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ORIGINAL ARTICLE

Gene–environment interactions and health inequalities: views of underserved communities

Aaron J. Goldenberg · Christopher D. Hartmann · Laura Morello · Sanjur Brooks · Kari Colón-Zimmermann · Patricia A. Marshall

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Abstract This article examines the beliefs and experiences of individuals living in underserved ethnically diverse communities in Cleveland, Ohio, regarding the influence of genetic, social, and environmental factors on health and health inequalities. Using a community-engaged methodological approach, 13 focus groups were conducted with African American, Hispanic, and White individuals residing in the Cleveland area to explore attitudes and beliefs about genetics, genetic research, and health disparities and inequalities. Results of this study highlight the range of meanings that individuals attach to genetic variation, genomic research, and gene–environment interactions, and their implications for addressing health inequalities. The majority of participants in all focus groups reported that social and environmental factors were more important than genetics in contributing to health inequalities. Most participants were unfamiliar with genetic research. These data have implications for how genetic information and research might be applied in conjunction with addressing social determinants of health to improve prevention strategies in underserved communities and ultimately reduce health inequalities.

Keywords Genetics · Health disparities · Gene–environment interactions · Multiple determinants of health

Introduction

Genetic researchers, social scientists, and health policy analysts have different views about the relevance of genomic research for reducing health disparities among population groups (Fine et al. 2005; Sankar et al. 2004; Whitfield et al. 2003). Some investigators and scholars believe that genomics can provide important clues for isolating causal factors in health disparities (Zhang et al. 2008, 2009). This perspective suggests that genomics research may help us better understand the processes and inheritance patterns that lead to a disproportionate burden of disease among some individuals and population groups (Shields et al. 2005). Others are more critical, arguing that an overemphasis on genetic determinants might lead researchers to ignore important social or environmental contributions to health inequalities and might promote a disproportionate reliance on downstream medical interventions at the expense of upstream social or political change (Fine et al. 2005; Sankar et al. 2004). Additionally, some scholars are concerned that any use of population categories in research contributes to the reification of false notions of biological differences between social groups, potentially exacerbating racism rather than reducing health inequalities (Ossorio and Duster 2005; Lee et al. 2001; Frank 2007).

These academic debates may be mirrored in the public's understanding of group health disparities, and in this context, they may create barriers to genomic research. For instance, underserved and ethnically diverse communities will be understandably resistant to research that appears to

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A. J. Goldenberg · C. D. Hartmann · L. Morello · S. Brooks · K. Colón-Zimmermann · P. A. Marshall
Department of Bioethics, Center for Genetic Research Ethics and Law (CGREAL), Case Western Reserve University, Cleveland, OH, USA

A. J. Goldenberg (✉)
Department of Bioethics, School of Medicine, TA-212, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, OH 44106-4976, USA
e-mail: aaron.goldenberg@case.edu

stigmatize either their lineage or their lifestyles as unusually unhealthy, even if the research is well intended (Goldenberg et al. 2011; Ossorio and Duster 2005; Sankar et al. 2004). People's beliefs about themselves, their families, their community, and racial and ethnic identity shape and reinforce opinions about genomic research and lay the foundation for research risks or possible health benefits that might emerge for underserved and low-income groups (Condit and Bates 2005; Lee et al. 2005).

Previous research using quantitative methods examined lay views of genetic and environmental risk factors that influence health and illness (Parrot et al. 2003; Bates et al. 2003; Lanie et al. 2004; Henderson and Maguire 2000). To our knowledge, this is the first qualitative study to discuss the influence of genetics on health disparities and gene–environment interactions. In this paper, we report findings from a community-engaged empirical study of beliefs and experiences of racial and ethnically diverse low-income individuals from underserved Cleveland neighborhoods regarding genetics and its application to understanding and addressing health inequalities. Results of this study highlight the range of meanings that individuals living in these communities attach to genetic variation, genomic research, and gene–environment interactions, and their implications for addressing health disparities.

