report on portion size and how well children answer questions when the serving size they consume is different from the one specified. Studies also are needed to compare the validity of questionnaires with adjusted portion size information to semiquantitative questionnaires with default sizes to understand whether this adjustment is necessary.

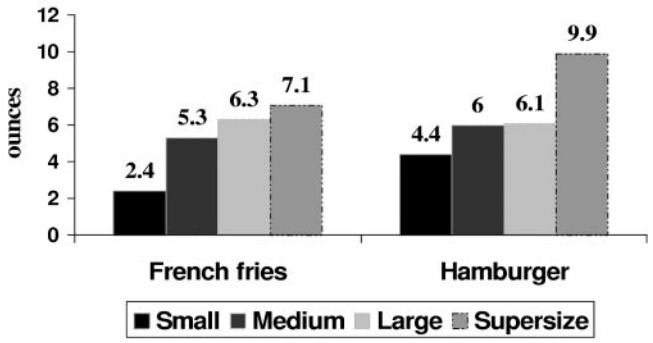

Figure 5: Portion sizes at fast food restaurants. Reprinted with permission from Young LR, Nestle M. Expanding portion sizes in the US marketplace: implications for nutrition counseling. *J Am Diet Assoc.* 2003;103:231–4.

Calories. Although a slight inequality in the ratio of energy intake to energy expenditure will result in weight change, none of the dietary intake assessment tools or the physical activity measures are finely tuned enough to pick up that modest difference. Perhaps the focus should be on how children eat rather than on trying to measure energy balance.

Unhealthy Eating Influences. Unhealthy eating influences deserve more study. The influences include, for example, defining what is fast food and the changing food options in vending machines. To better understand dietary intake from these sources, context needs to be studied, particularly to conduct interventions at the sites where the children are being influenced by unhealthy eating options. Are children mainly eating super sizes when eating with friends at the mall? Or are they having large size portions at home because that is what their family eats? Such contextual information is not usually included on short diet screeners or FFQs but could be assessed with 24-hour recalls. Because multiple 24-hour recalls are not practical for large studies, they should be used to craft and develop questions to be included on questionnaires designed for larger populations.

Summary and Discussion

Dietary assessment tools commonly used are most appropriate for predicting health outcomes and assessing dietary patterns. They are valid for ranking people but are not sufficiently accurate for precisely estimating energy intake. These tools need to be fine tuned in relation to portion size, eating context, and mixed dishes. At a minimum, prior validated questions should be recalibrated to ensure that they capture the diets of children and adolescents because more children and adolescents are eating outside of the home. Recalls can provide useful data on serving sizes and context. FFQs are practical but probably not sufficiently precise to accurately predict the development of obesity. Finally, questions on where and why people eat may be better predictors of weight gain than dietary intake information alone.

In response to a question about measures to increase understanding of why people behave the way they do with regard to activity or diet, Dr. Field and her group found that dietary restraint was mildly related to weight change among women, commitment to exercise was a much stronger predictor of weight change, and binge eating surpassed both. Furthermore, children underestimated how important their weight was to their mothers. Overall, motivation has been understudied in interventional and observational research. In response to a question about other techniques for dietary and energy intake that could be used in large studies, Dr. Field replied that, although measures such as doubly labeled water exist, there are even fewer studies among children than adults, partly because of concerns over protection of children and difficulty in obtaining reliable collections. Regarding pantry surveys, Dr. Field stated that she did not know of studies that used them. Pantry surveys are difficult to conduct because, like 24-hour recalls, multiple visits are necessary. Additional problems are fluctuations in food supply and larger, shared households. Nevertheless, pantry surveys might be useful to identify the level of presence of high-risk foods and could provide a validation measure of food intake for interventions rather than using self-reported data. In response to a question that was asked about the use of dual parent and child reporting, it was noted that this issue presents a research opportunity for both diet and physical activity because few studies match parents with their children in the same database. Joint reporting is another option, but there are still some issues with this method, such as children not wanting to report something they were not supposed to have eaten.

Physical Activity Assessment in Children and Adolescents

Harold (Bill) Kohl, Ph.D., Division of Nutrition and Physical Activity, CDC, Atlanta, GA

Diet and physical activity methodologies and their associations are key to determining why children and adolescents are overweight. Examining these associations offers enormous possibilities for future research. Concepts were reviewed for assessing accuracy and techniques used to assess physical activity in children and adolescents, and suggestions for research and future directions were provided.

Methodological Concepts

Physical activity can be defined as bodily movement that results in energy expenditure. Along with repeatability, validity, and sensitivity, a key issue in physical activity assessment is the choice of an appropriate validation standard. An update of a literature survey conducted earlier by Dr. Kohl and colleagues (164) showed a number of different validation standards of physical activity assessment, particularly in children. A frequent problem is that the criterion against which a test instrument is measured has not been shown to be less variable than the test method. Validation standards include direct and indirect measures. Because physical fitness improves with increased physical activity, it can serve as an indirect validity measure. Change in body composition is another indirect measure. An example of a direct measure is a mechanical monitor to validate self-report measures of physical activity. Examining the different types of validity standards is important for future research. In both dietary intake and physical activity assessment, practicality and non-reactivity to the measurement are important issues.

Activity Assessment Techniques

Assessment techniques can be roughly ordered by decreasing order of precision and difficulty in conducting as calorimetry, doubly labeled water, direct observation, electronic monitoring, and self-report.

Calorimetry measures energy expenditure through a measure of expired gases (indirect calorimetry) or living in a room calorimeter for a few days and measuring CO_2 production over that time. Living in a calorimeter is restrictive, but it is an accurate method of measuring physical activity in a controlled setting.

Doubly labeled water determines total energy expenditure over a maximum 14-day period by measuring radioisotope-labeled hydrogen and oxygen atoms in urine or blood after ingestion of a known amount of labeled water. Although highly accurate, this technique has been impractical for larger studies because of the cost and the difficulty of collecting samples over the time period. Because it is an overall measure of energy expenditure in general, it is not possible to detect patterns or timing of physical activity or other elements that might be related to overall health, particularly in children. Combining doubly labeled water assessments with an indirect calorimetric assessment of resting metabolic rate provides an estimate of energy expenditure from physical activity but does not show whether it is vigorous, moderate, or light activity.

Direct observation can be effectively used in children, particularly in defined settings. An individual observer or set of observers monitors an individual or set of individuals for a period of time. Videos and still photos do not convey the level of activity or the time being spent that on-site observation captures. The direct assessment in a defined period and place provides summary indices of energy expenditure such as intensity and duration. Such observation is potentially reactive and not practical for large population studies. Experience with a park project in Atlanta showed that if the unit of observation is not the child but actually a geographic unit, this may be a useful technique for a large population-based study assessing the use over time of a portion of a park or a playground. Interobserver reliability is at least 90% with appropriate training. Test-retest reliability is greater with shorter intervals between observations; this may be due to test design or to lack of stability in physical activity behavior. An interesting finding with direct observation is that there is little purposeful physical activity among children. Because of the range of validity standards and the fact that there are only a few studies, most of which are small studies in younger children, validity is difficult to assess. Generally, there are high to very high correlations ($r = 0.65$ to 0.95) between the test method and the chosen validity standard.

