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THE PRESENT AND FUTURE

STATE-OF-THE-ART REVIEW

Family-Based Approaches to Cardiovascular Health Promotion

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ABSTRACT

Cardiovascular disease is the leading cause of mortality in the world, and the increasing burden is largely a consequence of modifiable behavioral risk factors that interact with genomics and the environment. Continuous cardiovascular health promotion and disease prevention throughout the lifespan is critical, and the family is a central entity in this process. In this review, we describe the potential rationale and mechanisms that contribute to the importance of family for cardiovascular health promotion, focusing on: 1) mutual interdependence of the family system; 2) shared environment; 3) parenting style; 4) caregiver perceptions; and 5) genomics. We conclude that family-based approaches that target both caregivers and children, encourage communication among the family unit, and address the structural and environmental conditions in which families live and operate are likely to be the most effective approach to promote cardiovascular health. We describe lessons learned, future implications, and applications to ongoing and planned studies.
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Cardiovascular disease (CVD) is the leading cause of mortality in the world (1,2), and the incidence of CVD in the United States continues to rise, largely as a consequence of risk factors modifiable by changes in behavior (3). Behavioral risk factors in early childhood, such as physical inactivity and unhealthy diet, contribute significantly to childhood obesity (4,5), which, in turn, is related to increased risk of developing CVD risk factors, such as diabetes, hypertension, and dyslipidemia, ultimately resulting in increased risk of atherosclerotic CVD (6–8). Conversely, improving cardiovascular health from childhood onward can have lifelong positive effects (9–12). Because our behaviors as adults are linked to exposures and critical periods during childhood, there is a need for continuous cardiovascular health promotion and disease prevention throughout the lifespan, involving all ages and stages of family life (13,14).

Because parents clearly influence their children's life-styles, the health status of the parent is intricately linked to that of their children. Numerous studies show a strong association of parental obesity with obesity in their children (5,15–17). It follows, therefore, that prevention of childhood obesity should include efforts aimed at the parents. Indeed, studies have shown that family-based approaches to cardiovascular health promotion can have beneficial

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ABBREVIATIONS AND ACRONYMS

CAD = coronary artery disease

CVD = cardiovascular disease

DNA = deoxyribonucleic acid

GWA = genome-wide association

effects on both children and parents (18–22). These findings have been replicated in low- and middle-income countries, and in low-resource settings in high-income countries as well (23,24). In addition, school-based programs tend to have relatively greater benefit when parent/caregiver participation is an integral component of the intervention (25–27). Finally, increasing evidence demonstrates that interventions targeting children may have beneficial spillover effects for parents and caregivers (28). The family is therefore a linchpin for cardiovascular health promotion throughout the life course.

In this review, we describe a potential rationale and mechanisms for these observations. Specifically, we focus on: 1) mutual interdependence of the family system; 2) shared environment; 3) parenting style; 4) caregiver perceptions; and 5) genomics (**Figure 1**). Because a substantial number of children live with caregivers who are not their biological parents, we have elected to use the term "caregiver" in this paper whenever appropriate.

MUTUAL INTERDEPENDENCE OF THE FAMILY SYSTEM

FAMILY AS A SYSTEM. The family is a complex system, where the family members interact to influence each other in a reciprocal fashion. Effective interventions to produce changes in behavior require insight into family dynamics and mutual interdependence of the family system. There are several different theories of family process and function; an exhaustive review is beyond the scope of this paper, but we draw upon several of them to provide insights into family-based approaches to cardiovascular health promotion (**Table 1**).

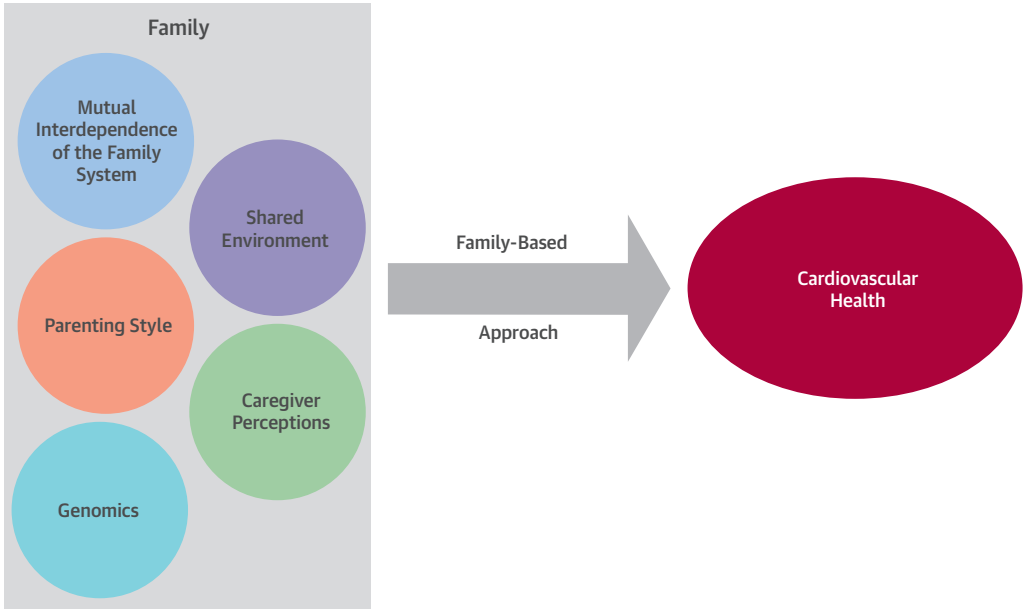
The Family Systems Theory proposes that the family is a complex social system where elements are interconnected, yet the system is best viewed as a whole, interacting with the environment (29). There are subsystems, such as sibling interactions and caregiver-child interactions, which can influence the whole system. In addition, a change in an individual's role can initiate a change in other family members. Although a substantial number of childhood obesity interventions have focused on parent-child dyads, it is likely that engaging the entire family may be more effective at cardiovascular health promotion (30,31).