Methods

A community-engaged methodological approach was used in this study. Our study was implemented in three low-income and medically underserved neighborhoods within the city of Cleveland. Each neighborhood had at least 30 % of its residents living below the poverty level according to the 2000 U.S. Census. Additionally, all three communities in which recruitment took place have been designated as medically underserved areas using federally defined parameters including characteristics such as poverty rate, infant mortality, and the ratio of physicians per 1,000 community members (HRSA 1995). The Detroit Shoreway neighborhood had a median household income of $25,300. The median household income of both the Glenville neighborhood and the Ohio City neighborhood was $23,000. The Glenville neighborhood is predominantly African American (97 %), and the other two are approximately one half White, one quarter African American, and one quarter Hispanic (NEOCANDO 2010).

A Community Advisory Board (CAB) was established to provide recommendations for achieving study goals and to assist in identifying issues and concerns relevant to the duration of this 2-year project. The 12 members of the CAB represented diverse segments of the Cleveland community and national collaborating partners, including, but not limited to: Cleveland NAACP, Cleveland Office of Minority Health, the Kirwan Institute for the Study of Race and Ethnicity at The Ohio State University, Duke University, and University of Michigan. The CAB was formed with the assistance and collaboration of the Case Center for Reducing Health Disparities, a center with strong expertise in the arena of community-engaged and community-based participatory research. A Network of Community Partners was also established to help us learn more about local communities and to help us achieve our recruitment efforts for this project. The 15 members of the Network of Community Partners represented leaders from non-profit organizations and included neighborhood centers, churches, local health clinics, and community development organizations.

CAB members were consulted about the composition and demographic stratification of focus groups. They recommended that focus groups include individuals from the same ethnic background because they believed participants would be more comfortable in this setting. The CAB also recommended stratifying the groups by age (older and younger).

Recruitment Flyers and postcards describing the project and inviting individuals to contact the research team were placed in public venues such as churches, community organizations, health clinics, and neighborhood businesses. The flyers and postcards described that the goal of the project was to learn more about the opinions of African-American, Hispanic, and White community members regarding factors that influence health inequalities and opinions and knowledge of genetics and genetic research. Information on who to contact about participation in the focus groups was provided. Additionally, the flyers and postcards indicated that researchers at Case Western Reserve University were conducting the study. Flyers and postcards were printed in English and in Spanish; both English and Spanish flyers and postcards were distributed in the Detroit Shoreway and Ohio City neighborhoods to accommodate individuals who spoke and read Spanish. Participants were recruited at social service agencies (e.g., health clinics, food and clothing distribution sites, etc.) and community-gathering locations (e.g., churches, libraries, community wellness fairs, etc.) in Cuyahoga County. Participants were also recruited at events sponsored by our community partners. Additionally, many participants were recruited through word-of-mouth referrals from enrolled participants and staff from our community partner organizations. Participants were also recruited utilizing more traditional methods such as posting flyers and leaving postcards, in both English and Spanish, at neighborhood sites.

The Focus Group Guide addressed a range of topics including possible causes of health inequalities and knowledge and understanding of genetics and genetic research. We utilized a more general definition of health disparities or inequalities

within this study that includes both equity and non-equity conceptualizations of causal factors impacting differences in health outcomes within populations. We did so to more broadly capture potential participant views that differences in rates of a particular disease may be caused by social or physical environments, solely by genetics, or by an interaction of the two. The focus group instrument was reviewed by the CAB and pretested in a mock focus group. The focus group guide, including our introductory language, questions, and probes, is available as Electronic supplementary material (Online Resource 1).

The research team underwent intensive training on how to conduct, facilitate, and moderate focus groups. This training occurred over a 3-month period and was consistent with a graduate level course on qualitative focus groups methods and implementation. The lead investigators, Drs. Marshall and Goldenberg, are experienced in focus group methodologies and provided the training. The Focus Group Guide for this study was used in the training practice sessions and revised as necessary.

