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The Effect of Individual or Study-Wide Report-Back on Knowledge, Concern, and Exposure-Reducing Behaviors Related to Endocrine-Disrupting Chemicals

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Background: To make informed decisions about endocrine-disrupting chemicals (EDCs), people need functional understanding of exposures and health and an ability to act on their knowledge. The return of biomonitoring results is an opportunity to educate people about EDCs and motivate exposure reduction.

Objectives: This study investigates environmental health knowledge about EDCs, concerns about health effects, and exposure-reducing behaviors before and after the return of individual-level exposure results or only study-wide results.

Methods: Women in the Child Health and Development Studies who were biomonitored for 42 EDCs were randomly assigned to receive a report with personal chemical results or only study-wide findings. We interviewed participants before and after report-back about their knowledge and concerns about EDCs and how frequently they performed exposure-related behaviors. We investigated baseline differences by education and race and examined changes after report-back by race and report type.

Results: Participants ($n = 135$) demonstrated general understanding of exposure pathways and health impacts of EDCs. For 9 out of 20 knowledge questions, more than 90% of participants ($n \geq 124$) gave correct responses at baseline, including for questions about chemicals' persistence in the body and effects of early-life exposure. Most participants held two misconceptions—about chemical safety testing in the United States and what doctors can infer from EDC results—although errors decreased after report-back. Initially, concern was higher for legacy pollutants, but report-back increased concern for consumer product chemicals. After report-back, participants took some actions to reduce exposures, particularly to per- and polyfluoroalkyl substances, and total behavior was associated with knowledge and concern but not race, education, or report type.

Discussion: This study demonstrated that participants had foundational knowledge about EDCs and that report-back further built their environmental health literacy. We conclude that future communications should target misconceptions about chemicals regulation in the United States, because information about regulations is crucial for people to evaluate risks posed by consumer product chemicals and decide whether to engage with public policy. https://doi.org/10.1289/EHP12565

Introduction

Endocrine-disrupting chemicals (EDCs) are ubiquitous in everyday environments and many consumer products.[1–3] Sources include some pesticides, flame retardants, ingredients in plastics and personal care products, and per- and polyfluoroalkyl substances (PFAS). EDCs operate via numerous biological pathways to upset the body's natural hormone signaling, and, because hormones help regulate nearly every system in the body, these chemicals can have diverse consequences for health.[4] EDCs have been associated with obesity, diabetes, detrimental impacts on male and female reproduction, hormonal cancers, thyroid disruption, and neurodevelopmental effects.[4] Exposures are influenced by personal behaviors, corporate decisions, and policies and laws from the local to national level.[5] Because members of the public can in turn influence each of these factors, public understanding of EDCs is an important foundation for environmental public health.

We propose that, to make informed decisions about EDCs, people need to have a functional understanding about sources of exposure, associated health risks, and individual and social controls that mediate exposure. This functional understanding, which includes what people know about environmental hazards as well as their ability to act on those hazards, comprises environmental health literacy (EHL).[6,7] We use EDC-EHL to refer to environmental health literacy about endocrine disruptors. Like health literacy, a closely related framework, environmental health literacy is expected to influence individual and population health.[8] Knowledge and behavior are two components of EHL, and levels of concern about an environmental risk are also relevant, because they can motivate information-seeking and changes in behavior.[9,10]

Few studies have assessed people's knowledge about environmental chemicals that are endocrine disruptors, but available evidence suggests that people's knowledge about EDCs is incomplete. One study surveyed 300 pregnant or postpartum women in France—77% of whom had a university-level education—and found that less than half (45.7%) had ever heard of EDCs.[11] Another survey of 554 adults in France focused on indoor environmental pollution and included some questions related to EDCs. Most participants (87%) knew that food containers may contain harmful substances, but fewer (57%) knew that infants and fetuses are more vulnerable to pollution than adults or elderly persons.[12] In focus groups conducted in Northern Ireland ($n = 34$ participants), participants were more familiar with specific environmental chemicals that are EDCs [like pesticides and bisphenol A (BPA)] than with the overall concept of EDCs.[13]