FAMILY COHESION AND COMMUNICATION. Family cohesion, flexibility, and communication are also important for the development and sustenance of healthy behaviors, as described by the Circumplex Model (32). Separation and connection should be balanced among family members, such that there is a healthy blend of individuality and independence, in combination with emotional closeness and loyalty (30). Families that exhibit this type of balance are more likely to be able to set and achieve goals, such as maintaining an active life-style, whereas unbalanced families may struggle with adherence to treatment (30,32). For instance, disruptive home environments with conflict generally have less cohesive families, and this has been shown to be associated with an increased risk of obesity among children (33). In addition, lower family cohesion and adaptability have been associated with adolescent overeating (34). Conversely, some prevention intervention programs that affect the parent-child relationship, the relationships between a child and his/her peers, and the relationship between a child and the media have shown an association with more positive outcomes with regard to eating disorders and body dissatisfaction (35). It is important to note, however, that children living in single-parent families exhibit no significant difference in physical activity levels relative to children from 2-parent families (36).

In addition, families who do not communicate effectively will also face challenges and may not achieve their goals. In contrast, individuals from families who discuss diet and physical activity are more likely to have a healthy diet and be physically active (37). Communicating respect was noted to be an important component that was associated with positive influences on healthy diet and activity. Family members who feel valued and respected in the conversation are more likely to be positively influenced with respect to attitudes and behaviors. Social influence is mutual and interdependent in the family system, and caregivers can also be influenced by children. For example, children's healthy attitudes towards diet and physical activity can influence a mother's health-related behaviors (37).

COPING WITH STRESS. Finally, how families cope with and adapt to stress can predispose toward the adoption of unhealthy behaviors (38–40). In the double ABCX model, the event (A), the family's resources (B), and the family's perception of the event (C) all play a part in determining the family's response to a crisis (X) (38). A family may respond to stressful events by developing unhealthy habits, such as poor nutrition and sedentary behavior. Parents who are under significant emotional stress, such as those experiencing depression or anxiety, are unlikely to be able to support their children in changing behaviors (41). In particular, maternal depression

FIGURE 1 Family-Based Factors and Cardiovascular Health Promotion



Conceptual model depicting the relationship between family-based factors—including mutual interdependence of the family system, shared environment, parenting style, caregiver perceptions, and genomics—and cardiovascular health promotion.

(42), self-esteem (43), financial strain (44), and maternal distress (45,46) appear to be linked to childhood obesity, even when controlling for the effect of maternal body mass index (41). Financial pressures can also lead to parent distress, marital conflict, and disruptive parenting (47). Financially related marital discord may affect basic behaviors such as meal planning and physical activity, leading to less successful weight management. Given the high prevalence of obesity among low-income families, understanding these factors must also be a consideration when designing obesity treatment interventions (48).

SHARED ENVIRONMENT OF CHILDREN AND CAREGIVERS

PHYSICAL AND BEHAVIORAL ENVIRONMENTS. The shared environment of children and caregivers is the setting in which children first observe and acquire health habits. This shared environment consists of both physical and behavioral components. The physical environment includes the availability, diversity, and accessibility of food and physical activity opportunities. The behavioral environment, however, includes issues such as self-efficacy, self-regulation, role modeling, and feeding practices taught among family members (**Figure 2**) (49). From the time of birth, parents and caregivers have a major effect on both physical and behavioral environments. Indeed, this effect is manifested shortly after birth, beginning with the decision to breastfeed or use formula. Subsequently, learning about appropriate eating is reinforced when the child starts to consume solid foods; likewise, learning about physical activity starts soon after the child becomes mobile (50).

