Toward a Developmental Conceptualization of Contributors to Overweight and Obesity in Childhood: The Six-Cs Model

Kristen Harrison, Kelly K. Bost, Brent A. McBride, Sharon M. Donovan, Diana S. Grigsby-Toussaint, Juhee Kim, Janet M. Liechty, Angela Wiley, Margarita Teran-Garcia, and Gwen Costa Jacobsohn

University of Illinois

ABSTRACT—***Overweight in childhood sets the stage for a lifelong struggle with weight and eating and raises the risk of health problems, such as obesity, diabetes mellitus, hypertension, sleep apnea, and heart disease. Research from multiple disciplinary fields has identified scores of contributing factors. Efforts to integrate these factors into a single "big picture" have been hampered by the challenges of constructing theoretical models that are both comprehensive and developmentally adaptable. This article reviews select genetic and environmental factors influencing childhood overweight and obesity, then explicates an ecological model mapping these and other factors. The Six-Cs model extends previous theoretical work on childhood weight imbalance by acknowledging dimensions of factors specific to heredity as well as the environment, to activity as well as nutrition, to resources and opportunities as well as practices, and to development from birth through adolescence. This article concludes by discussing the model's policy relevance and identifying important next steps for transdisciplinary research concerning child overweight and obesity.***

KEYWORDS—*obesity; ecological model; family; community; genetic*

Development of this article was funded by the State of Illinois Council for Food and Agriculture Research and the Illinois Department of Human Services via grants supporting the STRONG Kids Program at the University of Illinois.

Correspondence concerning this article should be addressed to Kristen Harrison, Department of Communication and Division of Nutritional Sciences, University of Illinois, 317 Communication Building, Urbana, IL 61801; e-mail: krishar@illinois.edu.

OVERVIEW

Obesity among children in the United States is a national public health concern. From 1976 to 2006, the rate of overweight for 2- to 5-year-olds rose from 5.0 to 12.4% (Centers for Disease Control and Prevention, 2009). Overweight children are at risk of remaining overweight in adulthood, with overweight by age 8 predicting the most severe adult obesity (Centers for Disease Control and Prevention, 2009). An increase in the rate of weight gain between ages 2 and 5 is a particularly potent predictor of adult overweight (McCarthy et al., 2007). These findings underscore the need to map the factors that promote excessive weight starting very early in life (Tabacchi, Giammanco, La Guardia, & Giammanco, 2007). In this article, we review some recent research advances that point to factors influencing childhood overweight and obesity from infancy through adolescence, and follow with a new ecological model that is adaptable to different developmental stages.

In the past decade, hundreds of articles have been published across disciplinary fields, each tackling a piece of the childhood obesity puzzle. It is challenging to synthesize such a vast body of research into a "big picture" of influences on childhood overweight and obesity. Some researchers (e.g., Davison & Birch, 2001; Neumark-Sztainer, 2005; Tabacchi et al., 2007) have attempted to remedy this problem by offering ecological models inspired implicitly or explicitly by Bronfenbrenner's ecological systems theory (Bronfenbrenner, 1979). These models summarize critical environmental influences on weight imbalance at specific stages in development (e.g., adolescence for Neumark-Sztainer's, 2005 model; early childhood for the Tabacchi et al., 2007 model). In this article, we extend their work by offering a new ecological model (the Six-Cs model; see Figure 1) that (a) acknowledges not only *environmental* but also *hereditary* influences, (b) specifies a system for *categorizing environmental*

influences, and (c) may be *adapted to any stage of child development* from infancy through adolescence.

In the following section, we present a summary of some recent advances in research on child overweight and obesity, organized according to the spheres of the Six-Cs model (*cell, child, clan, community, country,* and *culture*). The cell sphere represents genetic predispositions to body structure and other biological factors. The child sphere represents personal and behavioral characteristics, some (but not all) of which are within the child's control. The clan sphere represents family characteristics, such as parental dynamics and home rituals. For the sake of parsimony, three of Neumark-Sztainer's (2005) separate spheres of influence—peers, schools and other institutional factors, and community factors—have been combined into a single sphere called community, which represents factors concerning the child's social world outside of the home. The country sphere represents state- and national-level institutions that influence citizens' priorities and constrain their opportunities. Last, the culture sphere is analogous to what Neumark-Sztainer called "societal factors": culture-specific norms, myths, and biases that guide citizens' and policy makers' fundamental assumptions about eating, exercise, health, and the body.

Childhood overweight and obesity are complex, and there are hundreds if not thousands of contributing factors. A comprehensive summary is outside the scope of this article; instead, we have chosen to summarize a small number of factors within each sphere, looking at recent research documenting these factors' potential or enduring importance for children at various developmental stages. Following this summary, we present the Six-Cs model, which includes these factors as well as others identified in earlier research.