Exposure studies of EDCs are one setting in which people can expand their EDC-EHL. Returning personal biomonitoring results (known as report-back) is recommended for most studies by the National Academies of Science Engineering and Medicine, even when results have uncertain clinical significance, because report-back respects participants' "right-to-know" their own data, has low risk of harm, and offers multiple benefits, including empowering action to protect health.[14] Report-back provides an important opportunity to build EDC-EHL, because participants need contextual information to be able to interpret their own results.[15]

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To learn more about what people already know about EDCs, their concerns about these chemicals, and whether their knowledge, concerns, and behavior are changed by receiving personal or study-wide results reports, we conducted an experiment among participants in the Child Health and Development Studies (CHDS). In the MyCHDSReport Study, women who had been biomonitored for 42 persistent chemicals received a personalized report that included their individual chemical exposure levels and aggregate study results or a nonpersonalized report with aggregate study results only. Both types of reports included the same contextual information about the chemicals in the study. The sample was intentionally designed so that approximately half the participants identified as Black/African American. The MyCHDSReport Study was a community research collaboration comprising academically trained CHDS researchers at the Public Health Institute, the CHDS Participant Advisory Council, and Silent Spring Institute. Previously, we reported on the participants' engagement with these reports, their emotional responses, and their interest in future research participation.[16] Here, we report survey results for participants' knowledge and concern about environmental chemicals and exposure-relevant behaviors. Knowledge was measured as rates of correct responses to true/false questions, concern about health effects for different sources of chemicals was rated on a Likert-type scale, and behavior was assessed as self-reported frequency of performing exposure-related behaviors. We examined baseline levels of knowledge, concern, and behavior, and we tested for changes after report-back. We tested whether reports with individual results had a different impact from those that did not, and we investigated differences in knowledge and concern by race and education.

We hypothesized that report-back would lead to increases in knowledge, concern, and exposure-protective behaviors and that increases would be greater among those receiving their individual results. Although both reports included contextual information about the chemicals in the study, we previously found that receiving personal results motivated people to spend more time on their report, thus affording this group more opportunity to learn.[16] We also expected that learning one's individual exposure status—information that was only available to participants receiving personal results—could contribute to heightened concern. Further, we hypothesized that concern about some chemicals would be greater among Black participants prior to report-back because of the history of environmental racism, which often results in higher exposures and worse health outcomes in this group in comparison with others.[17,18] Previous research has found that Black people have higher levels of concern about some environmental health issues, including climate change as well as air pollution from industry and traffic.[19–21] Results examining race differences in risk perception of pesticides are mixed,[19,21] and we are not aware of studies that assessed concern about other chemical groups that we asked about in this study. However, Black women are known to have disproportionate exposures relative to non-Hispanic White women to a variety of EDCs.[22] We did not expect differences in knowledge by race.

This quantitative assessment of knowledge, concerns, and exposure-reducing behaviors related to EDCs before and after report-back in the CHDS provides a first look at important components of EDC-EHL in a diverse group of adult U.S. women. By comparing responses at baseline and after participants received their results, we investigate the effects of access to information about the EDCs in this study. Studying EDC-EHL in this context can improve future report-back of research results as well as other environmental health communications by enabling researchers to design messages that build on prior knowledge, fill in gaps, and mitigate misconceptions.

Methods

The design of the MyCHDSReport Study was previously reported in detail[16] and is briefly summarized here. Participants are part of the CHDS, a multigenerational cohort study that enrolled pregnant mothers in Oakland, California, from 1959 to 1967.[23] Blood samples were collected from 300 adult daughters from September 2010 to March 2013 as a part of the Three Generations Study or the Disparities in Health Study. Women whose mothers identified as Black/African American were intentionally oversampled to constitute half of participants. Self-reported race and highest level of education were obtained by interview at the time of blood collection. Blood samples were tested for lipids (total cholesterol and triglycerides) and 42 environmental chemicals, including seven polybrominated diphenyl ether (PBDE) flame retardants, 11 per- and polyfluoroalkyl substances (PFAS), seven legacy pesticides, and 17 polychlorinated biphenyls (PCBs). Levels of PBDEs, pesticides, and PCBs were adjusted by serum total lipids (as calculated from total cholesterol and triglycerides using the Phillips formula[24]). Of the 300 women, 295 were eligible for recruitment to the MyCHDSReport Study. The MyCHDSReport Study and earlier blood sampling were approved by the institutional review board at the Public Health Institute, and informed consent was obtained from all participants.