Monitoring devices include heart rate monitors, motion sensors, pedometers, and accelerometers. Current monitors can measure not only quantity but intensity of physical activity. Interinstrument reliability has been tested by having subjects wear two monitors simultaneously. The interinstrument reliability was very high ($r = 0.80$ to 0.95). All of the instruments seemed to consistently measure the same thing; whether or not it was what needs to be measured remains a question. In test-retest designs, modest to high correlations (0.38 to 0.91) were recorded. In general, the longer the time period was between the test and the retest, the lower the correlation.

In children, most validity work has been conducted with accelerometers in uncontrolled settings, such as parks and playgrounds. Correlations have been low to moderate (0.25 to 0.50), but validity measures varied widely from indirect measures, such as fitness change or body composition changes, to doubly labeled water analysis. Nevertheless, regardless of the standard used, correlations were similar. Better correlations have not been achieved with heart rate monitors.

Self-reports include diaries, interviews, and self-administered surveys. They are used most often in population-based studies with older children and adolescents. There are varying lengths of recall from 24 hours to 7 days to a month, all assumed to be usual indicators. Techniques vary widely, an issue that should be investigated. An instrument derived in one population may not be transferable to another population. There has not been much effort to understand how children's physical activity may differ in different settings, such as rural and urban locations, and among population subgroups.

Reliability has focused mostly on test-retest, with coefficients ranging widely from 0.20 to 0.99. There is a strong suggestion of age, gender, and time dependency between observations. Boys' reports are generally a little better than girls', and both improve with age. Self-report should not be used with children 10 years of age or younger. But parents also have difficulty accurately reporting their children's physical activity. Activity diaries are better for older adolescents than parental estimates. Self-reports, even though they are the most frequently used technique, have the highest variability in validation standards, with unimpressive low to modest correlations across study types.

Directions for Research

Future research in physical activity assessments among overweight children should focus on intensity, frequency, and patterns rather than just total activity. Self-reported activity needs research in information processing, including better use of prompts and visual cues to create key self-report measures (165). However, activity monitors will be the most productive future trend in measuring physical activity in children and youth, particularly in clinical studies. The electronics need to be improved to store multiple days of data, and they need to become less expensive. There is little information on combining assessment techniques, such as the added validity of combining electronic monitoring with self-report. Physical inactivity is another area for study once there is a consensus on what physical inactivity is. TV watching may be a good proxy. There is not much known about energy of various activities in children and youth. Although a compendium for physical activity energy expenditure has been published and revised, such a compendium is unavailable for children (166). Ascribing energy costs to children's physical activity levels, based on different efficiencies and different ways of doing physical activity, is a key research priority.

From a surveillance standpoint, it is important to track how well children are meeting CDC recommendations and to classify relationships to obesity and overweight. For example, is 60 minutes a day along with appropriate diet enough to prevent overweight? The potential dose-response is unknown for both children and adults. There is a lack of knowledge of intra-individual variations in physical activity. For diet, it has been estimated that >100 days of monitoring might be needed to get some micronutrients within a comfortable level of variability. Such information is unknown for physical activity. Is a 1- or 2- or 4-day period enough time to record usual physical activity? Methods are also needed for assessing non-aerobic activities, such as strength training.

Assessment of sex, age, and ethnic differences are needed. Boys and girls differ in terms of physical activity as they begin to enter puberty, and, perhaps, assessment methods need to differ. Few of the studies of physical activity have assessed validity and reliability across ethnic groups. Such information is needed to design and adapt intervention strategies. The family, rather than the individual, as a unit of observation, may prove fruitful. Pediatricians, as the primary health caregivers for children, need the tools to translate the need for assessing physical activity from anticipatory guidance into practical recommendations for increasing physical activity.

An understanding is needed of the influences of environmental and social policy on physical activity among children and adolescents. This area represents the most likely growth in the study of physical activity in youth in the foreseeable future. For example, what role (and what are their relative contributions) do various policies that promote or inhibit environmental barriers for physical activity play in promoting opportunities for physical activity for children and adolescents? Can relevant physical activity legislative policies be incorporated into an index across settings (school, community, work site, transportation) that will allow for an assessment of policy dose and subsequently correlate that dose with physical activity prevalence estimates (response)?

Built Environment: Measurement Considerations

Brian Saelens, Ph.D., University of Cincinnati, Cincinnati Children's Hospital, Medical Center, Cincinnati, OH

Little research has been conducted on the built environment and overweight among children. One reason may be difficulty in evaluating the environment. Measurement tools are being developed and refined to assess some built environment constructs, including land use mix, street connectivity, and residential density, and other factors thought to contribute to walkability.

Walkability Measurement Tools

Walkable communities tend to have a mix of commercial and residential uses, including a vertical mix in which there are small businesses on the bottom floors and residences on the top floors, with parking on streets in front and few large retail establishments. Parcel-level data for these environments show heterogeneity in the types of land use. Walkable communities usually have gridded streets, short block lengths, and points reached using multiple short routes. Poor street connectivity is characterized by short roads, often cul-de-sacs, feeding off a main arterial road, in which only one route is available to get from point to point, and that route is long and circuitous.

High-quality parcel-level data are required to measure land use mix, including consistency across the data to derive estimates of land use mix according to diversity of types of different parcel use, square footage, and specific type of mix. Although the specific type of mix that optimally promotes greater activity is unknown, the ratio of total square footage of retail establishments and residential areas is important. It is likely that a specific type of mix promotes different physical activity in different subpopulations. For example, children might be more likely than adults to react to a mix that includes active recreation spaces such as playgrounds and residences. To determine street connectivity, high-quality road network and pedestrian network data are preferred, but intersection density can be used as a proxy for street connectivity. The Active Living Research Program of the Robert Wood Johnson Foundation has funded studies aimed at determining the best metric of street connectivity (http://www.activelivingresearch.org/index.php/CFP_1_Brief_Profiles/245#MCB).

Environmental data can be used to create indices for an entire area, such as census tract level, or to make specific individual household estimates of connectivity, land use mix, and residential density, such as using radial distances from a given residence. In studying determinants of obesity, it may also be important to identify and examine the difference between environmental factors that are perceived as measured through report of the individual and actual as constructed through existing or collected objective data. Although it is important to understand objective environmental effects, the way in which an individual perceives land use mix or other environmental factors in the neighborhood may influence level of activity. One such tool developed to investigate perceived residential density, land use mix, and connectivity is the Neighborhood Environment Walkability Survey (100) found at http://www.drjamessallis.sdsu.edu/NEWS.pdf. Other perceived environment measures have been developed specifically targeted for children (167).

Detailed information about the routes that pedestrians use would be valuable but is generally not available at the parcel level or route level. Collecting this information is labor intensive, requiring assessments of such factors as buffer distance, buffer size between sidewalks, benches, existence of sidewalks, pedestrian amenities, cross-walks, etc. (168). Once gathered, however, this information tends not to change rapidly.