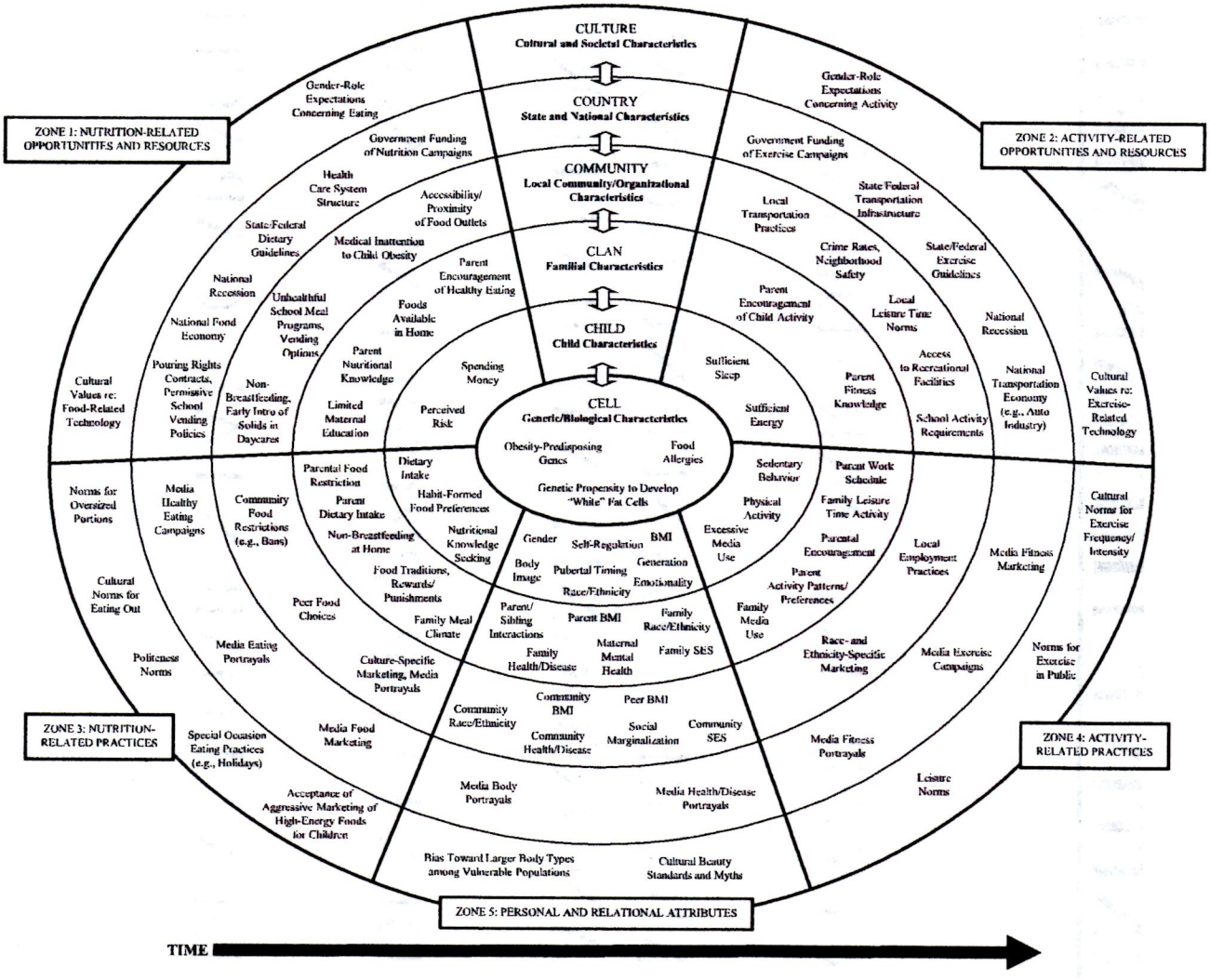

Figure 1. The Six-Cs developmental ecological model of contributors to overweight and obesity in childhood.

RECENT ADVANCES IN RESEARCH ON CHILDHOOD OVERWEIGHT AND OBESITY

Select Factors in the Cell Sphere

Child body composition is influenced first and foremost by heredity (Rankinen et al., 2006). Recent data from large twin studies confirm genetic influences on childhood and adult adiposity and appetite traits (Carnell, Haworth, Plomin, & Wardle, 2008; Wardle, Carnell, Haworth, & Plomin, 2008). Population and twin studies yield an estimated heritability of birth weight, body mass index (BMI), and obesity-related phenotypes such as fat mass, skinfold thickness, and adipose tissue distribution ranging from 30% to 77% (Rankinen et al., 2006; Wardle et al., 2008). Recent genome-wide association studies have facilitated the identification of novel obesity-predisposing variables in the *FTO*, *MC4R*, *TMEM18*, *MTCH2*, *NEGR1*, and *PCSK1* genes (Loos et al., 2008; Thorleifsson et al., 2009; Willer et al., 2009).

Stakeholders in children's health responded with optimism to recent news that the U.S. child obesity rate had leveled off at about 30% (Ogden, Carroll, & Flegal, 2008), but this ceiling introduces the possibility that a saturation point has been reached such that obesogenic factors in the environment have coaxed obesity into expression among the majority of children who are genetically predisposed toward it. Intervention efforts should not omit these children, because genetic susceptibility and behavioral practices work interactively to modify the risk of child overweight (Manolio, 2009; Teran-Garcia, Rankinen, & Bouchard, 2008). Factors in the remaining spheres of the model concern such behavioral practices.

Select Factors in the Child Sphere

Recent research underscores the emerging or enduring importance of three notable factors within the child sphere: self-regulation, media exposure, and sleep. Compromised self-regulation (i.e., failure to control impulses or behaviors) in the preschool and kindergarten years predicts rapid gains in BMI and higher BMI by the middle-school years (Francis & Susman, 2009). Further, children's media exposure predicts overweight (Lumeng, Rahnama, Appugliese, Kaciroti, & Bradley, 2006) at the rate of about 167 additional kilocalories consumed per daily hour of television (Weicha et al., 2006). Jordan and Robinson (2008) reviewed evidence of four causal mechanisms behind this relationship—lower resting energy expenditure, displacement of physical activity, food advertising leading to greater caloric intake, and eating while viewing leading to greater caloric intake—and concluded that the factor with the greatest research support is food advertising, which leads to encouragement of greater caloric intake and appetitive priming (Institute of Medicine, 2006). Media use is also implicated in poor quality and duration of sleep, a factor that itself is linked with obesity in research showing that inadequate sleep in toddlerhood predicts obesity in the school years (Taheri, 2006) and even at age 21 (Al Mamun et al., 2007). Obesity in return lowers the quality of sleep in childhood by contributing to obstructive sleep apnea (Ievers-Landis & Redline, 2007); thus, the relationship between poor sleep and obesity is cyclical.

Select Factors in the Clan Sphere

The family is the central socialization context for most young children (Bost et al., 2006), and parental characteristics such as maternal education level (Sanigorski, Bell, Kremer, & Swinburn, 2007) and maternal mental health, especially depression (Blissett, Meyer, & Haycraft, 2007), influence the risk of obesity in offspring. Parental behaviors directly influence children's eating and weight (Wake, Nicholson, Hardy, & Smith, 2007) starting before birth, when nutrition and health behaviors, such as overeating and smoking during pregnancy, raise the likelihood of overweight in offspring (Tabacchi et al., 2007), and continuing in infancy, when breastfeeding predicts lower fat mass at age 4 compared to nonbreastfeeding (Robinson et al., 2009). Parent dietary intake influences child dietary intake (Galloway, Fiorito, Lee, & Birch, 2005; but note that in the United States, resemblance between child and parent diets is small to moderate; see Beydoun & Wang, 2009), and feeding strategies, such as food restriction have been implicated as well, especially restriction and control imposed by mothers who are obese themselves (Powers, Chamberlin, van Schaick, Sherman, & Whitaker, 2006).