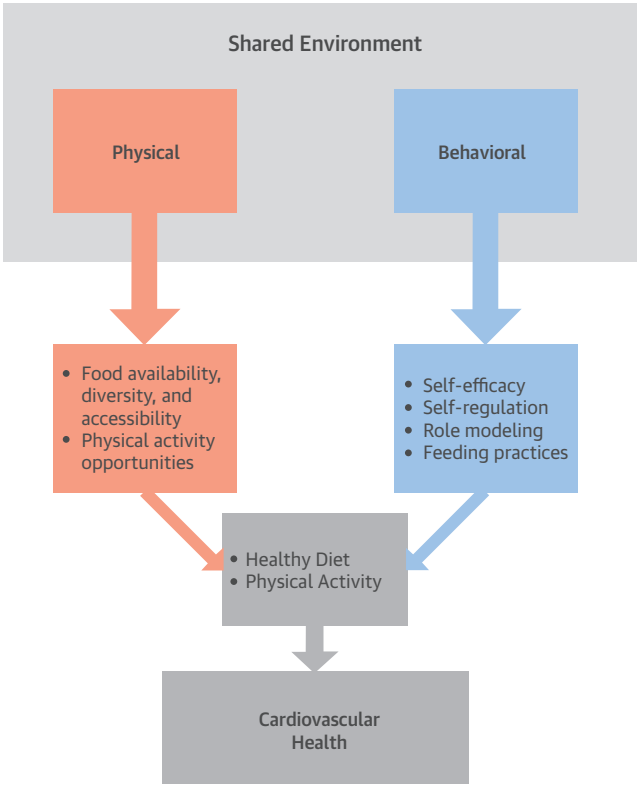
FOOD AVAILABILITY. Food availability and the family food supply are issues of critical importance that influence eating habits. A majority of families

TABLE 1 Central Elements of Family Theories and Their Relevance for CV Health Promotion

Theory	Central Element	Relevance for CV Health Promotion
Family Systems Theory	Elements of individual, family, and the environment are interconnected parts of a whole	Engaging the entire family in health interventions may be more effective
Circumplex Model	Families need to exhibit a healthy blend of cohesion and communication	Families with a balance of cohesion and communication are more likely to set and achieve goals
ABCX Model	An event (A), the family's resources (B), and the family's perception of the event (C) all play a part in determining the family's response to a crisis (X)	Parents who are better at coping with stress are less predisposed toward the adoption of unhealthy behaviors and better able to support their children to change behaviors

CV = cardiovascular.

FIGURE 2 Family Environment and Cardiovascular Health



Conceptual model depicting physical and behavioral elements of the shared family environment and their effects on cardiovascular health.

consume food outside of the home (51). In addition, when families eat meals at home, the source of food is often outside the home, including restaurants and fast food (52). Time spent cooking has declined over time, and this likely reflects increased use of pre-packaged and convenience foods that are moderately to highly processed (53). These processed foods are generally high in saturated fat, sugar, and sodium. Finally, snacking is nearly universal (54), and snack options are also quite often high in added sugars and salt and include sweetened beverages (55).

EATING HABITS AND ROLE MODELING. Furthermore, eating habits are influenced by home-based experiences very early in childhood. Children are exposed to family norms about what to eat, how to eat, portion control, table manners, rituals of eating, social interactions during mealtime, and timing of meals. Children tend to mimic caregiver eating behaviors. Indeed, consumption patterns of parents and other family members become a model for growing children (50,56,57). For example, it has been demonstrated that parental modeling of healthy behaviors was associated with lower fat intake and higher fruit and vegetable consumption among African-American families (57). In addition, companionship at mealtime and establishment of a positive atmosphere has been associated with improved dietary quality (58). In fact, family meals have been shown to have positive health, social, and educational benefits for children, including influencing the overall quality of the diet, language acquisition, and literacy development. Family meals can also serve as a "protective factor" against risky behaviors, such as substance use, in teenagers, and can also be beneficial for caregivers (49,59,60). The family and home environment is particularly influential on younger children's eating habits; in adolescence, the impact of peers and friends tends to increase (61).

PHYSICAL ACTIVITY AND THE SHARED ENVIRONMENT. With respect to physical activity, children have a natural inclination to be active and explore. The home environment and caregiver activity habits can influence this natural predisposition. Caregiver modeling of physical activity patterns is important in promoting physical activity among children. For instance, it has been shown that sedentary time of parents has been associated with sedentary time of pre-teen children. Similarly, higher parental television viewing has been associated with higher television viewing and sedentary time among children (62). In addition, parental physical activity levels are associated with pre-school children's activity levels in the school setting, thus demonstrating the important effect of parental role modeling on children's behaviors outside of the home setting (63). Having at least 1 physically active parent has been shown to be positively associated with children's physical activity levels (64). Notably, it has been shown that parental exercise may have a stronger influence on the physical activity of girls than boys (65).