Children and Walkability Constructs

Environmental factors discussed above seem more related to utilitarian trip-making than to recreational physical activity (169). With the exception of walking to school, children make considerably fewer utilitarian trips than adults, and even walking to school has decreased in frequency over time. However, children spend more time in

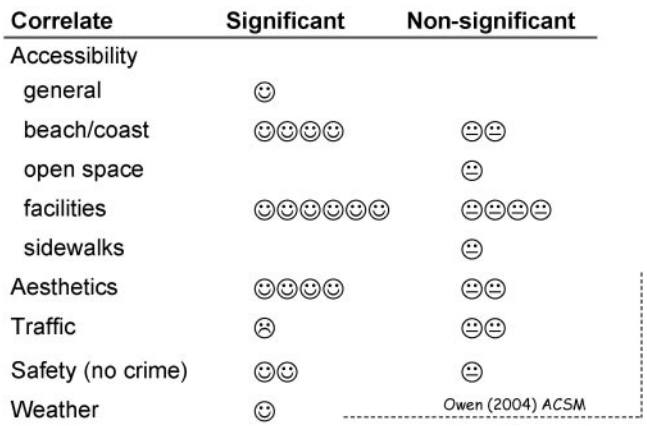

Figure 6: Environmental correlates of adults walking for exercise and recreation based on number of statistically significant associations. The increased number of faces relates to the degree of significance or non-significance. Source: N. Owen, American College of Sports Medicine, 2004.

recreational physical activity than adults. It is not known whether the characteristics that increase adult walkability actually encourage or even limit children's physical activity. For example, parents could feel that a more walkable neighborhood is less safe for their children; therefore, their children may be less physically active. Specific characteristics that make environments more walkable for adults, such as fewer cul-de-sacs, may curtail children's recreational activity. Data are just beginning to emerge examining the relationships between the built environment (mostly perceived environment at this point) and children's physical activity and obesity (170,171).

Accessibility of Physical Activity Facilities

Among adults, having facilities close by increases the likelihood of their use, but whether this is true among children needs to be determined (Figure 6) (172). For children, important physical activity facilities may include parks, playgrounds, and paid facilities. Cost and the quality and safety of the facilities also might be key factors. Although it is true that "You can't guarantee if you build it, they will come," they definitely cannot and will not come if it is not built. Accessibility and availability are not necessarily synonymous. Existence, but also distances to facilities and characteristics of routes to the facilities, should be evaluated. Understanding the quality of the facilities is, perhaps, equally important to proximity in determining children's use of them. In a study cited earlier that found no relationship between park and playground proximity and child weight status, there was no evaluation of the quality of the playgrounds. In fact, the children in the study were all in the Women, Infants, and Children program, and the majority of the playgrounds near their homes could have been of poor quality and unsafe (65).

Conclusions

Little is known about changing the built environment to make it more conducive to children's physical activity and healthful eating. Such changes could be expensive and may require broad policy changes. Despite the challenges, this may be the most influential way to address childhood obesity. In performing research in this area, randomized trials of environmental impacts on obesity are unlikely. On the other hand, there probably are enough natural experiments occurring at the threshold impact levels for environmental and outcome variables (physical activity, diet, and obesity) to estimate these environmental impacts. Understanding how environment is related to child physical activity, diet, and obesity and how environmental change happens and affects these critical behaviors and outcomes is critical for implementing change. Sound measurement of environmental constructs is needed, and development of measurement tools is being assisted by research in physical activity. However, there is little research on the measurement of the nutrition environment for children, with the exception of school food environments. Hypotheses need to be tested on the environmental factors that mediate childhood overweight. Further, little is known about the environments in which public health or clinic-based individual-based interventions are implemented and whether neighborhood environments serve as barriers or facilitators to individuals' intervention success. Better understanding of the settings in which intervention is occurring (not necessarily delivered) will enlighten researchers about such effects.

Family and Social Environment Measures

LeAnn Birch, Ph.D., The College of Health and Human Development, Human Development and Family Studies, PA State University, University Park, PA

As determinants of childhood overweight, the roles of family or social environment are not known, nor have many measurement tools been developed. Dr. Birch addressed these challenges along with an overview of her group's research and suggestions to meet the challenges.

Parental Influence

An ecological framework of childhood overweight suggests that dietary intake, physical activity, and sedentary behaviors that affect a child's weight are influenced first by the family environment and parents' characteristics and then by community and demographic factors, which may be more important influences for older children (Figure 4). For young children, all environments are socially constructed environments because the children do not make choices about where they will live, what they will eat, or whether or not the environment is conducive to activity. Therefore, it is especially important to identify these social environmental influences and how they can be part of the solution to the problem.

Parents influence their children's development through their genes and the family environment. What parents do in constructing the environments in which their children live is particularly powerful and important. Specific to the issue of childhood overweight, parents influence children's energy balance through their feeding practices and physical activity patterns. As noted earlier, what children do also influences parents. Additionally, children do not necessarily share environments because not all children in the same family are treated the same way.

A number of approaches have been suggested to identify the important family and social determinants of childhood obesity. Models can be informed by epidemiological data on associations and by relevant theory on family dynamics and parenting. Time-, labor-, and resource-intensive constructs need to be explored. A problem with current interventions is that they do not clearly identify which aspect of the intervention, if any, is producing effects. Reliable, valid, and multiple measures need to be developed, and intervention models need to be tested and evaluated.

There are some associations between potential determinants and childhood obesity that suggest targets to pursue, such as frequency of snacking, portion sizes, and soft drink consumption (56,71,173) For example, parents largely determine whether their children have free access to the refrigerator. Another topic of interest is parent-child similarities in intake and weight status (174). Genetic similarity aside, overweight parents may create different environments for their children, different foods, and different activities than non-overweight parents create for their children. Datasets such as CSFII could be used to look at patterns of intake and other relationships. A major parental influence on children's eating environments is sustenance: what children eat and when, such as formula or breastfeeding, energy density of foods and beverages, portion sizes, and frequency of meals and snacks. Another influence is structure, how parents organize their children's eating environments and where eating occurs. Parents also structure their children's activity environment, deciding where it is safe to play and protecting them from perceived environmental threats. Surveillance is an additional major influence: how parents monitor their children's eating and activity practices (109).

Conceptual Challenges

A significant challenge is the complex and multiple influences on childhood overweight, so that any single determinant may account for only a portion of variance in outcome. Relationships between parenting and children's weight will be moderated by various background and individual characteristics, including ethnicity, race, food insecurity, and other features. In addition, social influences would not be expected to operate directly on childhood overweight but will largely be mediated through the child's behavior.

Methodological Challenges

The management of social influences in childhood is subject to measurement error. For example, there is little research on direct measures of food environments. Instead, there is heavy reliance on self-report data, which can be useful regarding parental beliefs, attitudes, and perceptions. Approaches are needed to validate self-report measures and to provide precise information. Current links between eating behavior and weight status are weak and difficult to detect. Others issues are the bidirectional child-parent influences and non-shared environmental effects that differ across siblings.

Parenting Practices

Parents try to address environmental threats and promote children's successful adaptation to their environments. In an environment where food was scarce, successful parenting would have been seen as raising a child who was big and strong and probably overweight by today's definition. For 10,000 years or more, we lived in an environment where a big child would be a healthy child, and the child's weight would be a positive attribute. Parenting practices have changed more slowly than the environment in which food scarcity is uncommon. Thus, there is some evidence that today's parenting practices based on concern over undernutrition may promote overeating and obesity. For example, parents pressure children to eat, essentially coaching them to finish what is on their plates even when given very large portions.