The MyCHDSReport Study investigated the effect of returning biomonitoring results on participants' knowledge and attitudes toward environmental chemicals and exposure-related behaviors. Participants were randomly assigned to one of two report types: an aggregate report (AR), which showed study-wide results only, or a personal report (PR), which included individual and study-wide results. MyCHDSReport is an online report created using the Digital Exposure Report-Back Interface (DERBI).[25] Both report types contained contextual information about each of the chemical groups measured in the study—such as sources of exposure, relationships to health, and tips for reducing exposure—and a summary of study-wide findings. Results for each chemical were depicted as a strip plot showing the study distribution, and for those in the PR group, the participant's individual result was plotted on the study distribution. The plots also showed the median levels for non-Hispanic White and non-Hispanic Black women in the National Health and Nutrition Examination Survey (NHANES). PR reports included "headlines" that highlighted each participant's notable results. For each chemical group, participants got a "high" headline if one or more chemicals in a group exceeded the 95th study percentile, more than one chemical in a group exceeded the 75th study percentile, or more than 75% of chemicals in a group exceeded the study median; alternatively, participants received a "low" headline if they had serum levels below the median for every chemical in a group. Participants would also see a headline if their total cholesterol exceeded a health guideline of 200 mg/dL.[26] A sample report can be viewed online (http://derbidemo.com), and static excerpts from the interactive report are shown in Supplemental Material (Figure S1). Participants who viewed their reports online consented to having web analytics collected about their behavior on the site, including time spent on the site. Print reports were mailed to 15 participants who requested them.

All participants completed a baseline pre-interview and then received access to their report. Participants became eligible for the post-interview after viewing their report. Post-interviews were conducted 3 to 4 wk after the baseline interview. After completing the post-interview, participants in the AR group were provided with their personal exposure results. Interviews took place from July 2015 to March 2016. The study was also stratified by interview type. A total of 68 women (34 PR, 34 AR) were randomly assigned to a qualitative, semistructured telephone interview conducted by Silent Spring Institute, and 227 women (115 PR, 112 AR) were randomly assigned to a structured, computer-assisted telephone interview conducted by the Survey Research Group division of the Public Health Institute, Sacramento, California. We chose this mixed methods approach to maximize the richness of the data. The semistructured interviews facilitated comparisons to our earlier work[27–30] and allow participants to more freely describe their experiences, whereas the structured surveys can efficiently collect quantitative information with a larger sample size. This analysis used data from recipients of the structured interview.

The sections of interview questions used in this analysis investigated environmental health attitudes, knowledge, and behaviors. Participants were asked to rate their concern about health effects from 11 groups of chemicals [e.g., pesticides that have been banned, like dichlorodiphenyltrichloroethane (DDT); chemicals in cosmetics]. Participants could answer that they were not at all concerned, slightly concerned, somewhat concerned, concerned, or very concerned. In the knowledge section, participants were asked 11 yes or no questions about whether an item was a source of a particular chemical and 25 true or false questions assessing conceptual understanding of environmental chemical exposures and aims of the CHDS. For this analysis, we focused on 20 true or false knowledge questions that addressed core topics supporting EDC-EHL (exposure pathways, health impacts, and regulation). Finally, participants were asked how frequently they performed 17 exposure-related behaviors. One behavior question included a free-text follow-up: Participants who responded they had added or removed items from their home in the past month because of concerns about the chemicals in them were prompted to identify the items that they changed. Two behavior questions were excluded from analysis because they asked about behavior in the last 5 y, a time frame that could not be assessed during our follow-up period. The questions asked were identical in the baseline and post-interviews, but the order of knowledge and concern questions was randomized within each domain. The survey questions used in this analysis are shown in Supplemental Material, Survey Questions. We previously published on associations between pre-interview responses to nine of the behavior questions and blood levels of PFAS.[31]

Participants in all arms of the study also received a short pop-up survey while viewing their online report. Participants had the option to decline the survey. Of the four questions included in the pop-up survey, this analysis examined responses to the question, "Do you plan to make any changes because of learning these results?" If the participant responded "yes," they were asked to provide a free-text response to the question, "What do you plan to change?"