In addition, caregiver influence on children's physical activity is also affected by the facilitative role that caregivers play in supporting and assisting children's involvement in organized physical activity. Safe outlets for children's activity are required. For instance, parental availability to provide transportation to sport and fitness activities has been associated with elementary-age students' physical activity levels (66). Similarly, a recent trial to enhance the physical activity of adolescent children found that "instrumental support" (e.g., transportation, providing equipment, demonstration, and assistance with physical activity) was a more

important determinant of physical activity level than emotional social support, especially outside of the school setting (67). Caregivers can also create social activities that center on physical activities such as walking (50).

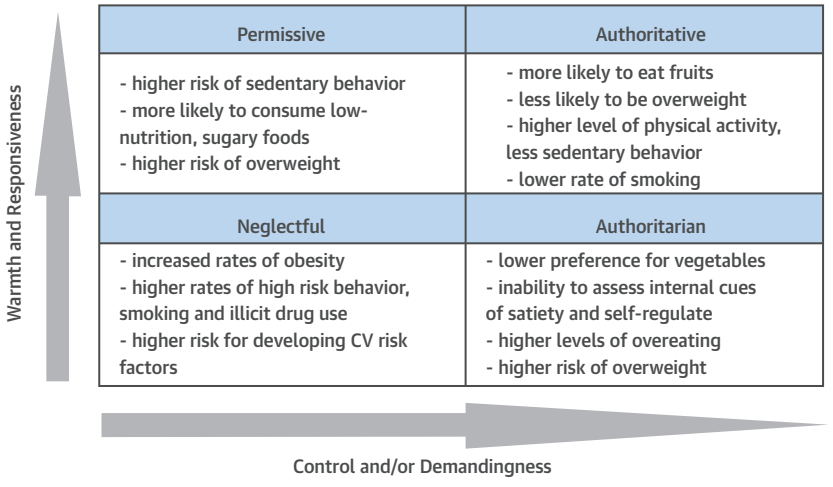
PARENTING STYLE

Parenting style forms the cornerstone of child-rearing and plays a critical role in shaping the context in which the family unit socializes, ultimately shaping a child's future habits (68). Classically, 4 distinct parenting styles have been described on the basis of varying degrees of caregiver sensitivity and expectations of self-control with regard to the child: authoritative, authoritarian, permissive, and neglectful (**Figure 3**) (69,70). The authoritative style is comprised of having both high levels of emotional connection with a child and self-control. On the other end of the spectrum, the neglectful parenting style demonstrates both low levels of sensitivity and poses minimal demands on a child's self-control. The authoritarian style requests maturity and self-control from the child, but lacks emotional warmth. Conversely, the caregiver with a permissive parenting style caters to the child's emotional needs, but expects very little self-control behavior (69). The authoritative style has been traditionally regarded as the ideal, with the child-product of this particular style of parenting obtaining higher academic achievements, developing positive coping mechanisms, and displaying greater degrees of self-control in comparison to his or her peers (71). In general, overly controlling methods, as well as indulgent behavior, can compromise the self-regulatory practices of children, which can have deleterious downstream effects on cardiovascular health promotion (72).

AUTHORITATIVE STYLE. The authoritative parenting style revolves around respect for the child and emotional responsiveness, although clear and strict boundaries are set. Authoritative caregivers are more willing to discuss the importance of healthy foods, negotiate and pose questions to a child to engage in conversation when there is disagreement, as well as praise the child for having made a wise food choice. Children raised in authoritative homes are more inclined to eat fruits and exhibit healthy behaviors in adolescence (73) and have lower levels of overweight in childhood and adolescence (71). Maternal authoritative parenting tendencies, in particular, predicted a lower body mass index for children in adolescence (74). Adolescent daughters of authoritative parents have also been shown to have higher levels of physical activity and less sedentary behavior (75). In addition, children exposed to authoritative parenting styles have a lower rate of smoking initiation in adolescence (76).

AUTHORITARIAN STYLE. In contrast, the authoritarian parenting style is common among strict disciplinarians where rules are enforced with very little

FIGURE 3 Parenting Style and Cardiovascular Health Promotion



Association among parenting style, cardiovascular-related health behaviors, and cardiovascular health promotion. Parenting styles to the **right** exemplify more control or demandingness from the child. Parenting styles on the **top row** show more warmth and responsiveness toward the child. CV = cardiovascular.

display of emotion or sympathy toward the child as the boundaries are being implemented. An atmosphere of tight control is exercised by caregivers in this scenario, including coercive feeding strategies such as demanding that the children continue eating beyond satiety, eat quicker, or "finish their plate" (77). In general, an insistent caregiver who demands that the child eat vegetables is inadvertently steering the child to have a lower preference for vegetables in the future (78,79). Similarly, the strict restriction of "junk food," desserts, or snack foods has also generally been unsuccessful (78), with children eventually favoring these foods, even after they are satisfied (77). Children raised in this environment are less likely to use internal cues to restrict caloric intake and show less responsiveness to the caloric density of a diet; increasing evidence suggests that this may affect girls more than boys (80). The authoritarian style has also been correlated with greater levels of overeating among children, because caregivers who are unable to support the child's development of emotional self-regulation foster an environment for maladaptive coping strategies that leads to overeating in times of stress (80). Children exposed to this parenting style have a higher risk of being overweight (81).