Restrictive Food Practices

To illustrate measurement issues, a detailed example of parental food restriction was presented. Surprisingly, parenting practices intended to counter overnutrition may also promote overeating. Studies with middle-class children, primarily girls, on restriction of access to snack foods to ensure that the girls do not become overweight indicate that such restrictions are likely to have the opposite effect (175,176). An inference from such studies is that children learn that when food that has been restricted becomes available, they should eat it whether or not they are hungry (177,178). For mothers of girls in a longitudinal study, the Child Feeding Questionnaire was developed as a self-report of parental beliefs, attitudes, and practices that addressed seven factors: perceived child weight, concern about child weight, restriction practices, pressure to eat, monitoring, parent responsibility for feeding, and perception of parent's weight (179). The study assessed eating in the absence of hunger when girls were 5, 7, and 9 years-old. Eating-in-the-absence-of-hunger behavior has some characteristics of and may be a

precursor of binge eating. Thus, restricting children's access to foods might result in significant long-term increase in food intake among children. The questionnaire has also been used to stratify children for experimental studies based on whether mothers were reporting high or low levels of restriction of snack food.

A recent literature review of 22 studies about parents' feeding styles, child energy intake, and relative weight showed that parental feeding restriction, but not other feeding practices, was associated with child eating and weight status (180). Given the evidence for an association between parental restriction and children's eating behaviors and weight status, more longitudinal studies are needed to test underlying causal pathways and to substantiate findings in the presence of other obesity risk factors. Family vulnerability, ethnicity, and culture also deserve more study.

Future Directions

Promising interventions should be selected using data from current research on etiology, epidemiology, and child developmental theory to develop a research base for effective prevention and intervention. Measures need to be developed for intervention constructs and components. Sequential experimentation can be used to systematically screen potential intervention components. Dr. Birch referred the audience to work done by a colleague to define what is meant by sequential experimentation (181). Small, randomized experiments in an initial phase of developing interventions are used to determine what works and what does not, possible interactions, and other effects such as ethnicity and race. The final phase is a full-scale intervention trial. This process could facilitate acquisition of the necessary science base while saving time.

Other future directions would include study of potentially important familial and social determinants that have not received much attention, focusing particularly on parents as models. Parents model portion size, food selections, dieting behaviors, and other eating behaviors such as frequency of snacking, eating out, and eating in front of the TV. For example, maternal patterns of milk and soda intake predicted daughters' milk and soda intake patterns (182). Thus, overweight mothers may need to be the target of interventions to reduce children's intake of soft drinks. Little research has been done using datasets that include parent-child similarities. There also has been very little research on other social determinants directly relevant to overweight, such as the influences of peers, siblings, coaches, and the media.

Summary

There are many potential family and social candidates as determinants of obesity, but few, if any, are obvious winners. Ethnic and income differences in parental perceptions of perceived threats complicate healthy eating and activity issues but need to be understood and addressed. During the first 5 years of life, parents and other caregivers powerfully shape children's eating and activity environments. The need to study and work with these preschool influences is particularly critical given that somewhere between 20% and 40% of children in some ethnic groups are overweight by the time they enter kindergarten. The long-term goal is to modify the family and social determinants for prevention and intervention of childhood overweight.

Session IV: Measures of Weight-Related Outcomes

Definition of Overweight and Obesity

Robert Kuczmarski, Director, Obesity Prevention and Treatment Program, Division of Digestive Diseases and Nutrition, NIDDK, Bethesda, MD

Overweight is defined as total body weight in excess of a specified threshold. Obesity, strictly speaking, is excess body fat, either excess total body adiposity or excess of a part of the body, such as intra-abdominal fat.

Total Body Weight and Body Fat

Total body weight is preferably measured with a calibrated scale. Total body fat is estimated using various body composition techniques such as underwater weighing, DXA, air displacement plethysmography (ADP), bioelectric impedance analysis (BIA), SFs, and so on. These are all indirect measurements; the only direct measure of body fat is through chemical analysis of cadavers.

Definition of BMI

BMI is an index of weight adjusted for stature [weight (kilograms)/height (meters)^2]. Height or stature is measured using a calibrated stadiometer. BMI is universally measured in studies of overweight and obesity because the validity and reliability of weight and stature are excellent, and the index can be easily and quickly calculated. Although BMI is internationally accepted as an index of overweight and obesity among adults, there are various definitions and criteria for overweight and obesity. BMI is not a quantitative measure of adiposity; therefore, it is not actually a measure of obesity. BMI refers to body mass, but it does not distinguish between or quantify fat mass and lean body mass. It is a clinical screening tool, and it should not be used as the sole diagnostic clinical criterion for obesity in adults or children because of the potential for misclassification, especially in children, who are still growing linearly.

Although not a measure of adiposity, BMI does, however, have a close relationship to body fatness and indicates high or low levels of body fat. The correlation of BMI with body fatness in children ranges anywhere from 0.4 or 0.5 to

0.9, depending on the criterion method used to assess body fatness and the age and sex of the children. Studies that have assessed total body fat mass as measured by BMI and DXA have included white girls 4 to 16 years of age in New Zealand, Italian white girls and boys 5 to 19 years of age, and Pima Indian boys and girls, again 5 to 19 years of age (183–185). The R^2 showed that 72% to 96% of the variation in fat mass could be explained by BMI using DXA as the criterion. One study has shown that children with the highest BMIs have body fat in excess of 30% (186). This level could be considered an upper threshold that would indicate obesity or excess body fat, but, in fact, we do not know what body fat percentage should be, and there is probably a range that is healthy or unhealthy. This is an area that needs further exploration. Another issue for future research concerns regional obesity, for which much more is known among adults than among children.

BMI vs. Weight-for-Stature

Weight-for stature was used before there were BMI growth charts as a reference for assessing overweight and obesity in children and adolescents. The advantage of weight-for-stature is that it can be used without knowledge of a child's age, making it particularly useful in developing countries. However, in developed countries, virtually everyone knows their age. The disadvantages are that weight-for-stature is specific for a particular set of reference data, there are no units (unlike BMI, where 20 kg/m^2 does not require reference data), and the 1977 National Center for Health Statistics weight-for-stature growth charts commonly used were developed for prepubescent children and only went up to ~4 feet 9 inches for boys up to 11 years of age and to 4 feet 6 inches for girls up to 10.5 years of age. Between those ages and adult years, there was no reference.

Why Use BMI for Children?

BMI works for ages where weight-for-stature previously did not and, thus, provides a reference that was not available before for adolescents; it can be used to rank individuals from early childhood, beginning at 2 years of age, when a child is able to stand unassisted and one can get a reliable measure, through adolescence and into adulthood. It provides continuity from the very youngest ages through adulthood such that there is a strong correlation between child and adult BMI levels. Tracking to adult BMI increases considerably after ~8 years of age. Also, BMI can be put on a single chart. In addition, BMI is not population-dependent, which allows national and international comparisons. Furthermore, childhood BMI may indicate or predict current or future health (187). Finally, when comparing weight-for-stature and BMI-for-age as adiposity measures, they performed equally up to 6 years of age, but BMI-for-age was better for children 6 years of age and older (188).