Analysis

The analysis of knowledge, concern, and behavior was restricted to participants in the structured interview group who completed both pre- and post-interviews and includes those who viewed their report online or received a hard copy. A computer error in the administration of the baseline interview caused skipped questions for 23 participants. All participants were called again to ask the skipped questions, but 16 participants were excluded from analysis because they had already viewed their reports by the time the error was detected and they were reached again. In addition, five participants were excluded because they received only a web report and their web analytics data showed that they had not logged into their report prior to the post-interview, despite giving a verbal confirmation that they had done so. All analyses were performed in R (version 4.1.1; R Development Core Team).

Demographic variables. Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree). Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. All other responses (non-Hispanic White, Hispanic, Asian, and mixed race and not Black) were grouped as non-Black.

Structured survey variables. Participants could decline to answer or answer "don't know" for any question. Answers to the knowledge questions were coded for analysis as correct or not correct, with "don't know" ($n=49/5{,}400$, 0.9%) and decline to answer ($n=29/5{,}400$, 0.5%) responses categorized as not correct. We also calculated a total knowledge index as the sum of correct answers (range of possible scores = 0–20). Concern questions were answered on a 5-point scale from not at all concerned to very concerned; "don't know" ($n=4/2{,}970$, 0.1%) and decline to answer ($n=11/2{,}970$, 0.4%) responses for these questions were substituted with the midpoint value (i.e., 3) for analysis. We created binary concern variables by combining the top two levels (concerned or very concerned) and the bottom three levels (not at all, slightly, or somewhat concerned). We also calculated a total concern index as the sum of all 5-point concern variables (range of possible scores = 11–55). Four environmental health behaviors were recorded on a no/yes binary scale, and the other 11 behaviors were recorded on three different 4- to 5-point frequency scales. To calculate a total behavior index, we first rescaled the 4- and 5-point items to span from zero to one and then summed all behaviors, except for using a fish-buying guide or other information to avoid fish with high pollution levels, which was only asked of participants who indicated consuming fish (range of possible scores = 0–14). Of questions asked to all participants, missing responses ($n=11/3{,}780$, 0.3%) were excluded from the behavior analysis with one exception: When a response was missing at one interview only, we substituted their response from the alternate interview during the calculation of the total behavior index. All behaviors in the index were scored such that the behavior was a protective environmental health action; in some cases, the protective action was not performing a harmful environmental health behavior (e.g., not using air freshener, not eating microwave popcorn).

Knowledge analysis. We first calculated frequencies of correctly answering each EDC-EHL knowledge question at baseline for all participants combined and stratified by participant education and race. We used logistic regression to test whether education and race were associated with answering each question correctly at baseline and then used multiple regression to test the same associations with baseline knowledge index. In both models, we first tested the hypothesis that race modified the relationship between education and answering correctly by including the interaction between race and education. In the absence of a significant interaction (alpha = 0.05), we ran the regression with the main effects only. We calculated the odds ratios (OR) as $\exp(\beta)$. Because logistic regression cannot handle quasi-separation, we restricted the analysis to questions where no race by education subgroup had 100% accuracy. This excluded four questions, which had baseline accuracy 93%–98% overall.

We calculated mean knowledge index at baseline and after report-back stratified by report type (PR or AR) and race. We tested whether knowledge index differed after report-back using paired *t*-tests within each report type by race subgroup. Finally, we tested for differences in the proportion of participants who correctly answered each knowledge question at baseline and after report-back using McNemar's test. This analysis was restricted to questions with a baseline percent correct <90%, because there is little potential to observe increases in knowledge at high baseline levels.

Concern analysis. We first calculated frequencies of percent concerned for each chemical group at baseline for all participants combined and stratified by participant education and race. We used logistic regression to test whether education and race were associated with being concerned about each chemical group at baseline. We first tested the hypothesis that race modified the relationship between education and concern by including the interaction between race and education. In the absence of a significant interaction (alpha = 0.05), we ran the regression with the main effects only.

We calculated mean concern index at baseline and after report-back stratified by report type (PR or AR) and race. We tested whether concern index differed after report-back using paired *t*-tests within each report type by race subgroup. We tested for differences in the proportion of participants who were concerned about each chemical group at baseline and after report-back using McNemar's test.