PERMISSIVE STYLE. The permissive parenting style lacks discipline and is sometimes described as indulgent; relatively few rules or demands are placed on children, and there is very little structure to support their upbringing. The permissive style allows for children to eat without restrictions, even eating unhealthy foods beyond satiety (82). Despite some evidence of healthier eating among this group of children, children of permissive parents were twice as likely to be overweight in first grade in comparison with children with authoritative caregivers (71). In addition, children of low socioeconomic status with permissive parents have a higher body mass index when compared with low socioeconomic status children with authoritarian caregivers (82). Children raised in the permissive parenting style also have fewer restrictions on the duration of television watching, which has been associated with adverse dietary behaviors, such as consumption of low-nutrition but energy-dense and sugary foods (56).

NEGLECTFUL STYLE. The neglectful parenting style is characterized by an "uninterested" caregiver who is unable to show affection properly and is without any signs of sensitivity or regard for the child's emotional needs. Discipline is rarely provided, setting the stage for an environment without structure or boundaries. This "laissez-faire" attitude to parenting is perceived by the child as a lack of interest in his or her well-being and is associated with significant rates of obesity in young adulthood (83). This style of parenting is also associated with a high risk of the child developing cardiovascular risk factors. In addition, rates of delinquency and harmful behaviors, such as smoking tobacco and illicit drug use, become more prevalent in adolescence (84,85).

Current data indicate that the offspring of authoritative parents are best able to self-regulate energy consumption, employ positive coping mechanisms, have lower overweight rates, and exhibit healthier eating habits (85–89). Conversely, authoritarian and permissive parenting styles have been associated with various eating disorders, such as the need for thinness, bulimia, and body dissatisfaction in both children and their caregivers (90–92). Neglectful parenting styles have also been associated with body dissatisfaction, anorexia, and bulimia (93). As such, the authoritative parenting style has been deemed the ideal with regard to healthier habits and reducing cardiovascular risk factors. However, several studies have shown that there is not 1 "ideal" parenting style suitable for all, and that different parenting styles may affect children differently, depending on race and ethnicity (88,94). In addition, multiple parenting styles may be adapted by the same caregiver within the household across different situations, or across different children. Ultimately, regardless of ethnic background, race, or country of origin, the current consensus is that all children should be ideally allowed to choose from a healthy variety of foods, including fruits and vegetables, and then be promoted to self-regulate in response to internal cues (72), as well as encouraged to engage in physical activities that would interest them. In contrast, bribes, threats, and rewards, when used to regulate children's food intake, can be counterproductive (72,95). Importantly, self-efficacy and -regulation ensure sustainable adoption of healthy behaviors, and interventions should aim to increase self-efficacy, -regulation, and -esteem.

CAREGIVER PERCEPTIONS

PERCEPTIONS OF OVERWEIGHT AND OBESITY. Parent and caregiver perceptions of obesity and, in particular, his/her own child's weight status, can play an important role in affecting childhood obesity (96). Parents of overweight children tend to underestimate their child's weight status, especially in younger children (<6 years of age) (97,98). Many parents fail to link their child's overweight condition as a health

risk (99). This tendency has been associated with the level of maternal education (96). Conversely, a family history of diabetes or CVD heightened the perception of obesity-associated risk in families (100). In some instances, parents attempt to convince themselves that their children will "grow out" of their baby fat (optimistic bias). Independently, in many cultures (e.g., African American and Latino), being overweight or "big-boned" has been described as being healthy and a marker of prosperity or good parenting (101).

It has also been reported that many parents disregard the height and weight growth charts, with the result that overweight/obesity only becomes a significant concern when related to the issue of body image, limitations in physical/sports activities, or being teased at school (102,103). There is also the parallel issue of parents not recognizing their child's weight issue to avoid acknowledging their own weight-related issues, to avoid blame from health care providers for their children's weight, or to avoid the burden of life-style change (96,103). Finally, it has been reported that parents tend to be more concerned with weight issues in girls than in boys (96).

PERCEPTIONS OF DIET. Parents' and caregivers' perceptions of a child's diet quality can potentially be an important factor with an effect on child feeding behaviors, food availability, and the actual quality of the child's diet. For example, parent and caregiver preferences and beliefs have been shown to influence dietary milk fat intake by pre-school children (104). However, parent and caregiver perceptions of diet quality may not necessarily correlate with actual quality of the child's food intake (105). One study from Greece reported that mothers overwhelmingly tend to overestimate the quality of their children's diet (106). In this study, although 100% of children had diets that were determined to be either poor or needing improvement, over 80% of mothers felt that their child's diet was good, very good, or healthy. In fact, mothers who reported that their main concern when choosing their child's food was "having a healthy diet" had an 86% "overestimation" rate. Similar discordance between parent/caregiver perceptions and actual diet quality have been reported in Canada (107) and the United States (108). Generational issues may also affect parent/caregiver perceptions, wherein elders in the family may view perceiving and labeling children as overweight as an unhealthy parenting strategy, and may therefore not support dietary changes (101). Elders have also been reported to resist labeling certain traditional foods as unhealthy. In summary, it appears quite likely that unhealthy dietary practices may persist, partially due to the misperception by different caregivers that these diets are "healthy."