Guidelines for Use of BMI

Guidelines for Adolescent Preventive Services screening, identification, and classification criteria for adolescents 11 to 21 years were developed in the early 1990s (189). In developing these guidelines, the work group created the two terms, overweight and at-risk-of-overweight. An in-depth medical assessment was recommended for overweight, which was defined as being at the 95th percentile or above for BMI-for-age. An at-risk-of-overweight child had a BMI-for-age between the 85th and 95th percentiles, and the recommendation was for a second level screen that included tests for high blood pressure (BP) and total cholesterol. If these measures were abnormal, or there was a large increase in BMI in the last year, family history, or personal concern about weight status, an in-depth medical assessment was recommended. Other groups that have recommended BMI-for-age as the best way to screen for overweight in children and adolescents are the Maternal and Child Health Bureau in their Bright Futures anticipatory guidance, the AAP, and the American Academy of Family Practitioners.

Avoiding the Obesity Label

A reason for using the terms overweight and at-risk-of-overweight, rather than obesity, is that there is a risk of misclassification because a child's weight might stabilize as height increases. Also, little is known about the immediate health implications for children at specific BMI cut-off values. Another reason for avoiding the obesity label with children is the potential for social stigma that may trigger inappropriate psychological responses, such as depression and social withdrawal, or lead to eating disorders and inappropriate behaviors, such as smoking or use of laxatives or other unhealthy means to try to control weight, although such a relationship has not been well documented. Because of the trend to call obesity a disease, applying this label implies the need for treatment, but primary care providers are generally ill-equipped to provide treatment to children. Labeling someone as obese and then not being able to do anything about the problem is of questionable value.

Current U.S. Reference: 2000 CDC Growth Charts

Because the BMI-by-age criteria for overweight rely on growth charts, it is important to understand the strengths and limitations of the charts. In the 2000 CDC growth charts, datasets were combined from five nationally representative studies conducted between 1963 and 1994 by the National Center for Health Statistics to establish the BMI curves (http://www.cdc.gov/nchs/data/series/sr_11/sr11_246.pdf) (190–192). In combining these datasets, weights for ages 6 years and over for children who were measured after 1988 were excluded because there was a positive trend in the weight gain that was considered undesirable and would have led to underclassification of overweight because the percentiles were shifted upward. The empirical or observed

percentile estimates were plotted against the median values of each age group. The resulting curves were then smoothed to make a clinically useful tool. Comparisons between the plotted data and the reference percentiles show the approximate level for a child, relative to other children of the matching age and sex, who belong to a well-defined population that provided data for construction of the charts. Basically, the charts compare an individual with the national distribution. A growth chart should be considered a reference rather than a standard that suggests a norm or target.

Accepted normal ranges are determined by the boundaries of outlying percentiles. Internationally, the 3rd and 97th percentiles are used. In the United States, the 5th and 95th are considered the extremes. Serial measures are desirable to determine growth patterns over time and to look at trends for the child.

Racial and Ethnic Considerations for BMI Charts

Separate race- and ethnic-specific charts were not developed because sample sizes did not meet the statistical requirements for such precise estimates of the outer percentiles. Another reason for not including race- and ethnic-specific charts is that there is not clear evidence that the differences in growth for these groups are genetically determined. Although there are differences in growth potential for non-Hispanic blacks, whites, and Mexican Americans, these differences seem to be quite small when comparisons are made among higher SES groups. Furthermore, ethnicity and race are also imprecise and ambiguous terms related to ancestral heterogeneity and geographic origins. Children may have ethnically diverse backgrounds, making it difficult to develop and apply ethnic-specific charts.

Characteristics of BMI in Longitudinal Studies

In normal growth, BMI increases steeply to ~8 or 9 months of age and then decreases to a nadir at ~4 to 6 years of age. The increase in BMI after this nadir is termed BMI rebound. To be meaningful, children must be measured at frequent intervals to determine when their nadir occurs. Ideally, these measurements would be every 6 months, but at least annually, and, according to the AAP, this should occur on annual visits up to 6 years of age. The earlier the age of the BMI rebound, the more likely a child will track at a higher BMI percentile. When a rebound occurs before ~4 years of age, it tends to be associated with higher BMI in adolescence and into adulthood. Therefore, by age 21 years, the BMI is highest in the early rebound group and smallest in the late rebound group. As a measurement tool, the age of the BMI nadir may add considerable information not available from one or two BMI measurements. It can also be used as an early warning alarm for prevention and needs to be communicated more strongly to clinicians, as well as being part of research endeavors.

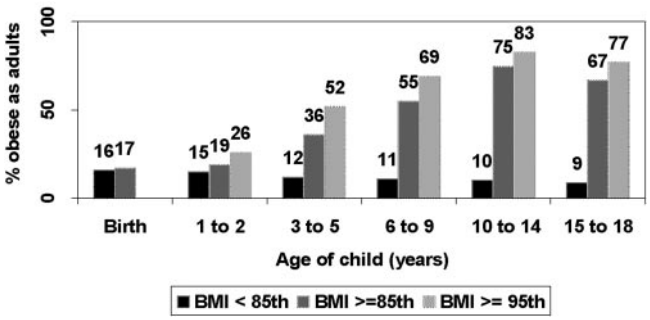

Figure 7: Tracking BMI-for-age from birth to 18 years with percentage of overweight children who are obese at age 25. Reprinted with permission from Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med.* 1997;337:869–73.

Tracking or the tendency to retain the rank order of values across time is another useful characteristic of BMI growth charts in longitudinal studies. BMI tracks better than other indices such as SFs or waist and hip circumferences. For children <3 years of age, parental obesity is a stronger predictor of adult obesity than a child's BMI. By age 4 years, ~20% of children at the 95th percentile of BMI track to adult obesity. By adolescence, such tracking increases to 80% (Figure 7). At older ages, the better the tracking (that is, staying within a percentile canal), the higher the predictability of adult obesity, which provides an advantage in terms of prediction (193,194). Another potential use of serial BMI measures is identification of decanalization, which is a marked lack of tracking defined as two or more major percentile lines in such a way that the points shift from one major canal to a non-contiguous canal.

Body Composition and Metabolic Measures

Jack Yanovski, M.D., Ph.D., Head, Unit on Growth and Obesity, Developmental Endocrinology Branch, National Institute of Child Health and Human Development, Bethesda, MD

Dr. Yanovski presented body composition measures considered reasonable for sequentially studying large groups of children and relevant metabolic measures among the same population.

Body Composition Measures and Anthropometry

At the least, pediatric body composition measures should include age- and sex-specific BMI standard deviations (SDs) or *z* scores for body circumferences and pubertal staging, separating gonadarche and adrenarche. Studies

can use two-compartment models for body composition that include measurements such as ADP, isotope dilution, and underwater weighing. A detailed characterization of pediatric body composition would include three-compartment (e.g., DXA for muscle, bone, and fat) or four-compartment models and subcompartment models with magnetic resonance imaging or computerized tomography scans that allow estimates of the abdominal visceral adipose tissue, subcutaneous adipose tissue, and, perhaps, intramyocellular muscle-containing lipid fat. Subcompartment models are difficult to carry out and are not reasonable for population studies. Nevertheless, these more difficult, expensive, but potentially more informative measures such as complete four-compartment modeling, magnetic resonance imaging, or magnetic resonance spectroscopy may have use in a subsample if resources permit.