The focus groups were conducted by members of the research team. Ethnic diversity in team membership was an important methodological issue for our study. The four research staff members employed for the project lived in the Cleveland area and represented a diverse group of individuals: Two women were African-Americans, one woman was Hispanic and bilingual in Spanish and English; one man was white and spoke Spanish. Two research team members were present at each focus group; one individual facilitated the discussion, and the other individual observed and took notes at the focus group. Focus group guides were matched by ethnicity to the focus groups being conducted.

All focus groups were conducted in English. Thus, a requirement of participation in the study was the ability to speak English. Regardless of their ability to speak Spanish, all participants in the Hispanic focus groups discussed the issues in English.

Thirteen focus groups were conducted with self-identified African-American, Hispanic, and White individuals and were conducted between April and October, 2010. Five focus groups were completed with self-identified African Americans, four with self-identified Hispanics and four with self-identified Whites. Focus groups included men and women and were stratified by younger and older age groups, 18–35 years of age (seven focus groups) and 36–65 years of age (six focus groups). Focus groups were audio-taped. Individuals received a $30 gift card to a local grocery store for their participation in the study. All participants were asked to complete an anonymized Demographic Form to help characterize focus group participants.

Data analysis Audio files from focus groups were sent to a transcriber through a secured Internet site. Focus group data was entered into *ATLAS.ti* (v.6), a software program for analyzing text data. Research team members were trained in *ATLAS.ti* by an expert with considerable experience using this software program for qualitative analysis.

Standard procedures for analyzing qualitative data were employed. Transcripts from two focus groups were used to begin the code development. Thematic domains were identified through a process of intense review of transcript data. Successive coding passes began with open coding of content at the level closest to the content of the text and continued through broader and more analytic codes. Using the well-established grounded theory method, thematic domains were further delineated as the content analysis of text data continued (Strauss and Corbin 1998). The constant comparative method was applied throughout data analysis; this method refers to a process of comparing new data with categories that emerged in previously collected data. A coding scheme and a coding dictionary were developed. Each transcript was independently coded by two project staff followed by a process of consensus coding. Any differences in coding that were not resolved through the consensus process were then reviewed and resolved at weekly team meetings. Analysis of the transcripts resulted in eight primary domains of inquiry and included 45 sub-codes within the primary domains resulting in a total of 53 codes. All data were coded using the code for the primary domain along with the sub-code. To assess differences between groups, we utilized a comparative analysis that examined the presence or absence of particular major domains and sub-themes across the 13 focus groups to look for areas of discussion that were unique to particular groups. Demographic information was entered into SPSS for developing descriptive statistics. Data were independently entered by two research associates and crosschecked to ensure accuracy.

Human subjects This study was approved by Case Western Reserve University's Institutional Review Board. Written informed consent was obtained from each individual participating in the study. The research team underwent training on obtaining informed consent in a culturally sensitive manner.

Results

Sample characteristics

Of the 106 focus group participants, 40 % (n=42) were African-American, 29 % (n=31) were Hispanic, and 31 % (n=33) were White (Table 1). Approximately two thirds of participants were female (n=71), and the median age was 41 years. Indicative of the study's aim to capture the opinions of individuals living within local underserved