Emerging research also points to both quantity and quality of family mealtimes as predictors of children's eating (Larson, Neumark-Sztainer, Hannan, & Story, 2007). A study of 8,000 children tracked from kindergarten through third grade indicated that each family meal they missed per week resulted in an 8% increase in overweight (Gable, Chang, & Kroll, 2007). Family environments of obese children are also marked by more conflict and negative mealtime behavior than those of nonobese children (Rhee, Lumeng, Appugliese, Kaciroti, & Bradley, 2006; Zeller et al., 2007), whereas positive and open parent–child communication is associated with less child obesity and greater consumption of nutritious foods (Golan & Crow, 2004; see also Fiese & Schwartz, 2008). The influence of family mealtime characteristics appears to be wide ranging, as troubled home mealtimes distinguish obese children from nonobese children regardless of child sex or race (Zeller et al., 2007).

Select Factors in the Community Sphere

The influence of community on children's weight status is extensive. Nearly 75% of U.S. preschool children spend part of the day in nonparental child care (U. S. Department of Education, 2005). Infants in day care settings are at higher risk for overweight and obesity, due in part to less breast milk consumption and earlier introduction of solids (Kim & Peterson, 2008). Moreover, child care licensing regulations vary, with most states having few nutrition and physical activity regulations related to obesity (Benjamin, Cradock, Walker, Slining, & Gillman, 2008; Kaphingst & Story, 2009). Unhealthful school meal programs and vending policies (Finkelstein, Hill, & Whitaker, 2008) and

medical inattention to child obesity (Benson, Baer, & Kaelber, 2009) are two noteworthy factors that further encourage excess weight.

Children's weight status is also influenced by the company they keep. Peer food choices affect children's food choices, for both healthful (such as vegetables) and less healthful (such as French fries) foods (Patrick & Nicklas, 2005). Peer networks may also exacerbate the negative social and psychological effects of overweight among children, thereby leading to continued overeating for psychological comfort. Obese children and adolescents are more likely to be socially marginalized, bullied, and depressed than nonobese children (McNeely & Crosnoe, 2008; Zeller, Reiter-Purtill, & Ramey, 2008). Conversely, perceptions of low social status predict weight gain over time among adolescent girls (Lemeshow et al., 2008). Thus, the relationship between social marginalization and overeating appears to be bidirectional.

Neighborhood factors also belong in the community sphere. Access to facilities that encourage exercise (such as parks and pools) increases physical activity (Bell, Wilson, & Liu, 2008) and predicts decreased BMI (Evenson, Scott, Cohen, & Voorhees, 2007). However, the influence of such resources is minimized in communities where violent crime rates deter active play (Gomez, Johnson, Selva, & Sallis, 2004; Molnar, Gortmaker, Bull, & Buka, 2004). Retail food environments also determine child dietary habits. Youth residing in neighborhoods with more supermarkets are at reduced risk for overweight (Liu, Wilson, Qi, & Ying, 2007; Powell, Auld, Chaloupka, O'Malley, & Johnston, 2007), whereas increased proximity to convenience stores and fast-food outlets is associated with poor dietary intake and greater child BMI (Davis & Carpenter, 2009; Jago, Baranowski, Baranowski, Cullen, & Thompson, 2007).

Select Factors in the Country Sphere

Emerging evidence suggests that the national economic recession is contributing to child obesity rates (Foundation for Child Development, 2009) by prompting parents to favor low-cost, low-micronutrient, high-calorie foods, such as convenience and fast foods. Within the context of the economy, state and federal policies concerning child nutrition and exercise set parameters that influence community resources and practices. Recently, these policies have been accommodating toward corporate interests and permissive about enforcing adherence. About 55% of the schools that Finkelstein et al. (2008) studied had "pouring rights" contracts with beverage companies allowing them sole-distributor privileges in school vending locations, and fewer than 43% of schools participated in the Department of Defense's Fresh Fruit and Vegetable program or state "farm-to-school" fresh-produce programs. Some states have enacted legislation to fight these trends. Arkansas Act 1220 of 2003 to Combat Obesity placed restrictions on competitive foods (foods and beverages sold at schools separately from USDA school meal programs) and required school districts to measure body mass annually and report results to parents (Raczynski et al., 2005). Following passage of the act, the proportion of children in Arkansas who were overweight dropped from 20.9% in 2003–2004 to 20.6% in 2006–2007, a small but significant reversal of a previously increasing obesity trend (Arkansas Center for Health Improvement, 2007). Thus, state and federal legislation holds promise for effecting change, provided schools and other community institutions comply with it and lobbyists representing food companies that market to children do not block or overturn it (see Clifford, 2008).

Select Factors in the Culture Sphere

Citizens' and policy makers' beliefs and behaviors surrounding eating and exercise are shaped by overarching cultural and social norms. Portion size is a concern because consumption norms, such as cleaning one's plate, accepting second helpings, buying in bulk at discount rates, and eating from oversized bowls and plates (Fisher, 2007; Wansink & Cheney, 2005) have been shown to increase the amount of food that citizens consume. Further, cultural values celebrating food technologies that promise modern ways of eating may lure consumers to a diet rich in energy but stripped of essential micro- and macronutrients (Ames, 2006). Advertising to child and adolescent audiences for such foods is ubiquitous (Gantz, Schwartz, Angelini, & Rideout, 2007; Harrison & Marske, 2005; Montgomery & Chester, 2009) and creates the impression that it is natural to eat large quantities of refined and fast foods, especially for minority markets, such as African Americans (Harrison, 2006). Moreover, characters in commercials for fast foods are typically average weight (Harrison, 2006), thereby obscuring the real-world connection between a fast-food diet and excess adiposity. Cultural values regarding body shape also inform citizens' perceptions of what is attractive and healthy, and these values vary for different ethnic cultures, with African Americans and Latinas and Latinos favoring fuller body shapes than White/Anglo Americans (Schooler, Ward, Merriwether, & Caruthers, 2004) and identifying heavy child body shapes as healthy (Skelton, Busey, & Havens, 2006).