Behavior analysis. We calculated frequencies of performing exposure-related behaviors at baseline and after report-back; participants with a missing response at the pre- or post-interview were excluded from the frequency report at both time points only for the behavior having missing data. We tested for differences in the proportion of participants performing each behavior at baseline and after report-back using McNemar's test for binary variables and the Wilcoxon-Pratt signed-rank test for 4- and 5-point variables. We calculated mean behavior index at baseline and after report-back stratified by report type (PR or AR) and race. We tested whether behavior index differed after report-back using paired *t*-tests within each report type by race subgroup.

We used multiple regression to evaluate mutually adjusted associations between behavior index at the post-interview and participant characteristics (race, education, report type, post-interview knowledge index, and post-interview concern index).

One author (K.B.) coded the free-text responses from the pop-up survey and post-interview about planned or actual changes in environmental health behavior after report-back. Categories were developed iteratively during a preliminary round of coding, and then all responses were recoded using the final set of 21 categories.

Table 1. Characteristics of women in the MyCHDSReport Study who completed a pre- and post- structured interview and were eligible for analysis ($n = 135$).

Characteristic	Level	Number (%)
Black/African American race[a]	No	73 (54.1)
	Yes	62 (45.9)
Bachelor's degree[b]	No	69 (51.1)
	Yes	66 (48.9)
Household member under age 18 y	No	78 (57.8)
	Yes	57 (42.2)
Employed or in school	No	29 (21.5)
	Yes	106 (78.5)
Self-reported perception of general health	Excellent	20 (14.8)
	Very good	56 (41.5)
	Good	36 (26.7)
	Fair	20 (14.8)
	Poor	3 (2.2)
Total cholesterol result above guideline[c]	No	87 (64.4)
	Yes	48 (35.6)
Number of "high" chemical headlines[d]	0	3 (2.2)
	1	33 (24.4)
	2	29 (21.5)
	3	56 (41.5)
	4	14 (10.4)

[a]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Of the 73 non-Black participants, 62 (85%) were non-Hispanic White, 5 (7%) were Hispanic, 4 (5%) were Asian, and 2 (3%) were mixed race and not Black.
[b]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).
[c]Participants received a recommendation to contact their doctor if their total cholesterol exceeded 200 mg/dL.[26]
[d]Participants were assigned a "high" headline for a chemical group if one or more chemicals in a group exceeded the 95th study percentile, more than one chemical in a group exceeded the 75th study percentile, or more than 75% of chemicals in a group exceeded the study median.[16]

Results

Characteristics of the Study Population

Of 295 women eligible for the MyCHDSReport Study, 227 were assigned to the structured interview, 156 completed both the baseline and post-interviews, and 135 remained after applying other exclusion criteria. Among the 135 participants, 62 (46%) identified as Black, 57 (42%) had a child under 18 y of age living at home, and 106 (79%) were employed (Table 1). Most participants [112 (83%)] reported being in "good" or better general health; 48 (36%) received a headline about having total cholesterol above a guideline. Nearly all participants [132 (98%)] received at least one "high" headline about having higher chemical levels than others in the study for a chemical group. Participants were 49–56 y old (median = 53 y) in 2015 when reports began to be disseminated.

Knowledge

Participants in the MyCHDSReport Study had generally high EDC-EHL knowledge at baseline (Table 2). Nine out of 20 questions were correctly answered by >90% of participants; five of these nine questions were in the health category, and four were in the exposure category. Most participants knew that the chemicals in the study could affect cancer risk ($n = 129$, 96%), child brain development and IQ ($n = 127$, 94%), and adult fertility ($n = 125$, 93%). 92% of participants ($n = 124$) knew that babies can be exposed to chemicals before they are born. Only four questions were answered correctly <50% of the time. Most participants ($n = 103$, 76%) wrongly thought that chemicals must be tested for safety before they can be used in products in the United States. Despite this misconception, a similar proportion ($n = 102$, 76%) did know that some chemicals used in U.S. beauty products are banned in Europe. The other major misconception held by participants ($n = 94$, 70%) was that doctors can use the chemicals results in the MyCHDSReport to predict future health impacts. In contrast, 88% of participants ($n = 119$) responded that scientists are not sure about all the health effects of the chemicals in the study.