Table 1 Focus group demographic characteristics

Characteristic	Black		Hispanic		White		Total
Age group	18≤35	36≤65	18≤35	36≤65	18≤35	36≤65	
No. of focus groups	3	2	2	2	2	2	13
Participants, *N*	16	26	13	18	15	18	106
Gender							
Female, *N* (%)[a]	9 (56)	18 (69)	10 (77)	15 (83)	12 (80)	7 (39)	71 (67)
Age (mean+SD)	27 (±7)	54 (±9)	25 (±6)	49 (±11)	30 (±9)	50 (±9)	41
Education, *N* (%)[a]							
<High school	3 (19)	2 (8)	2 (15)	4 (22)	3 (20)	3 (17)	17 (16)
High school/GED	12 (75)	7 (27)	9 (69)	7 (39)	9 (60)	7 (39)	51 (48)
Community college	1 (6)	8 (31)	2 (15)	1 (6)	1 (7)	6 (33)	19 (18)
College/university	0 (0)	4 (15)	0 (0)	4 (22)	2 (13)	1 (6)	11 (10)
Graduate/professional school	0 (0)	5 (19)	0 (0)	2 (11)	0 (0)	1 (6)	8 (8)
Income, *N* (%)[a]							
≤$15,000	12 (75)	9 (35)	10 (77)	11 (61)	12 (80)	14 (78)	68 (64)
$15,001≤$35,000	3 (19)	7 (27)	1 (8)	5 (28)	2 (13)	3 (17)	21 (20)
$35,001≤$55,000	1 (6)	5 (19)	0 (0)	0 (0)	1 (7)	1 (6)	8 (8)
$55,001≤$75,000	0 (0)	3 (12)	0 (0)	1 (6)	0 (0)	0 (0)	4 (4)
≥$75,001	0 (0)	2 (8)	0 (0)	0 (0)	0 (0)	0 (0)	2 (2)
No response	0 (0)	0 (0)	2 (15)	1 (6)	0 (0)	0 (0)	3 (3)
Medical insurance, *N* (%)[a]							
Yes	8 (50)	19 (73)	11 (85)	10 (56)	12 (80)	8 (44)	68 (64)
No	8 (50)	6 (23)	2 (15)	8 (44)	3 (20)	10 (56)	37 (35)
Unknown/no response	0 (0)	1 (4)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)

[a] Percentages may not add up to 100 % due to rounding

communities, approximately two thirds of participants reported a household income of less than or equal to $15,000 ($n$=68), and more than one-third of respondents lacked any form of public or private health insurance (n=37).

Community perspectives on genetic predisposition, health inequalities, and gene–environment interactions

The influence that genetics and genetic research may have on the health inequalities experienced by underserved and low-income communities was a central focus of discussion among participants in all 13 focus groups in this study. Analysis of these discussions revealed a number of common themes expressed by participants across all racial and ethnic and age groups. Overall, perspectives about the ways in which genetics may contribute to individual health outcomes and the development or perpetuation of health inequalities within communities focused on four thematic areas: (1) Genetic predisposition and family health history; (2) genetics, race/ethnicity, and health inequalities; (3) genetics in the context of multiple determinants of health; and (4) the interaction that social and environmental factors may have on the impact of genetic traits for health outcomes. Taken together, the views expressed within these thematic areas suggest that participants have a robust understanding of the importance of gene–environment interactions and their relevance to health inequalities in underserved communities.

The following sections explore each of the four thematic domains. Within these categories, we also discuss some differences between racial/ethnic and age groups in conceptualizing these themes. Additional representative quotes from our participants for each of these major thematic areas are displayed in Table 2.

Genetic predisposition and family health history

When discussing the influence of genetics on health and health inequalities, many of our participants talked about the potential for having a genetic predisposition to particular diseases such as hypertension or diabetes. Our analysis revealed that participants across all racial/ethnic and age categories talked about the influence of genetics on their own health and the health of their families and communities. However, most participants did not use the language of "genetics," "genetic variation," or "DNA traits" to share how genetics had affected them or their communities.