Potential Proximal–Distal Factor Interactions

We discussed the factors we described in the preceding section independently, but in reality factors within one sphere may influence factors within the same sphere or another sphere in significant ways (Neumark-Sztainer, 2005). For instance, parents and family members influence children's media and sleep opportunities and practices, so one potential proximal–distal factor interaction might be the role of parents (clan sphere) in constraining and facilitating children's home media and sleep behaviors (child sphere). Other potential interactions include the role of community availability of grocery stores (community sphere) in determining children's participation in family meal shopping and preparation (clan sphere), and the effect of state policies and spending priorities (country sphere) on the development of municipal infrastructures supporting physical activity (community

sphere). Very distal factors may also interact with proximal factors through media vehicles, as when media portrayals of a culture's "truths" about health and attractiveness (culture sphere) influence parents' views of their children's body weight (clan sphere) and result in family resistance to educational or clinical interventions that challenge these "truths."

THE SIX-CS DEVELOPMENTAL ECOLOGICAL MODEL

No theoretical model can provide an exhaustive list of all conceivable factors that determine an individual child's weight status. The multidimensional model we present in Figure 1 is intended to illustrate the types of factors that belong in each sphere, and to offer a method for organizing them that will contribute to continued research and evidence-based policy making. Like Walker et al. (2007), we use the term *factors* to refer to the biological, psychosocial, and environmental hazards that can compromise healthy development. Outside the cell and child spheres, the model represents only factors that can be modified by education, interventions, or public policy (Walker et al., 2007). Although genetically inherited factors are not modifiable by traditional interventions, they interact with factors in the other spheres in ways that should inform interventionists' efforts to customize their programs by population.

Dimension 1: The Six-Cs Dimension

The first dimension of the model refers to the six broad spheres of influence within and surrounding the child, namely, the *cell*, *child*, *clan*, *community*, *country*, and *culture* spheres, which we defined in the Overview. Some factors may reside in more than one sphere (e.g., school policy decisions occur at both community and country levels), and there is interplay between the spheres such that factors in one sphere may influence factors in another (Neumark-Sztainer, 2005), as represented by the double-headed arrows linking the spheres. Although children and families have relatively little direct control over the most distal spheres, opportunities for control exist for some factors. For instance, families can choose to reject cultural assumptions, such as unhealthy beauty ideals. Moreover, factors across spheres may interact to produce outcomes not produced by any of the factors alone (cf. Bronfenbrenner's "mesosystem"; Bronfenbrenner, 1986). As in Bronfenbrenner's (1986) model, this feature of the Six-Cs model highlights the need to generate data that will shed light on important mediating and moderating factors within and across proximal and distal spheres.

Dimension 2: The NAP Dimension

The second (NAP) and third (ROP) dimensions split the model into five zones that encompass all but the cell sphere. The *NAP dimension* reflects the fact that eating, exercise, and person-specific characteristics all determine weight status. It therefore splits the model into sections representing *nutrition* (Zones 1 and 3), *activity* (Zones 2 and 4), and *personal and relational attributes* (Zone 5). As weight status is influenced by energy intake *and* expenditure, nutrition- and activity-related hemispheres balance one another. Personal and relational attributes range from those of the child himself or herself, in the proximal spheres, to those of people in general as they are presented via cultural myths and values, in the distal spheres.

Dimension 3: The ROP Dimension

The *ROP dimension* reflects the fact that a child's weight status is influenced not only by daily behaviors (i.e., practices) but also by structural constraints on those behaviors (i.e., opportunities and resources). It therefore splits the model into sections representing *resources and opportunities* (Zones 1 and 2) and *practices* (Zones 3 and 4), all of which reflect more (practices) or less (resources and opportunities) controllable realms of influence. The ROP dimension is particularly useful for informing evidence-based policy making. For instance, policies designed to influence practices might culminate in media public service campaigns to persuade families to eat more fruits and vegetables, whereas those designed to influence resources and opportunities might generate initiatives to change neighborhood transportation infrastructure to provide more bicycle lanes.

Dimension 4: The Time Dimension

The fourth dimension, *Time*, represented by an arrow at the bottom of the model, is analogous to Bronfenbrenner's "chronosystem" (Bronfenbrenner, 1986). The time arrow signifies two types of developmental changes in the model. First, the strength of the outward-pointing arrows in Figure 1, which represent the relative *control of agents in the proximal spheres* (i.e., the child and his or her family) *over factors in the distal spheres*, is hypothesized to increase with development. In the model, the inward- and outward-pointing arrows are equally weighted, but in reality the influence of factors in the distal spheres on the proximal spheres tends to be greater than the reverse because distal factors impose constraints that limit both activity in the proximal spheres and the power of interventions affecting factors within these spheres. For example, families in "food deserts" (Kipke et al., 2007) do not have reasonable, affordable access to a variety of fresh vegetables no matter how persuasive a local vegetable-consumption campaign might be. However, the influence of agents in the proximal spheres, especially the child sphere, should grow as children gain autonomy and begin to influence activity in the distal spheres. For instance, as children's linguistic and reasoning abilities develop, their influence over parental shopping decisions via persistent attacks on parental resolve (i.e., "kidfluence," "the nag factor," or "pester power"; see Morton, Stanton, Zuppa, & Mehta, 2005) increases dramatically. Thus, the child's control over the contexts that constrain his or her eating and exercise is not fixed but should increase with the gains in personal agency that come with development.