PERCEPTIONS OF PHYSICAL ACTIVITY. Similar to diet quality, parents and caregivers tend to overestimate the level of physical activity in which their children engage. For example, 1 study among British schoolchildren reported that 80% of parents of inactive children wrongly perceived that their child was sufficiently physically active (109). Similarly, 1 study from the United States reported that nearly 90% of mothers felt that their child was very active (110); however, accelerometer-based data from the National Institutes of Health indicate that <50% and <10% of elementary school children and teenagers, respectively, are meeting physical activity guideline recommendations (111).

Parents' and caregivers' perceptions about the *importance* of physical activity can have an effect on children's physical activity, but the evidence is weak with mixed findings (112). One study among preschool children in South Carolina reported that parental perception of the importance of physical activity was positively associated with physical activity levels, likely due to increased parental support, encouragement, and parental availability to provide transportation (113). In contrast, caregiver perceptions about the child's physical *competence* have been more consistently associated with children's physical activity (114,115). The key lesson from these findings is that parents who perceive that their child has low physical competence should be encouraged to provide support and facilitation for their child's physical activity.

Health care providers can play a critical role in influencing caregiver perceptions and, in turn, the child's health. Conversations with family members need to be inclusive, being cognizant of the sociocultural and demographic construct of the family, as well as the sex and age of the child. To help design culturally sensitive and efficacious intervention programs, further longitudinal research is needed to better understand the parent-child influence axis as the child grows and the changing influence of ethnicity and sex (116).

GENOMICS

CVD AS A POLYGENIC DISORDER. CVD or, more specifically, atherosclerotic coronary artery disease (CAD), is driven by a particularly elaborate interplay of genetic, genomic, and environmental factors. From seminal studies on the basis of twin registries

performed in the 1980s, it is known that genetic variance accounts for some 40% to 60% of the likelihood of developing CAD (117). However, unlike *single-gene disorders*, such as Marfan syndrome or Huntington's disease, atherosclerosis and CAD are fundamentally more complex. Rather, CAD is a *polygenic* or *common complex disorder*, other examples of which include hypertension, diabetes, stroke, and obesity. Unlike single-gene disorders, the etiology of polygenic disorders typically involves significant contributions from both genetic and environmental risk factors and their interactions. In addition, unlike single-gene disorders, where disease-causing genetic alterations usually have a large effect on the phenotype, in polygenic disorders, each disease-relevant genetic alteration has only a minimal to modest effect, but there are usually many such genetic alterations implicated in disease pathogenesis (118).