Table 2 Participant quotes on health and gene–environment interactions

Major themes	Participant quotations
1. Family history and disease predisposition	"You could be perfectly healthy, your mate could be perfectly healthy, but you never know down the line that grandfather, that great-grandmother, that great-great-ancestor or whatever could've had diabetes and it could've been in their genes, like in their DNA, genetically, so you can't control a baby or a child being born with diabetes." (African-American participant, age 18–35 years)
	"Some people have a disposition through their DNA to have heart trouble or to have various diseases." (African-American participant, 36–65 years)
	"You can acquire sicknesses from your generations, from your great grandparents and from your grandparents, and I have my mother's mother. She became schizophrenic, okay? So then as I was growing up, I would listen to this and that worried me. It worried me because I was scared that I might develop that …Maybe along the line there, maybe my grandchildren or my great-grandchildren might develop it." (Hispanic participant, age 36–65 years)
2. Genetics, race, and health disparities	"There are diseases that are genetic to certain groups, like Sickle Cell and you know Tay Sachs to Jewish people. So there are some genetic things that are just you know within our ethnic group that's where its origin is coming from I don't necessarily basically know, but there are some things that are definitely based on the color of your skin or where you were, you know, raised" (African-American participant, 36–65 years)
	"I know high blood pressure is very high in Black Americans. I think we are the most culture out of all of them to have the blood pressure problems. I mean this is what the scientists say on TV." (African-American participant, age 36–65 years)
3. Addressing multiple determinants of health	"You don't become aware until such a later age that you don't even tell your kids or your teenagers that 'This is why this has happened to me.' You just think automatically 'Oh well, it was inherited.' You don't say 'Well I was eating this food and that food and that food.' And on top of it being inherited, that made it worse, and it's like we should educate our children more on not only the inheritance, but the damages that eating bad can do in your future." (African-American participant, age 18–35 years)
	"I think there are some things that we can't control, so genetics has an influence on what people have to deal with medically, but I also think that our parents influence our behaviors. If they're not healthy eaters, if they are big on high-fattening or sugar-containing products, then their kids are most likely to do the same things." (White participant, age 18–35 years)
	"And I'm glad you said the environment too, because I think that especially in this area, there are so many chemicals that people are exposed to just because of the traffic, the industries that are putting out chemicals into the environment ….We have all these factories over there and they're putting out all these chemicals into the environment." (African-American participant, age 36–65 years)
4. Social/environmental triggers of genetic traits	"I think it lays dormant in some people and stuff. Like they have a higher disposition to get it, but they might not get it, but there's a possibility down the road that something might trigger it, you know they will develop it, or they can be lucky and throughout their whole entire life they don't get it, but their kids will get it or something." (Hispanic participant, age 18–35 years)
	"If you have a predisposition to high blood pressure, if you have a predisposition to a stressful environment that will trigger something else, (then) everything that you said contributes. (African-American participant, age 36–65 years)

Instead, the common narrative that emerged in these discussions was centered on knowing one's family history. Participants provided detailed accounts of the ways in which knowledge of family history helped them to be aware of whether they may be predisposed to certain illnesses in their families. Some participants expressed concerns that a disease may be unavoidable if it were associated with an inherited trait. One participant voiced this concern stating, "You can't control your genes."

When focus participants were asked about what "genetics" meant to them, many participants expressed the potential increased chances of having a disease experienced by other family members. One older Hispanic individual stated that, "If a lot of people in your family have it, it's a higher percent of chance that you're going to have it. So it's like a gene that's being passed on." For others, the word "genetics" meant familial predisposition. "It all depends on family history and being predisposed to certain diseases. If someone in the family has high blood pressure, you're more predisposed to getting it," said one participant.

Our participants clearly understood the strong impact family history has had on their health and the health of their families and communities. Many participants recounted experiences of generations affected by diabetes, heart disease, and cancer, as well as struggles with mental illnesses such as depression. Perhaps because of such experiences, many participants talked about how they valued the importance of knowing their family history because it motivated them to

take action to prevent the onset of disease. One participant conveyed this, by stating that, "If you know if you have (a disease) in your family, then maybe you can take those kinds of steps so that you can eliminate it." Another participant talked about how knowledge of family history empowered him to discuss prevention goals with his physician and the life style changes he needed to make for his health:

> "There's three major people in my life who's died of cancer …so I've talked sensibly with my doctor about this because you know I just said 'Hey, I don't want to die of cancer too' ….That's one of the reasons I say let's look at this and stuff. So genetically I feel that I am inclined to have cancer, whether I do or not, so I try to at least go to the doctor all the time." (African-American participant, age 36–65 years)

Across the focus groups, opinions varied on how participants would implement changes at the personal and familial levels. Many participants talked about the generational barriers that hindered them from fully knowing their family health histories. For example, some Hispanic participants discussed how "broken links" to family members due to immigration or migration can make assessing one's family history difficult. Other participants noted that, in the past, it was often considered disrespectful to discuss personal health issues with family members. However, being aware that a lack of knowledge would affect future generations, many participants reported that they embraced a different approach with their children and grandchildren, choosing to share their personal health history information with these family members.