Second, the *relevance of particular influences* is hypothesized to change with development. For instance, national formula

marketing campaigns, community constraints on public breastfeeding, and day care introduction of solid foods would all be relevant during infancy. By adolescence, school vending policies and teen-directed marketing would become relevant. To illustrate the model's adaptability to development over time, in Table 1, we present the factors from the preceding section along with notation representing the relevance of and degree of research support for each factor for children at each of five developmental stages (infancy, toddlerhood, preschool, school age, and adolescence). The entries marked by asterisks denote areas where more research support is needed and should therefore be of particular interest to investigators wishing to fill research gaps.

The Six-Cs model in Figure 1 is essentially an omnibus collection of factors relevant to overweight/obesity for children at multiple stages of development. It should not serve as a practical working model for any single age group. Rather, we present it illustratively, in the hope that it will inspire the construction of separate Six-Cs working models tailored to each developmental stage by specifying the most relevant and research-supported factors for children at that stage. To that end, the construction of schematics like Table 1 will help researchers build age-appropriate working models by identifying both known factors for a particular age group (the "X" entries in the table) and potential factors for that group (the asterisked entries).

POLICY RELEVANCE OF THE MODEL

The public policy implications of childhood weight imbalance are myriad (Simpson, Alendy, Cooper, & Murphy, 2008). Meta-analytic evaluations of interventions to prevent obesity among children have shown only small effects on target behaviors and no significant impact on BMI (Kamath et al., 2008). The Six-Cs

Table 1

Select Contributors to Childhood Overweight and Obesity, by Developmental Stage

			Developmental stage				
Six-Cs sphere	Select contributing factors	Example of recent supporting literature	Infancy	Toddlerhood	Preschool	School age	Adolescence
Cell	Obesity-predisposing genes	Loos et al., 2008	X	X	X	X	X
Child	Compromised self-regulation	Francis & Susman, 2009	*	X	X	X	*
	Excessive media exposure	Lumeng et al., 2006	*	*	X	X	X
	Inadequate sleep	Taheri, 2006	*	X	X	X	X
Clan	Limited maternal education	Sanigorski et al., 2007	*	*	X	X	*
	Compromised maternal mental health	Blissett et al., 2007	*	X	X	*	*
	Nonbreastfeeding at home	Robinson et al., 2009	X	*	—	—	—
	Parent dietary intake	Galloway et al., 2005	*	X	X	X	X
Community	Nonbreastfeeding and early introduction of solids in daycare	Kim & Peterson, 2008	X	*	—	—	—
	Medical inattention to child obesity	Benson et al., 2009	*	X	X	X	X
	Proximity to convenience and fast-food outlets and absence of nearby fresh-food outlets	Davis & Carpenter, 2009	*	*	*	X	X
	Unhealthful peer food choices	Patrick & Nicklas, 2005	—	—	X	X	X
	Lack of access to playgrounds and other recreational facilities	Evenson et al., 2007	—	*	*	X	X
	Unhealthful school or daycare meal programs and/or vending options	Finkelstein et al., 2008	*	*	*	X	X
	Social marginalization	Lemeshow et al., 2008	—	—	*	X	X
Country	Pouring rights contracts and permissive school vending policies	Finkelstein et al., 2008	—	—	—	X	X
	National economic recession	Foundation for Child Development, 2009	X	X	X	X	X
Culture	Positive bias toward larger body types among high-risk populations	Skelton et al., 2006	*	*	X	X	X
	Oversized portions	Fisher, 2007	*	X	X	X	X
	Aggressive marketing of high-calorie foods to/for children	Montgomery & Chester, 2009	—	*	*	X	X

Note. Evidence of the role of some factors has emerged quite recently, so a solid body of research support does not yet exist for those factors among children of all developmental stages. This table therefore contains three entries: "X" where research clearly supports the importance of a particular factor for a particular developmental stage (note that genetic and economic factors are assumed to exert an influence across the lifespan); "*" where support is scant and additional research is called for; and "—" where the relevance of a particular factor is low. We encourage investigators to pay special attention to the "*" entries as opportunities for research that will contribute to evidence-based policymaking via knowledge generation (Choi, 2005).

model reveals why unidimensional intervention approaches may be inadequate. For instance, organized efforts to reduce childhood overweight by altering child and family behavior (e.g., Carr, 2009; Dalton & Kitzmann, 2008) or local community practices (DeMattia & Denney, 2008) reside chiefly in the proximal spheres of Zone 3. Opportunities in other zones remain underexplored. Initiatives to change children's weight status should be based on multidimensional research efforts (Maziak, Ward, & Stockton, 2008) and program design and implementation that respects the diversity of children's needs and local contexts (Institute of Medicine, 2009; Wiley & Ebata, 2004). If the three main steps toward evidence-based policy making are knowledge generation, knowledge exchange and dissemination, and knowledge uptake and implementation (Choi, 2005), then the key contribution of this article is knowledge generation, in particular the identification of factors at multiple ecological levels along with potential interactions between these factors, as well as the resulting recommendation that we should avoid unidimensional interventions. Continued efforts to plot factors within the model's zones and identify the most critical combinations of factors for each developmental stage, to determine where more multilevel intervention and policy work is needed, will be valuable for stakeholders wishing to attack the problem of childhood obesity from all possible angles for children of all ages.

CRITICAL ISSUES AND IMPORTANT NEXT STEPS

One of the highest funding priorities in child obesity research is work that identifies key environmental determinants of youth obesity and sustainable environmental solutions, with special attention to high-risk populations (Story, Sallis, & Orleans, 2009). Researchers' ability to accomplish this will be contingent on their willingness to continue identifying factors within the child, clan, community, country, and culture spheres and testing their interaction with factors in the cell sphere by analyzing self-report, geospatial, and genetic and biometric data from children, their parents, and their care and education providers. Transdisciplinary research is therefore essential to identifying understudied aspects of the model and mapping changes in the model over time and development.

Equally important will be efforts to adapt the model to high-risk populations. Latinas and Latinos, African Americans, Native Americans, and lower-income families in the United States are especially vulnerable to environmental effects on obesity (Eichner et al., 2008). In addition, rural families living in areas where food insecurity is high face special challenges in maintaining a balanced diet (Gundersen, Lohman, Garasky, Stewart, & Eisenmann, 2008; Olsen & Strawderman, 2008). We hope that the Six-Cs model will be a useful tool for multidisciplinary research teams who share our twin goals of documenting predictors and facilitators of childhood overweight and obesity across and within different socioeconomic, cultural, geographical, and developmental groupings, and developing tailored, evidence-based prevention and intervention programs that lower the risk of obesity and its comorbidities in the childhood years and beyond.