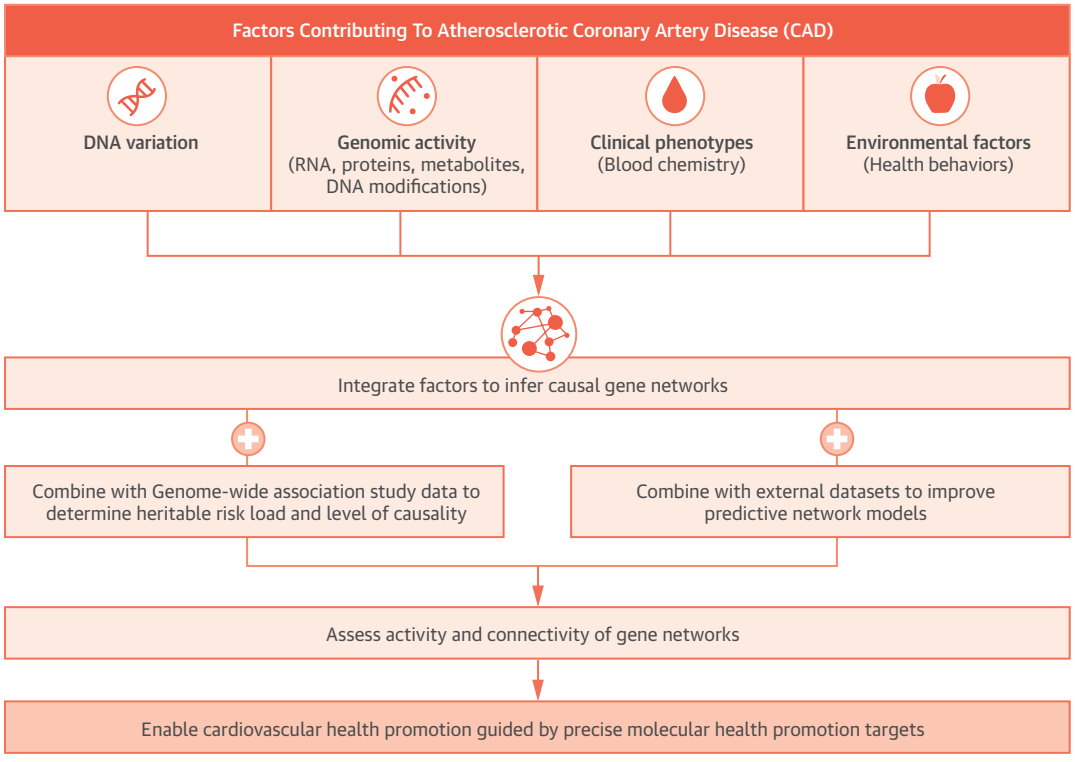
CONTEXT-DEPENDENT RISK VARIANTS. At the present time, using the well-described approach of genome-wide association (GWA), over 150 suggestive deoxyribonucleic acid (DNA) variants have been identified that are potentially associated with the likelihood of developing CAD, with 50 of these already replicated and validated using meta-analyses of GWA study datasets (119). These variants are highly prevalent across the population, but their effect size is relatively weak, each conferring a minimal to modest average of ~18% increase in relative risk of developing CAD (120). Moreover, despite the seemingly large number of DNA variants that have been identified, collectively they are estimated to be responsible for only ~10.6% of the genetic variation of CAD in the general population (119), and the bulk of heritability (approximately 90%) remains unexplained by loci identified so far by GWA studies (118). In fact, there is increasing appreciation that a substantial genetic contribution to the "missing" heritability might very well come from variants that exert their effects on CAD only in certain environmental contexts (i.e., *context-dependent risk variants*). For example, specific variants may be particularly deleterious for CAD development in smokers, but they may have no effect in nonsmokers.

SYSTEMS GENETICS. As a path forward to identifying these context-dependent risk variants and drivers of CAD that have proven elusive to GWA studies, systems genetics is now increasingly acknowledged as being the most promising investigative approach. In brief, rather than solely focusing on DNA, as in GWA studies, systems genetics aims to primarily understand CAD by integrating DNA variation with genomic activity measures (e.g., ribonucleic acid, proteins, metabolites, and DNA modifications), clinical phenotypes (e.g., blood chemistry, imaging), and environmental factors (such as health behaviors) (**Central Illustration**). By integrating these diverse data, it is possible to construct network models and then apply those models to define disease-causal molecular processes, including molecular interactions in regulatory gene networks through a process of *network inference*. In addition, joint analysis of GWA studies in the context of these network models allows direct assessment of the heritable risk load carried by these disease-causal networks (118). Finally, external genomic data from datasets derived from relevant human studies and experimental models can be aggregated into ever-improving descriptive and predictive network models. This approach has the implicit advantage of allowing an assessment of the combined effects of environmental and genetic factors in modulating the activity and/or connectivity of regulatory gene networks and disease pathways. In fact, we postulate that because environmental influences are known to affect disease-causal regulatory gene networks, favorable changes in behavior, such as smoking cessation or increased aerobic exercise, will produce changes in the activity and/or connectivity of these networks that are detectable via a systems genetics approach.

This is particularly relevant to family-based approaches to cardiovascular health promotion because, by leveraging this aspect of systems genetics, we can now begin to study shared environmental and lifestyle exposures among family members in the context of CAD heritability and understand their effect at a far deeper level than was previously possible. In fact, molecular responses to healthy behavior can be identified and can help to identify new health promotion targets. In addition, variation in health promotion outcomes can be adjusted for heritable risk load in adults and children. In essence, by using systems genetics, it is becoming possible to understand the very complicated genetic and genomic aspects underlying CAD, while at the same time accounting for the effect of the many life-style and other nonheritable factors that may share common exposure across family members. This complex and mutually influential genome-environment-disease interaction ultimately culminates in the final clinical phenotypic presentation of CAD in any given person (118).

Therefore, although there are many more questions than answers in terms of the heritability of CAD at the present time, the path forward using systems genetics appears clear and has the advantage that, for the first time, we can begin to concurrently study

CENTRAL ILLUSTRATION **Family-Based Approaches to Cardiovascular Health Promotion: Systems Genetics and Health Promotion**



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A wide range of genetic, genomic activity, clinical phenotype, and environmental factors are integrated to infer causal gene networks reflecting central disease processes in complex diseases. The combination with information from GWAS data allows for determination of heritable risk load and level of causality. External datasets comprising relevant prior information and existing genomic data generated from other sources, such as relevant human studies and experimental models, are also compared to ultimately determine the activity and/or connectivity of regulatory gene networks and disease pathways. The final goal is to enable cardiovascular health promotion on the basis of more precise molecular health promotion targets, reflected by the activity status of disease networks. The **center** shows an example of a disease-causing gene network. CAD = coronary artery disease; DNA = deoxyribonucleic acid; RNA = ribonucleic acid.

heritability, environmental influences, and the family unit. It is anticipated that this will richly inform family-based approaches to cardiovascular health promotion, while at the same time shedding light on the development of CAD.