Genetics, race/ethnicity, and health inequalities

While concepts of family history were discussed at great length during the focus groups, many participants also raised the concept of connecting disease prevalence and genetic predisposition to one's racial or ethnic group. Some participants reported that genetics may play a role in why certain racial and ethnic groups had a higher incidence of particular diseases. However, most participants felt that there were not strong connections between genetic predisposition to disease and identifying with a particular racial or ethnic group. One participant recognized that, while some diseases might have a genetic component, most were fundamentally about social or environmental factors:

> "I can see that there are definite genetic links, like with something like sickle cell…but it seems to me like some of the other issues are more linked to maybe economic status. It's cultural, like how the things that they've grown up with and the kinds of foods that they've eaten that might make them more susceptible than their genetic factors." (White participant, age 36–65 years)

While most participants did not see a strong genetic predisposition for certain diseases between specific racial and ethnic communities, some African-American participants shared a different opinion. They felt that, in the African-American community, individuals believed in a stronger genetic influence on disease due to race or ethnicity. A few participants attributed that difference to the role that the media, physicians, and the overall health care community may have played in shaping this message. One participant commented that both health care providers and the health-related messages heard in news stories perpetuate these differences stating that, "They tell us that medically, 'Black Americans are going to get such and such and such,' or 'White people will get such and such and such.'" (African-American participant, age 36–65 years)

Perspectives on multiple determinants of health

Along with discussions about the influence of inherited traits on health inequalities, most participants discussed how their health and the health of their community have been affected by multiple determinants. Social, environmental, behavioral, and genetic factors are frequently included in "multiple determinants of health" models. Participants were generally knowledgeable about various behavioral and environmental factors that may influence health inequalities, especially in relation to lack of access to health foods, poor nutritional choices, and environmental exposures. One Hispanic participant noted, for example, that inadequate housing and pollution can lead to negative health outcomes in physical and mental health:

> "I think environment plays a big deal, especially, and it can go back to economics also, like if you can't afford like a nice place. I have friends that live in places where they didn't have heat or the heat didn't work right or even though the heater works, there's like no insulation and all of that adds to the stress. Plus you get sick. You know you can get sick more and you don't know if like the paint is bad for your kids or what's coming into the air and all that stuff." (Hispanic participant, age 36–65 years)

Some participants diminished the importance of the role that genetics play in health outcomes. Instead, they emphasized the influence of physical environment or social factors on health and illness. For example, a younger White participant noted that, "As much as we want to blame genetics …I think resources are very important." Nevertheless, community members across all 13 focus groups, regardless of racial/ethnic group, suggested that a combination of biological, environmental, social, and

behavioral factors must be considered together in order to better understand health outcomes and inequalities within and between populations.

A number of participants also called attention to the potential impact that addressing a combination of both genetic and environmental factors may have on the health of individuals and communities. As with family history, community members highlighted the importance of recognizing multiple determinants of health as a more holistic approach for health prevention rather than simply focusing on either social, behavioral, or environmental factors alone. One participant noted that discussing the multiple determinants of health with their children would be an important preventive measure, "We should educate our children more on not only inheritance, but the damages that eating bad can do in your future." (African-American participant, age 18–35 years)

Environmental triggers of genetic traits

Many participants recognized that genetic traits might be affected by the influence of social, behavioral, or environmental variables in their own lives or the lives of their family or community. Some community members discussed the potential influence that an environmental factor may have on "triggering" a genetic trait. One participant voiced this concern stating:

> "When somebody got a gun in their hand and they pull the trigger, they triggered it, the bullet can come out you know and explodes. Maybe it's the same way for something to just sit inside your DNA and it's just sitting there and it's just waiting for the exact moment to just explode, to just come out, so you've just got to trigger it. You know what I'm saying? So if you can, just like your grandma say, try to eat healthy, do your normal exercises, routines or whatever, 'cause you don't want to trigger those certain traits; and then next thing you know you wake up in the morning and have asthma or bronchitis or diabetes and some sort, because you could trigger those traits inside of you." (African-American participant, age 18–35 years)

Recognizing the social, behavioral, and environmental influences on genetics helped some participants see that their personal health behaviors could influence whether certain physical traits would be expressed by inherited genes. In addition to discussing gene–environment interaction, a few participants also suggested that gene expression changes may be inherited by future generations.