REFERENCES

Al Mamun, A., Lawlor, D. A., Cramb, S., O'Callaghan, M., Williams, G., & Najman, J. (2007). Do childhood sleeping problems predict obesity in young adulthood? Evidence from a prospective birth cohort study. *American Journal of Epidemiology, 166*, 1368–1373.

Ames, B. N. (2006). Low micronutrient intake may accelerate the degenerative diseases of aging through allocation of scarce micronutrients by triage. *Proceedings of the National Academy of Sciences, 103*(47), 17589–17594.

Arkansas Center for Health Improvement. (2007). *Assessment of childhood and adolescent obesity in Arkansas: Year four (fall 2006-spring 2007)*. Little Rock: Author.

Bell, J. F., Wilson, J. S., & Liu, G. C. (2008). Neighborhood greenness and 2-year changes in body mass index of children and youth. *American Journal of Preventive Medicine, 35*, 547–553.

Benjamin, S. E., Cradock, A., Walker, E. M., Slining, M., & Gillman, M. W. (2008). Obesity prevention in child care: A review of U.S. state regulations. *BMC Public Health, 8*, Article No. 188.

Benson, L., Baer, H. J., & Kaelber, D. C. (2009). Trends in the diagnosis of overweight and obesity in children and adolescents: 1999–2007. *Pediatrics, 123*(1), e153–e158.

Beydoun, M. A., & Wang, Y. (2009). Parent–child dietary intake resemblance in the United States: Evidence from a large representative survey. *Social Science and Medicine, 68*, 2137–2144.

Blissett, J., Meyer, C., & Haycraft, E. (2007). Maternal mental health and child feeding problems in a non-clinical group. *Eating Behaviors, 8*, 311–318.

Bost, K. K., Shin, N., McBride, B., Brown, G., Vaughn, B., Coppola, G., et al. (2006). Maternal secure base scripts, children's attachment security, and mother–child narrative styles. *Attachment and Human Development, 8*, 241–261.

Bronfenbrenner, U. (1979). *The ecology of human development*. Cambridge, MA: Harvard University Press.

Bronfenbrenner, U. (1986). Ecology of the family as a context for human development. *Developmental Psychology, 22*, 723–742.

Carnell, S., Haworth, C. M., Plomin, R., & Wardle, J. (2008). Genetic influence on appetite in children. *International Journal of Obesity, 32*, 1468–1473.

Carr, A. (2009). The effectiveness of family therapy and systemic interventions for child-focused problems. *Journal of Family Therapy, 31*, 3–45.

Centers for Disease Control and Prevention. (2009). Childhood overweight and obesity. Retrieved June 16, 2009, from http://www.cdc.gov/obesity/childhood/index.html

Choi, B. C. (2005). Twelve essentials of science-based policy. *Preventing Chronic Disease, 2*(4), 1–11.

Clifford, S. (2008, July 30). Tug of war in food marketing to children. *The New York Times*. Retrieved January 13, 2009, from http://www.nytimes.com/2008/07/30/business/media/30adco.html?_r=1&emc=eta1

Dalton, W. T., & Kitzmann, K. M. (2008). Broadening parental involvement in family-based interventions for pediatric overweight: Implications from family systems and child health. *Family and Community Health, 31*, 259–268.

Davis, B., & Carpenter, C. (2009). Proximity of fast-food restaurants to schools and adolescent obesity. *American Journal of Public Health*, *99*(3), doi:10.2105/AJPH.2008.137638.

Davison, K., & Birch, L. (2001). Childhood overweight: A contextual model and recommendations for future research. *Obesity Reviews*, *2*(3), 159–171.

DeMattia, L., & Denney, S. L. (2008). Childhood obesity prevention: Successful community-based efforts. *Annals of the American Academy of Political and Social Science*, *615*, 83–99.

Eichner, J. E., Moore, W. E., Perveen, G., Kobza, C. E., Abbott, K. E., & Stephens, A. L. (2008). Overweight and obesity in an ethnically diverse rural school district: The Healthy Kids Project. *Obesity*, *16*, 501–504.

Evenson, K. R., Scott, M. M., Cohen, D. A., & Voorhees, C. C. (2007). Girls' perception of neighborhood factors on physical activity, sedentary behavior, and BMI. *Obesity*, *15*, 430–445.

Fiese, B. H., & Schwartz, M. (2008). Reclaiming the family table: Mealtimes and child health and wellbeing. *Society for Research in Child Development Social Policy Report*, *12*(4), 3–18.

Finkelstein, D. M., Hill, E. L., & Whitaker, R. C. (2008). School food environments and policies in U. S. public schools. *Pediatrics*, *122*, e251–e259.

Fisher, J. O. (2007). Effects of age on children's intake of large and self-selected food portions. *Obesity*, *15*, 403–412.

Foundation for Child Development. (2009). The 2009 Foundation for Child Development child and youth well-being index (CWI) report. Retrieved June 5, 2009, from http://www.fcd-us.org/usr_doc/Final-2009CWIReport.pdf

Francis, L. A., & Susman, E. J. (2009). Self-regulation and rapid weight gain in children from age 3 to 12 years. *Archives of Pediatrics and Adolescent Medicine*, *163*, 297–302.

Gable, S., Chang, Y., & Kroll, J. (2007). Television watching and frequency of family meals are predictive of overweight onset and persistence in a national sample of school-aged children. *Journal of the American Dietetic Association*, *107*, 53–61.

Galloway, A. T., Fiorito, L., Lee, Y., & Birch, L. L. (2005). Parental pressure, dietary patterns, and weight status among girls who are "picky eaters". *Journal of the American Dietary Association*, *105*, 541–548.

Gantz, W., Schwartz, N., Angelini, J. R., & Rideout, V. (2007). *Food for thought: Television food advertising to children in the United States*. Menlo Park, CA: Henry J. Kaiser Family Foundation.