LESSONS LEARNED AND FUTURE DIRECTIONS

Clearly, the family is a system with interconnected individuals existing within a largely shared environment and with common genomic components. Family-communicated attitudes, knowledge, and behaviors substantially affect an individual's health behaviors. "Nature" (genomics), "nurture" (parenting styles, perceptions), the surrounding environment, as well as the interaction among these factors all play a crucial role in the promotion of cardiovascular health of children, caregivers, and families.

Family-based approaches that target both caregivers and children, as well as encourage communication among the family unit, are likely to be the most effective approach to promote cardiovascular health (22,50,56,121–123). Family dynamics are essential to address the foundation for behavior change and promotion of healthy behaviors. Recent studies targeting childhood obesity have already shown favorable outcomes when family-based interventions are used in comparison with control subjects (33). Family-based interventions should,

TABLE 2 Lessons Learned, Implications for Future Programs, and Implementation Details for the Planned FAMILIA Project

Category	Lessons Learned	Implications for Future Programs	Implementation Details
Mutual interdependence of the family system	Family is an interdependent system	Integrated family-based interventions may be beneficial	Integrated intervention targeting both pre-school–aged children and caregivers
	Family communication is critical	Encourage communication between and among caregivers and children	Weekly family activities for all household members
Shared environment	Family environment can promote healthy behaviors	Facilitate the creation of a family environment that is conductive to cardiovascular health	Group intervention includes attention to environment and role of caregivers
	Policy and structural approaches create the conditions and surrounding environment within which families live and operate	Target multiple levels of political, community, school, and family systems	Working actively with Mayor's office, City departments, school administration, parent leadership, and community groups; promoting family-school partnerships
Parenting style	Parenting skills are influential	Optimize parenting skills	Active targeting of parents and caregivers; support groups for parents and caregivers
	Self-efficacy and self-regulation ensure sustainable adoption of healthy behaviors	Augment and increase self-efficacy and self-regulation	Child and caregiver interventions contain content dedicated to self-efficacy and self-regulation
Caregiver perceptions	Caregiver perceptions may be discordant with actual diet quality and level of physical activity	Correct caregiver misperceptions, and encourage parental support for healthier diet and physical activity choices	Alignment of children's and caregivers' interventions and messaging
Genomics	Nature, nurture, and environment are all important factors	Address environment, target parents/caregivers, and include genomic component	Targeting school and community environments, aggressively targeting parents and caregivers, and assessing interactive relationship between genomics and behavior

FAMILIA = Family-based Approach to Promotion of Health.

therefore, be at the core of heart health initiatives to modify cardiovascular risk factors in children and families (124).

Implications for caregivers include optimization of parenting skills, modifying the family environment to promote the adoption and sustenance of healthy behaviors, modeling appropriate life-style behaviors, and encouraging self-efficacy of both caregivers and children. In addition, policy and structural approaches need to be promoted at the community and political levels to create a more favorable surrounding environment within which family systems function. These include public-private partnerships to provide tools to caregivers; family-school partnerships; coordination among food assistance, public health, social service, and education programs; partnerships with media; and the promotion of economic stability and conditions that enable families to provide healthy food and foster healthful eating patterns (125).

Our team has implemented and evaluated school- and family-based programs in both Colombia and Spain. We have demonstrated that a pre-school-based program in Colombia, targeting 3- to 5-year-old children, can have beneficial effects on children, parents, and teachers (126), with beneficial effects observed after 3 years of follow-up (127). We have also shown that a similar program can be implemented in a variety of communities in Spain (128), with beneficial effects seen on biological parameters, such as body mass index and blood pressure, in addition to behavioral effects (129). On the basis of these lessons and the experiences of those described in this paper (**Table 2**), we have launched an integrated family-based approach to cardiovascular health promotion in Harlem, New York, targeting pre-school children with a school-based program and their adult caregivers with both individual and group-based interventions (FAMILIA [Family-based Approach to Promotion of Health]; NCT02343341) (130).

CONCLUSIONS

CVD is the leading cause of mortality in the world, and the increasing burden is largely a consequence of modifiable behavioral risk factors that interact with genomics and the environment. Continuous cardiovascular health promotion and disease prevention throughout the lifespan is critical, and the family is a central entity in this process. There are several different potential mechanisms that contribute to the importance of family for cardiovascular health promotion, including mutual interdependence of the

family system, shared environment, parenting style, caregiver perceptions, and genomics. Family-based approaches that target both caregivers and children, encourage communication among the family unit, and address the structural and environmental conditions in which families live and operate, are likely to be the most effective approach to promote cardiovascular health.

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