BMI (kilograms per meter squared) z score or BMI-SD score is a transformation of BMI useful for comparing children for whom varying age distributions may have different means and SDs. Mean BMI varies dramatically by age and sex during childhood, necessitating the use of z scores or percentiles for comparison of children differing in age or sex (191). BMI-for-age and weight-for-stature will not give identical results and are not interchangeable (195). Age- and sex-specific BMI-SD scores are recommended because percentiles, although intuitive, are not as useful in statistical analyses (see additional slides of growth charts at http://www.cdc.gov/needphp/dnpa/growthcharts/training/powerpt/slides/001.htm). BMI-SD scores for age and sex better approximate fat mass than BMI alone. The percentage of variance explained by BMI-SD score (79%) is higher than by BMI alone (72%) (196).

Although measured BMI is more accurate than self-reported BMI, there is a high correlation ($r = 0.97$) of self-reported and measured BMI-SDs; however, there are notable individual exceptions; for example, children with very high measured BMI tend to have more under-reported BMI. Silhouette scores compared against measured BMI-SD scores also correlate well ($r = 0.75$). Waist circumference is another easily obtained measure of body adiposity or body size, but more reference data are needed to derive age- and sex-specific scores among children for reliable use. In large field studies, there might be a role for waist circumference z scores in addition to age- and sex-specific BMI z scores.

Other than DXA, other non-invasive ways to measure body fat include equations based on ADP (using Bod Pod), BIA, SF thickness, or a combination (197–202). A study of ~120 African-American and white children examined the accuracy of these measures against DXA for predicting body fat percentage (203–205). Significant error was found with SF equations and BIA. ADP and hydrometry or water dilution performed better in cross-sectional analysis. Of these, ADP would be preferred in large studies, but the cost and time of performing either ADP or DXA need to be carefully considered. None of the simple measures such as SF thickness or bioelectrical impedance is able to estimate small changes in body fat adequately. For serial measures, BMI is the only non-invasive technique that should be used.

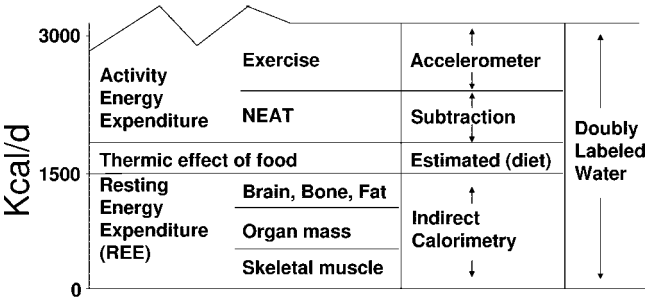

Figure 8: Contributions to energy expenditure phenotyping.

Energy Intake and Expenditure Phenotyping

Techniques for energy intake phenotyping in children, such as diet diaries, FFQs, and 24-hour recalls, tend to underestimate, and the relative contributions of the information supplied by children and their parents are unclear. Observation while eating under laboratory conditions has provided valuable insights. For example, overweight children who report past binge eating consume significantly more during laboratory test meals than other children. Although measuring food intake under laboratory conditions may be a better strategy to learn about actual consumption patterns, the applicability of this strategy in large studies is an issue.

An energy expenditure phenotype consists of resting energy expenditure, thermic effect of food, and physical activity. At rest, muscle, organ mass, and brain, bone, and fat contribute to energy expenditure. A model of the components and measures of energy expenditure is shown in Figure 8. African-American children have lower resting energy expenditure per kilogram of lean body mass than white children because of greater appendicular skeletal muscle, which contributes little to energy expenditure at rest. When skeletal muscle mass and residual (organ) mass are accounted for separately, there is no difference in resting energy expenditure for African Americans and whites (206). This example illustrates that one must be careful in controlling for the right variables and in measuring body composition properly to accurately interpret metabolic data. Energy expenditure from physical activity consists of purposeful movements such as walking and of non-exercise activity thermogenesis, as seen in fidgeting. All these components must be considered in studying energy expenditure in children and adolescents.

In the laboratory setting, the most commonly used measure of fitness is maximal oxygen uptake during exercise. A

12-minute walk-run test in which the subjects run back and forth down a hallway has an acceptable correlation with maximal oxygen uptake (0.58 in one study), suggesting that there may be less invasive ways of measuring exercise fitness (207).

None of the more accurate measures of energy intake and expenditure is suitable for large studies, whereas the accuracy of simple, inexpensive measures is problematic. Nevertheless, if they are used, an FFQ can rank energy intake, accelerometers or pedometers are the most reasonable tools for energy output, and a simple walk-run test can estimate fitness. More difficult and expensive measures include eating in laboratory conditions for energy intake and doubly labeled water, resting energy expenditure, and treadmill or cycle ergometry to obtain a more complete idea of energy expenditure.

Metabolic Measures

Most measures of metabolic phenotyping in children are difficult to perform in a field setting. In order of increasing complexity within category, such measures include:

- Insulin sensitivity: fasting measures such as the quantitative insulin sensitivity check index, a measurement of glucose and insulin in fasting that is better in adults, the homeostasis for insulin resistance test, which is considered better for children, the frequently sampled intravenous glucose tolerance test, and hyperglycemic or euglycemic clamps;
- Insulin secretion: the oral glucose tolerance test (OGTT) and intravenous glucose tolerance test with hyperglycemic clamp;
- Lipids: triglycerides (TGs), high-density lipoprotein (HDL), and estimated or measured low-density lipoprotein (LDL) and a nuclear magnetic resonance lipoprofile for particle size and other aspects;
- Gut hormones and adipocyte hormones such as leptin, resistin, tumor necrosis factor-α, and adiponectin; and
- Serum inflammatory markers such as fibrinogen or plasminogen activator inhibitor type-1, which are expensive to measure.

All metabolic measures must be interpreted relative to age- and sex-specific standards, which are currently inadequate for most of the gut hormones and inflammatory markers. Because of significant fluctuations of many measures throughout the day, they need to be taken at a standardized time of day (208).

For relatively simple, inexpensive measures, Dr. Yanovski recommended a two-point OGTT with measures of insulin sensitivity, glucose, lipid profile, and, perhaps, non-esterified fatty acids. More difficult, expensive measures are difficult to justify in large studies but would be valuable in subsets to monitor the effectiveness of interventions. These potentially more informative measures include hyperglycemic/euglycemic clamps, nuclear magnetic resonance lipoprofiles, gut hormones before and after a fixed meal, and inflammatory adipocyte-derived markers.