Golan, M., & Crow, S. (2004). Targeting parents exclusively in the treatment of childhood obesity: Long-term results. *Obesity Research*, *12*, 357–361.

Gomez, J. E., Johnson, B. A., Selva, M., & Sallis, J. F. (2004). Violent crime and outdoor physical activity among inner-city youth. *Preventive Medicine*, *39*, 876–881.

Gundersen, C., Lohman, B. J., Garasky, S., Stewart, S., & Eisenmann, J. (2008). Food security, maternal stressors, and overweight among low-income US children: Results from the National Health and Nutrition Examination Survey (1999–2002). *Pediatrics*, *122*, 529–540.

Harrison, K. (2006). Fast and sweet: Nutritional attributes of television food advertisements with and without Black characters. *Howard Journal of Communications*, *17*, 249–264.

Harrison, K., & Marske, A. L. (2005). Nutritional content of foods advertised during the television programs children watch most. *American Journal of Public Health*, *95*, 1568–1574.

Ievers-Landis, C. E., & Redline, S. (2007). Pediatric sleep apnea: Implications of the epidemic of childhood overweight. *American Journal of Respiratory and Critical Care Medicine*, *175*, 436–441.

Institute of Medicine (IOM) Committee on Childhood Obesity Prevention Actions for Local Governments. (2009). *Local government actions to prevent childhood obesity*. Washington, DC: National Academies Press.

Institute of Medicine (IOM) Committee on Food Marketing and the Diets of Children and Youth, and Food and Nutrition Board. (2006). *Food marketing to children and youth: Threat or opportunity?* Washington, DC: National Academies Press.

Jago, R., Baranowski, T., Baranowski, J., Cullen, K., & Thompson, D. (2007). Distance to food stores and adolescent male fruit and vegetable consumption: Mediation effects. *International Journal of Behavior, Nutrition, and Physical Activity*, *4*, 35.

Jordan, A. B., & Robinson, T. N. (2008). Children, television viewing, and weight status: Summary and recommendations from an expert panel meeting. *Annals of the American Academy of Political and Social Science*, *615*, 119–132.

Kamath, C. C., Vickers, K. S., Ehrlich, A., McGovern, L., Johnson, J., Singhal, V., et al. (2008). Behavioral interventions to prevent childhood obesity: A systematic review and metaanalyses of randomized trials. *Journal of Clinical Endocrinology & Metabolism*, *93*, 4606–4615.

Kaphingst, K. M., & Story, M. (2009). Child care as an untapped setting for obesity prevention: State child care licensing regulations related to nutrition, physical activity, and media use for preschool-aged children in the United States. *Preventing Chronic Disease*, *6*(1), A11.

Kim, J., & Peterson, K. E. (2008). The effects of infant child care on infant feeding practices and weight gain among U. S. infants. *Archives of Pediatrics and Adolescent Medicine*, *162*, 627–633.

Kipke, M. D., Iverson, E., Moore, D., Booker, C., Ruelas, V., Peters, A. L., et al. (2007). Food and park environments: Neighborhood-level risks for childhood obesity in east Los Angeles. *Journal of Adolescent Health*, *40*, 325–333.

Larson, N., Neumark-Sztainer, D., Hannan, P. J., & Story, M. (2007). Family meals during adolescence are associated with higher diet quality and healthful meal patterns during young adulthood. *Journal of the American Dietetic Association*, *107*, 1502–1510.

Lemeshow, A. R., Fisher, L., Goodman, E., Kawachi, I., Berkey, C. S., & Colditz, G. A. (2008). Subjective social status in the school and changes in adiposity in female adolescents. *Archives of Pediatrics and Adolescent Medicine*, *162*, 23–28.

Liu, G., Wilson, J., Qi, R., & Ying, J. (2007). Green neighborhoods, food retail and childhood overweight: Differences by population density. *American Journal of Health Promotion*, *21*, 317–325.

Loos, R. J. F., Lindgren, C. M., Shengxu, L., Wheeler, E., Zhao, J. H., Prokopenko, I., et al. (2008). Common variants near MC4R are associated with fat mass, weight, and risk of obesity. *Nature Genetics*, *40*, 768–775.

Lumeng, J. C., Rahnama, S., Appugliese, D., Kaciroti, N., & Bradley, R. H. (2006). Television exposure and overweight risk in preschoolers. *Archives of Pediatrics and Adolescent Medicine*, *160*, 417–422.

Manolio, T. A. (2009). Cohort studies and the genetics of complex disease. *National Genetics*, *41*, 5–6.

Maziak, W., Ward, K. D., & Stockton, M. B. (2008). Childhood obesity: Are we missing the big picture? *Obesity Reviews*, *9*, 35–42.

McCarthy, A., Hughes, R., Tilling, K., Davies, D., Smith, G. D., & Ben-Shlomo, Y. (2007). Birth weight; postnatal, infant, and

childhood growth; and obesity in young adulthood: Evidence from the Barry Caerphilly Growth Study. *American Journal of Clinical Nutrition, 86*, 907–913.

McNeely, C., & Crosnoe, R. (2008). Social status, peer influence, and weight gain in adolescence: Promising directions for addressing the obesity epidemic. *Archives of Pediatric and Adolescent Medicine, 162*, 91–92.

Molnar, B. E., Gortmaker, S. L., Bull, F. C., & Buka, S. L. (2004). Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. *American Journal of Health Promotion, 8*, 378–386.

Montgomery, K. C., & Chester, J. (2009). Interactive food and beverage marketing: Targeting adolescents in the digital age. *Journal of Adolescent Health, 45*(3), S18–S29.

Morton, H., Stanton, R., Zuppa, J., & Mehta, K. (2005). Food advertising and broadcasting legislation: A case of system failure? *Nutrition and Dietetics, 62*, 26–32.

Neumark-Sztainer, D. (2005). Preventing the broad spectrum of weight-related problems: Working with parents to help teens achieve a healthy weight and a positive body image. *Journal of Nutrition Education and Behavior, 37*, S133–S139.