Finally, a few participants also discussed the importance of promoting research that addresses the interactions between genes and environmental factors. One community member stated that there needs to be more research that compares as one community member stated "people who had certain genetic predispositions to food and people who ate well, who exercised, who breathed unpolluted air, drank unpolluted water (White participant, age 36–65 years)." These participants expressed that increased attention to the non-genetic components of health could help researchers better understand how environmental and social factors may exacerbate genetic diseases.

Discussion

The potential that genomic science has for advancing health inequalities research remains unknown. While increasingly studies are attempting to integrate social and environmental factors into multiplex testing (Ramos and Rotimi 2009), many studies that have attempted to use genetic information have done so only through genetic variation research and genome-wide association studies (Need and Goldstein 2009; Manolio et al. 2009; McCarthy et al. 2008). These studies attempt to look for differences in genetic marker frequencies among population groups that are predisposed to a particular disease or health outcome. This approach has a number of limitations, including the controversial use of socially-constructed racial categories as a basis for defining differences in genetic variation and associated disease predisposition between populations. Additionally, many of these studies are entirely biological in nature and fail to take into consideration environmental exposures that could alter gene expression and, consequently, disease prevalence (Khoury and Wacholder 2009). Moreover, many health disparities researchers have also voiced concerns, arguing that a heightened focus on genetic factors as an explanatory model for health outcome differences between underserved and low-income populations may lead to decreased attention on social and environmental determinants of health (Sankar et al. 2004; Krieger 2005).

These concerns have led to a decreased level of enthusiasm about the potential impact of genetic information for explaining and addressing health inequalities. In response to these limitations, Fine et al. (2005) have suggested that because genetics has a yet "unproven role" in disparities research, a new research paradigm is needed in order to "move the intersecting fields of genetics and health disparities forward." Data from our study suggest that community members participating in our focus groups support this new paradigm of promoting research that accounts for gene–environment interactions and multiple determinants of health. Indeed, our study participants did not perceive genetic factors to be a primary contributor to health inequalities on their own but did emphasize the importance of gene–environment interactions and their effect on one's health and the health of their families and communities. Participants across all focus groups suggested that both

social and environmental factors affected the phenotypic expression of their genetic makeup, which resulted in poorer health. These perspectives are clearly in line with the increased focus on multiple determinants of health within the larger public health community, particularly regarding health inequalities (Braveman et al. 2011; Diez Roux 2012; Krieger 2011; Woolf and Braveman 2011).

Promoting intervention strategies that consider individual and environmental factors is not new (McLeroy et al. 1988; Sallis and Owen 2002; Stokols 1992). Increasingly, public health practitioners and researchers have advocated for the need to use frameworks for both evaluating and addressing health inequalities that consider biological, social, behavioral, and environmental factors to assess risks and explain health outcomes in populations. One such approach, the ecological model, proposes that health outcomes are best studied through "analysis of determinants and outcomes at different levels of organization" (Susser and Susser 1996), including social processes and dynamics at the individual through the broader societal level. The ecological approach to understanding health and illness has gained credibility because increasing chronic disease rates cannot be properly explained without considering the contexts within which they develop (McLeroy et al. 1988). While the acknowledgement that both individual and social factors play an important role in explaining health outcomes does not necessarily translate to widespread acceptance of the impact that genetic factors may have on health inequalities, there have been recent calls to better integrate genetic and environmental factors into our understanding of health and disease (Burke et al. 2010; Khoury et al. 2011; McBride et al. 2010). Stoltenberg (2005), for example, suggests that considering genetic factors in population health studies that focus on environmental causes could add a greater level of "precision to disease etiology research."