Overweight-Related Health Measures

Aviva Must, Department of Family Medicine and Community, Tufts University School of Medicine, Boston, MA

Being overweight may cause severe health and psychosocial consequences for children that can be measured, although there are challenges to doing so. Nevertheless, obesity-related outcomes in children should be studied for advocacy, for tertiary prevention, and for additional outcomes in observational and experimental studies of overweight. Health consequences for children have stimulated advocacy. Given that a very large proportion of the pediatric population is now overweight, it has become necessary to consider other health outcomes and to try to ameliorate the health consequences through tertiary prevention for those who are already overweight and obese. Finally, health outcomes can serve as additional outcome measures as researchers plan observational and experimental studies.

Health Consequences

Physical health consequences of overweight during childhood include the classic cardiovascular risk factors: hypertension, elevated blood glucose, type 2 diabetes, dyslipidemia, and the metabolic syndrome. Other health consequences include gallstones, polycystic ovary syndrome, sleep apnea, perhaps asthma, orthopedic conditions, and early puberty. Early puberty could be both a consequence of and a predictor of overweight, but evidence is stronger that early puberty is a consequence rather than a predictor of overweight.

A school-based study in Alabama showed a consistent pattern by race and by gender in both systolic and diastolic BP elevations in the overweight children (209). An accumulation of risk factors associated with overweight also was demonstrated in the Bogalusa Heart Study (210). Virtually all children 5 to 10 years old with four of five risk factors for heart disease (low HDL and elevated TG, LDL, insulin, and BP) were overweight, and 80% of 11- to 17-year-old children with four of the five risk factors were overweight (Figure 9). In another cohort, the prevalence of the metabolic syndrome increased with the severity of obesity, reaching ~50% in severely obese children and adolescents (211). Similar findings were shown for C-reactive protein. Using modified criteria for children, the prevalence of the metabolic syndrome among overweight adolescents was estimated at 29% in the third NHANES (212).

A strong combined effect of overweight and high central adiposity for cardiovascular risk factors has been found among boys (213). In addition to cardiovascular risk, type 2

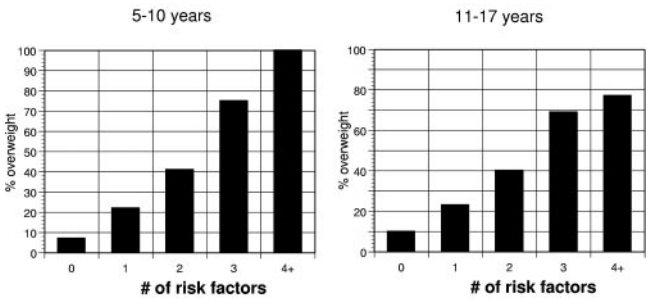

Figure 9: Number of adverse risk factors (elevated TG, LDL, insulin, or BP; low HDL) in relation to overweight in the Bogalusa Heart Study. Reprinted with permission from Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics.* 1999;103:1175–82.

diabetes is increasing disproportionately in minority populations (214). In some inner city health clinics, more than one-half of the newly diagnosed children with diabetes have type 2. A relationship between overweight and other health consequences among children is less clear. For example, children with asthma might gain weight because they exercise less and because of side-effects of their asthma treatment. Nevertheless, at least one study found a relationship of increasing weight with the development of asthma (215).

Psychosocial Consequences

Lowered self-esteem, lack of social acceptance, and possibly depression are the major psychosocial consequences of overweight and obesity, particularly among girls (216). Overweight children also tend to be more socially isolated (217). A large study of Canadian children 11 to 16 years old found that overweight and obese children, particularly girls, were more likely to be the victims and perpetrators of bullying behaviors than their normal-weight peers (218). In a comparison of quality-of-life scales among children who were healthy, obese, or undergoing cancer treatment, the children who were obese had quality-of-life impairment similar to the children with cancer (219).

Measurement Issues

The health and psychosocial outcomes of childhood overweight are at relatively low prevalence, but they are becoming more common. Due to the low prevalence and incidence, some health effects may not be practical to measure because they would require large sample sizes and long follow-up times. Another restriction is the participant burden in terms of time, invasiveness, and research ethics. Even given these challenges, whatever continuous variables are studied may provide interesting information as additional outcome measures. For planning future research, health outcomes for overweight in children and adolescents should include measures of psychosocial functioning, fasting blood levels of standard cardiovascular risk factors, perhaps an OGTT, and stored samples for future susceptibility screening.

Report of Breakout Sessions

Issues for future research that were raised in the presentations were integrated into breakout discussions. These breakout sessions and their leaders were as follows.

- Conceptual Framework: Wendell Taylor, Ph.D., School for Health Promotion and Prevention Research, University of Texas Health Science Center at Houston, TX
- Measurements: Barbara Ainsworth, Ph.D., Department of Exercise and Nutritional Sciences, San Diego State University, CA
- Study Design: Jo Anne Grunbaum, Division of Adolescent Health, CDC, Atlanta, GA

Conceptual Framework

Because environmental and behavioral influences consist of several domains or layers, effective research will benefit from the application of a study question to a conceptual framework to better understand the various factors and their interrelationships. To this end, the group suggested using the Davison and Birch specifics of the childhood ecological model (Figure 3) to adapt the framework of Booth et al. (220) that was developed during a workshop entitled, "Partnership to Promote Healthful Eating and Active Living."

The adapted framework included the following determinants and related factors for physical activity and eating behavior, radiating outward from the center or core:

- Psychobiologic core: self-identities, pleasure, hierarchy of needs, genetics, and physiology;
- Culture: habits, ethnic identities, beliefs, values, and life experience;
- Social: social roles, life stage, interpersonal relationships, educational attainment, and SES; and
- Enablers of choice: social trends, seasonality, convenience, accessibility, situation or context, source of information, cost, time, safety, and knowledge.

Beyond these four key areas, behavioral settings and proximal and distal leverage points were other related determinants affecting physical activity and eating behavior.

The group identified four research opportunities for identifying environmental and behavioral determinants related to overweight and obesity:

- When and how do changes in food selection and taste preferences develop?
- What are the predictors, motivators, and antecedents of overeating?

- What are the important antecedents of physical activity? and
- How do constructs for sedentary behavior and physical activity differ?

For elaboration, two or three important study topics or questions for each layer or domain of the framework were presented for physical activity. These issues would apply equally well to eating habits.

Psychobiologic Core. The first question was, "What are some innate hedonic effects of exertion and different types of physical activity?" Dr. Taylor cited an example in which adolescent girls were administered an annual maximum treadmill test over 5 years. Some girls stopped exercising almost immediately, whereas others continued well beyond the standard time, leading investigators to conclude that there are different reactions to exertion. An example of further research questions raised by such findings might be, "How does the intrauterine environment influence physical activity predispositions?"

Culture. The group asked, "What are the influences of role models on children's physical activity?" In some identifiable groups, role models are very powerful, whereas in others, their effect may be minimal. A second question was, "What are the norms for obligatory and recreational physical activity, by gender, age, and ethnic identity, and how do they interact?" For example, in some groups, physical activity is perceived as being a very important and positive action; in others, it may not be such a priority.

Social. The first two questions were, "What are the peer, sibling, and parental influences on children's physical activity patterns?" and "What are the effects of social roles on physical activity behaviors and perceptions across gender and age?" A subpart of these initial questions was, "How do changing roles affect physical activity patterns for a specific population?" The third major question was, "How does outsourcing of parenting (including TV) influence physical activity patterns?"