Ogden, C. L., Carroll, M. D., & Flegal, K. M. (2008). High body mass index for age among U. S. children and adolescents, 2003-2006. *Journal of the American Medical Association, 299*, 2401–2405.

Olsen, C. M., & Strawderman, M. S. (2008). The relationship between food insecurity and obesity in rural childbearing women. *Journal of Rural Health, 24*, 60–66.

Patrick, H., & Nicklas, T. A. (2005). A review of family and social determinants of children's eating patterns and diet quality. *Journal of the American College of Nutrition, 24*(2), 83–92.

Powell, L., Auld, C., Chaloupka, F., O'Malley, P., & Johnston, L. (2007). Associations between access to food stores and adolescent body mass index. *American Journal of Preventive Medicine, 33*, S301–S307.

Powers, S. W., Chamberlin, L. A., van Schaick, K. B., Sherman, S. N., & Whitaker, R. C. (2006). Maternal feeding strategies, child eating behaviors, and child BMI in low-income African-American preschoolers. *Obesity, 14*, 2026–2033.

Raczynski, J. M., Phillips, M., Bursac, Z., Pulley, L., West, D., Birdsong, M., et al. (2005). *Establishing a baseline to evaluate Act 1220 of 2003: An act of the Arkansas General Assembly to combat childhood obesity*. Little Rock: University of Arkansas College of Public Health.

Rankinen, T., Zuberi, A., Chagnon, Y. C., Weisnagel, S. J., Argyropoulos, G., Walts, B., et al. (2006). The human obesity gene map: The 2005 update. *Obesity (Silver Spring), 14*, 529–644.

Rhee, K., Lumeng, J., Appugliese, D., Kaciroti, N., & Bradley, R. (2006). Parenting styles and overweight status in first grade. *Pediatrics, 117*, 2047–2054.

Robinson, S. M., Marriott, L. D., Crozier, S. R., Harvey, N. C., Gale, C. R., Inskip, H. M., et al. (2009). Variations in infant feeding practice are associated with body composition in childhood: A prospective cohort study. *Journal of Clinical Endocrinology and Metabolism, 94*, 2799–2805.

Sanigorski, A. M., Bell, A. C., Kremer, P. J., & Swinburn, B. A. (2007). High childhood obesity in an Australian population. *Obesity, 15*, 1908–1912.

Schooler, D., Ward, L. M., Merriwether, A., & Caruthers, A. (2004). Who's that girl: Television's role in the body image development of young White and Black women. *Psychology of Women Quarterly, 28*, 38–47.

Simpson, L., Alendy, C., Cooper, J., & Murphy, C. (2008). *Childhood obesity: The role of health policy*. Report to the Second National Childhood Obesity Congress, Miami, FL.

Skelton, J. A., Busey, S. L., & Havens, P. L. (2006). Weight and health status of inner city *African American children: Perceptions of children and their parents. Body Image, 3*, 289–293.

Story, M., Sallis, J. F., & Orleans, C. T. (2009). Adolescent obesity: Towards evidence-based policy and environmental solutions. *Journal of Adolescent Health, 45*(3), S1–S5.

Tabacchi, G., Giammanco, S., La Guardia, M., & Giammanco, M. (2007). A review of the literature and a new classification of the early determinants of childhood obesity: From pregnancy to the first years of life. *Nutrition Research, 27*, 587–604.

Taheri, S. (2006). The link between short sleep duration and obesity: We should recommend more sleep to prevent obesity. *Archives of Disease in Childhood, 91*, 881–884.

Teran-Garcia, M., Rankinen, T., & Bouchard, C. (2008). Genes, exercise, growth, and the sedentary, obese child. *Journal of Applied Physiology, 105*, 988–1001.

Thorleifsson, G., Walters, G. B., Gudbjartsson, D. F., Steinthorsdottir, V., Sulem, P., Helgadottir, A., et al. (2009). Genome-wide association yields new sequence variants at seven loci that associate with measures of obesity. *National Genetics, 41*, 18–24.

U.S. Department of Education. (2005). *National Household Education Surveys Program. Child care and early education arrangements of infants, toddlers, and preschoolers: 2001* (Report No. NCES 2006-039). Washington, DC: National Center for Education Statistics.

Wake, M., Nicholson, J. M., Hardy, P., & Smith, K. (2007). Preschooler obesity and parenting styles of mothers and fathers: Australian National Population Study. *Pediatrics, 120*, e1520–e1527.

Walker, S. P., Wachs, T. D., Gardner, J. M., Lozoff, B., Wasserman, G. A., Pollitt, E., et al. (2007). Child development in developing countries 2: Child development: Risk factors for adverse outcomes in developing countries. *Lancet, 369*, 145–167.

Wansink, B., & Cheney, M. M. (2005). Super bowls: Serving bowl size and food consumption. *Journal of the American Medical Association, 293*, 1727–1728.

Wardle, J., Carnell, S., Haworth, C. M. A., & Plomin, R. (2008). Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *American Journal of Clinical Nutrition, 87*, 398–404.

Weicha, J. L., Peterson, K. E., Ludwig, D. S., Kim, J., Sobol, A., & Gortmaker, S. L. (2006). When children eat what they watch: Impact of television viewing on dietary intake in youth. *Archives of Pediatrics and Adolescent Medicine, 160*, 436–442.

Wiley, A., & Ebata, A. (2004). Reaching "the American family": Making diversity real in family life education. *Family Relations, 53*, 273–281.

Willer, C. J., Speliotes, E. K., Loos, R. J. F., Li, S., Lindgren, C. M., Heid, I. M., et al. (2009). Six new loci associated with body mass index highlight a neuronal influence on body weight regulation. *National Genetics, 41*, 24–34.

Zeller, M. H., Reiter-Purtill, J., Modi, A. C., Gutzwiller, J., Vannatta, K., & Davies, W. H. (2007). Controlled study of critical parent and family factors in the obesogenic environment. *Obesity, 15*, 126–136.

Zeller, M., Reiter-Purtill, J., & Ramey, C. (2008). Negative peer perceptions of obese children in the classroom environment. *Obesity, 16*, 755–762.