We then tested whether education and race were associated with answering each question correctly at baseline. There was no significant interaction between education and race for any knowledge question (Table S1), so we report here on the regression models including main effects only. Education was a significant predictor for the two biggest misconceptions but not for any other knowledge questions (Table 3). Participants with a bachelor's degree were more likely to know that chemicals are not tested for safety in the United States [OR = 3.2; 95% confidence interval (CI): 1.4, 8.0] and more likely to know that doctors are unable to use chemical levels to predict health outcomes (OR = 2.6; 95% CI: 1.2, 5.8). Race was a significant predictor for one question only: Black participants were more likely to know that Californians do not have the same level of flame retardants in their blood as other Americans (OR = 3.3; 95% CI: 1.6, 7.2). Similar outcomes were observed when analyzing the summed baseline knowledge index. There was no significant interaction between education and race (Table S2); in the regression with main effects only, having a bachelor's degree ($\beta = 1.1$, 95% CI: 0.2, 1.9) was a significant predictor of baseline knowledge, but race was not ($\beta = -0.3$, 95% CI: -1.1, 0.6) (Table 4).

We next examined changes in knowledge index after report-back, stratified by report type and race (Table 5). Non-Black

Table 2. Proportion of participants at baseline ($n = 135$) who correctly answered each question assessing environmental health knowledge, stratified by participant race and education.

			n (%) correct				
			Black participants[a]		Non-Black participants		
Category	Question	Answer	No bachelor's degree[b] ($n = 38$)	Bachelor's degree ($n = 24$)	No bachelor's degree ($n = 31$)	Bachelor's degree ($n = 42$)	All
Exposure	Some chemicals in people's blood can come from spending time in an older building.	TRUE	37 (97.4)	24 (100)	29 (93.5)	42 (100)	132 (97.8)
Exposure	Even though fish is a healthy food, some fish contain high levels of chemicals, such as PCBs, that are harmful for health.	TRUE	35 (92.1)	23 (95.8)	30 (96.8)	41 (97.6)	129 (95.6)
Exposure	City people usually do not have any pesticides in their blood.	FALSE	35 (92.1)	23 (95.8)	29 (93.5)	40 (95.2)	127 (94.1)
Exposure	Babies in the womb are not exposed to pollution or harmful chemicals before they are born.	FALSE	35 (92.1)	20 (83.3)	29 (93.5)	40 (95.2)	124 (91.9)
Exposure	People can get chemicals in their blood from the dust in their home.	TRUE	35 (92.1)	20 (83.3)	24 (77.4)	36 (85.7)	115 (85.2)
Exposure	Most people do not have any industrial chemicals in their blood.	FALSE	28 (73.7)	21 (87.5)	28 (90.3)	37 (88.1)	114 (84.4)
Exposure	The pesticide DDT was banned years ago, so people are not exposed anymore.	FALSE	29 (76.3)	18 (75)	25 (80.6)	37 (88.1)	109 (80.7)
Exposure	The U.S. Centers for Disease Control has found many chemical contaminants in blood samples from everyone they tested.	TRUE	25 (65.8)	17 (70.8)	24 (77.4)	34 (81)	100 (74.1)
Exposure	Californians have the same levels of flame retardants in their blood as other Americans.	FALSE	25 (65.8)	21 (87.5)	15 (48.4)	21 (50)	82 (60.7)
Exposure	Washing your hands removes germs but has no effect on a person's exposures to harmful chemicals.	FALSE	16 (42.1)	9 (37.5)	14 (45.2)	23 (54.8)	62 (45.9)
Exposure	Leafy vegetables are more likely than meat, cheese, or whole milk to contain residues of long-lasting chemical contaminants.	FALSE	14 (36.8)	11 (45.8)	14 (45.2)	23 (54.8)	62 (45.9)
Health	Scientists have some evidence that some of the chemicals studied by the CHDS can cause cancer.	TRUE	34 (89.5)	24 (100)	30 (96.8)	41 (97.6)	129 (95.6)
Health	Some chemicals from pollution, food, or everyday products can remain in a person's body for years.	TRUE	33 (86.8)	24 (100)	31 (100)	39 (92.9)	127 (94.1)
Health	Exposure in early life to some of the chemicals tested in CHDS can affect a baby's brain development and IQ.	TRUE	34 (89.5)	23 (95.8)	30 (96.8)	40 (95.2)	127 (94.1)
Health	Some of the chemicals tested in CHDS can affect fertility (the ability of a man or woman to have children).	TRUE	32 (84.2)	24 (100)	30 (96.8)	39 (92.9)	125 (92.6)
Health	Whether or not a chemical exposure affects your health depends partly on how much you are exposed to.	TRUE	34 (89.5)	21 (87.5)	28 (90.3)	41 (97.6)	124 (91.9)
Health	Scientists are not sure about all the health implications of the chemicals tested by the CHDS.	TRUE	32 (84.2)	21 (87.5)	27 (87.1)	39 (92.9)	119 (88.1)
Health	A doctor will be able to tell me how the chemical results in MyCHDSReport will affect my health in the future.	FALSE	6 (15.8)	10 (41.7)	8 (25.8)	17 (40.5)	41 (30.4)
Regulation	Some of the chemicals used in beauty products in the U.S. are banned in Europe.	TRUE	29 (76.3)	22 (91.7)	23 (74.2)	28 (66.7)	102 (75.6)
Regulation	Chemicals have to be tested for safety before they can be used in products in the U.S.	FALSE	5 (13.2)	11 (45.8)	5 (16.1)	11 (26.2)	32 (23.7)