Enablers of Choice. "How do time demands influence child and family physical activity patterns?" was the entry question. If both parents are working, children may have more responsibilities at home, and physical activity, if not incidental, has to be scheduled. Next, "What can we learn from physically active families?" This question included many other questions such as: What are they doing right? How do they handle time demands? What can be learned from them in general and how can that knowledge be applied to families who are not physically active?

Behavioral Settings. The group asked, "How do neighborhood settings influence physical activity patterns?" For example, are there certain attributes of a particular neighborhood that facilitate or hinder children's physical activity? Secondly, "What in the childcare setting can hinder or facilitate physical activity patterns?" Given the current social trend of more children being placed in childcare settings, the group felt very strongly that the childcare setting warrants further research and investigation.

Proximal and Distal Leverage Points. The question was asked, "How do legislative and state policies influence physical activity patterns (e.g., in specific settings such as schools, daycare, neighborhoods)?" Dr. Taylor offered as an example Washington State legislation regarding walking to school and safe bicycle areas. Other states have instigated "walking buses," where parents and children meet a mile from school and walk together.

There was general consensus regarding the importance of studying protective behaviors, rather than focusing solely on individuals in adverse ranges.

Measurements

Discussion of measurements began with four questions:

1. What are the critical exposures and outcomes to measure?
2. How frequently should they be measured and for how many years?
3. What is acceptable participant burden?
4. What additional susceptibility measures, including genetics, should be considered?

To answer these four questions, it was believed to be important to measure the behaviors that determine physical activity and eating behaviors. It is critical for a cohort study to operate on a multilevel approach—to measure the individual's behavior, social environment, and physical environment—for both physical activity and eating behaviors. Assuming that a cohort study will span as long as 10 years, it is important to measure these factors for the participants annually. It is also important to identify two age cohorts at enrollment, including 3- to 4-year-olds and 9- to 10-year-olds, whose ages will overlap during follow-up. Significant planning would be needed to identify the appropriate measures for critical time-points. Real-time measures, ones that are non-intrusive and that offer reliable on-line data that could be downloaded and managed, would be ideal. However, for many situations, such measures are not yet available.

At the individual level, accelerometers can gather data on the intensity and duration of physical activity. Spatial information can be obtained using global positioning system chips imbedded into clip-on devices. Supplemental surveys would identify sedentary time use such as TV and computers. For diet at the individual level, input from parents regarding children's eating behaviors was considered probably the best way to gain information on young children. Other indicator variables are also important to measure, including fat consumption and food preparation practices.

Family, school, and social environment affect both physical activity and nutrition and need to be measured. With regard to the physical environment, instruments are becom-

ing available so that researchers can conduct neighborhood audits for both food intake and physical activity. This information will aid in determining what type of environment is necessary for children to be physically active and eat healthy foods and what needs to be made available to parents who must make healthy food selections and make it possible for their children to be physically active. In addition to conducting audits, researchers need to identify perceptions of neighborhoods and food availability because perception is a very important variable in the determination of behavior.

Appropriate access to body composition methods, such as DXA, is critical. Under optimal circumstances, subjects would have blood drawn from which glucose, insulin, and lipids could be measured and a sample stored for future genetic and environmental interaction studies. BP is also an important outcome that needs to be measured. Participant burden for the identified measurements for eating behavior and physical activity was thought to be acceptable. A possible lack of variability within families and environments in the United States argues for the performance of international studies.

Study Design

Dr. Grunbaum addressed issues of study design and resource sharing, concentrating on three main issues: the need to determine a focus for study, the need to look forward to what can be done as opposed to reflecting on what has happened and cannot be changed, and the recognition that the type of studies discussed at this conference cannot be used to determine cause and effect to the same extent as randomized controlled trials.

A study model with centralized data center with common protocols has the advantages of being able to pool data collected at various sites, provide increased sample sizes, and broaden diversity. Decentralization could encourage more innovative spin-off research but would add to the burden placed on the data coordinating center faced with numerous different protocols. Having a parallel resource center where measures could be developed would be a particularly useful means of drawing investigators together from multiple sites.

Traditional study aims would be to identify the specific contributions of various types of diet and activity to childhood obesity or to study in more detail some of the psychosocial variables. However, those goals might not move the field ahead. It was suggested that, perhaps, a better aim would be to examine what is driving the epidemic and produce data that can be a basis for advocating change, such as devising or justifying interventions regarding availability of food, food prices, or infrastructure for physical activity. A cohort study based on selecting a variety of interventions may not provide answers to those questions because of the lack of variability. Investigations involving environmental, societal, and policy variables probably demand a different type of study format. Detailed discussions would be needed to identify and prioritize the key study questions that would drive study design.

An interesting approach is to allow interventions to go forward in cohort studies. It might be possible to observe responses to certain types of interventions at the same time as investigators follow the natural history of obesity and overweight, and this is especially important when recruiting vulnerable populations.

The point was made that although there may not be much variability in the United States in the penetration of marketing and advertisement, there is still a great deal of variation among individuals and overweight. Although there may be universal messages being disseminated, they obviously do not have the same effect on everyone who receives them. Variation is an important consideration and warrants more attention because it is a major component of study design and will, therefore, influence future research direction and opportunity. Individual communities have a multitude of different ongoing activities that could be investigated as natural experiments, although the nature of those activities necessitates that quick action be taken on the part of researchers. Current mechanisms may not fit the rapid response model required to evaluate the changes that are occurring. Such comments highlighted the questions of how to respond quickly to current events in the field, how to ensure methodological rigor, what endpoints ought to be measured (particularly when BMI data are unavailable), and how data should be captured.

A first step might involve determining a more appropriate mechanism for studies that examine the process of change. An obesity-related environmental surveillance system could be envisioned, where media, environment, technology, family life patterns, and so on are tracked. Data collection centers could facilitate the efforts of researchers to set up surveillance and then design appropriate studies.

Overall, the group concluded that despite the fact that researchers tend to study individuals who are either overweight or who are at high risk for overweight, it is equally important to consider those who are lean, particularly lean children in families with obese or overweight parents. It is also important to include a focus on positive models and contrasting factors that exist between lean children and those who are overweight or obese. Examining the variety of attributes found in different groups of people will provide information for segmenting and tailoring subsequent studies to particular populations. Researchers should use experimental approaches that will maximize contrasts observed in both positive models and high-risk individuals, allowing investigators to study potential responses to change. The group concurred with comments during earlier discussions regarding the importance of sequential experimentation.

Acknowledgments

We acknowledge the contribution of each of the presenters who provided intellectual content for the meeting and gave willingly of time to review this document for content accuracy. The authors also acknowledge the meeting sponsors. We thank Helyn Oscanyon for preparing a transcription of the meeting. NIDDK was the primary sponsor of this workshop. Other NIH and U.S. Department of Health and Human Services sponsors and advisors for the workshop included: CDC, the NIH Division of Nutrition Research Coordination, the National Cancer Institute, the National Heart, Lung, and Blood Institute, the National Institute of Child Health and Human Development, the National Institute of Environmental Health Sciences, and the Office of Behavioral and Social Sciences Research, Office of the Director, NIH.

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