Our findings have a number of implications for public health. First, family health history represented a conduit for understanding possible disease predisposition and effected behavior change (e.g., seeing the doctor). Echoing others, our data suggest that practitioners and researchers need to continue to find ways to increase the integration of family history into health prevention strategies (Yoon et al. 2002).

Participants' responses from this study also help to contextualize the important role that gene–environment interactions play in determining health outcomes and further indicate the need to bridge genetics and other prevention strategies that account for multiple determinants of health. These findings also indicate that geneticists and genetic epidemiologists should be encouraged to promote the inclusion of social and environment data into genetic research studies that utilize next generation genomic sequencing methods. As our ability to interpret the findings from whole genome sequencing and multiplex testing continues to grow, the impact of these results on human health and disease prevention will be limited unless the complex interactions between genomic variation and environmental factors are addressed. The integration of both environmental and genetic factors into models of health and health disparities should be matched by more complex gene expression research that truly accounts for the interaction of these factors rather than merely their individual effects on health outcomes.

Finally, given participants' interest in thinking about the relationship between health, genetics, and the social environment, researchers should be encouraged to include community perspectives in the design and implementation of research to advance our understanding of the causes of health inequalities. We believe that the involvement of ethnically and economically diverse populations, especially underserved groups who are often at greater risk of experiencing health inequalities, is vital to any efforts to better understand or reduce these inequalities.

This study has several limitations that should be noted. First, participants were not presented with questions regarding the impact of genetics on particular diseases or specific types of genetic research studies, rather their opinions were in response to more general questions about genetics. In addition, while participants were asked to define what genetics meant to them, they were not asked how they individually define social or physical environments. Knowledge of these views would help to better contextualize how individuals may see the interactions of genes and the environment on health. Future research exploring these questions would help to refine our understanding of these views.

Second, participants in the focus groups do not represent a randomized sample population. Thus, our findings may not be generalizable to all ethnically diverse low-income populations. More specifically, the demographic makeup of some of our focus groups may limit the generalizability of our sample to low-income and underserved communities nationally. Our older African-American and Hispanic groups contained a number of individuals in higher income and education categories, even though these individuals were from the underserved communities where our recruitment took place. Additionally, women were overrepresented in a number of our focus groups. Therefore, our sample may not have had enough men to adequately account for potential gender differences in opinions on genetics and health inequalities. There have been a number of recent discussions about potential gender differences in knowledge and attitudes regarding genetics (Henneman et al. 2006; Jayaratne et al. 2009). For example, one study reported higher levels of knowledge among women regarding the genetic determination of race (Christensen et al. 2010). Given that these studies have seen some evidence of gender differences concerning genetics more generally,

attitudes toward genetics and health inequalities may also differ between men and women. Future research on these issues will require greater gender diversity among participants to assess these potential differences.

Lastly, our study did not include formal "genetic literacy" assessment within our focus groups and thus are not able to compare differences in attitudes among participants based on their actual level of genetic knowledge. A number of recent studies have begun to explore the potential impact of genetic knowledge on views regarding genetics and gene–environment interactions (Christensen et al. 2010; Jayaratne et al. 2009; Singer et al. 2004). One study for example found that African-American and Latino participants were less likely to utilize genetic services based on a lack of knowledge provided to them through their health care providers (Suther and Kiros 2009). Again, future research in this area is needed to better assess the connections between knowledge and attitudes toward genetics and their implications for health inequalities. Despite these limitations, study results provide rich and valuable information about knowledge, beliefs, and experiences associated with genomic research and health inequalities among underserved, low-income, and ethnically diverse groups in Cleveland, Ohio.

Our participants' views on disease predisposition, multiple determinants of health, and gene–environment interactions run parallel to the underpinnings of the ecological approach and other explanatory models of health that integrate genetic, social, and environmental factors. Given that these approaches to understanding health and disease have become central to both the public health community and the underserved populations experiencing health inequalities, translational genomic research must find new ways to integrate multiple determinants of health into genome-wide variation studies if it is to remain relevant in health disparities research.

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