Note: CHDS, Child Health and Development Studies; DDT, dichlorodiphenyltrichloroethane; PCBs, polychlorinated biphenyls.

[a]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.

[b]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).

Table 3. ORs from logistic regressions evaluating whether education and race were associated with correctly answering environmental health knowledge questions at baseline ($n = 135$).

Category	Question	Answer	n (%) correct	OR (95% CI)	
				Education[a] (Ref: no bachelor's degree)	Race[b] (Ref: non-Black race)
Exposure	Some chemicals in people's blood can come from spending time in an older building.	TRUE	132 (97.8)	—	—
Exposure	Even though fish is a healthy food, some fish contain high levels of chemicals, such as PCBs, that are harmful for health.	TRUE	129 (95.6)	1.7 (0.31, 13)	0.45 (0.06, 2.5)
Exposure	City people usually do not have any pesticides in their blood.	FALSE	127 (94.1)	1.6 (0.37, 8.3)	0.92 (0.2, 4.1)
Exposure	Babies in the womb are not exposed to pollution or harmful chemicals before they are born.	FALSE	124 (91.9)	0.66 (0.18, 2.4)	0.42 (0.1, 1.5)
Exposure	People can get chemicals in their blood from the dust in their home.	TRUE	115 (85.2)	1 (0.39, 2.8)	1.7 (0.64, 4.9)
Exposure	Most people do not have any industrial chemicals in their blood.	FALSE	114 (84.4)	1.5 (0.57, 4.1)	0.5 (0.18, 1.3)
Exposure	The pesticide DDT was banned years ago, so people are not exposed anymore.	FALSE	109 (80.7)	1.3 (0.52, 3.1)	0.58 (0.24, 1.4)
Exposure	The U.S. Centers for Disease Control has found many chemical contaminants in blood samples from everyone they tested.	TRUE	100 (74.1)	1.3 (0.57, 2.8)	0.57 (0.25, 1.2)
Exposure	Californians have the same levels of flame retardants in their blood as other Americans.	FALSE	82 (60.7)	1.6 (0.78, 3.5)	3.3 (1.6, 7.2)**
Exposure	Washing your hands removes germs but has no effect on a person's exposures to harmful chemicals.	FALSE	62 (45.9)	1.1 (0.57, 2.3)	0.67 (0.33, 1.3)
Exposure	Leafy vegetables are more likely than meat, cheese, or whole milk to contain residues of long-lasting chemical contaminants.	FALSE	62 (45.9)	1.5 (0.73, 2.9)	0.7 (0.35, 1.4)
Health	Scientists have some evidence that some of the chemicals studied by the CHDS can cause cancer.	TRUE	129 (95.6)	—	—
Health	Exposure in early life to some of the chemicals tested in CHDS can affect a baby's brain development and IQ.	TRUE	127 (94.1)	1.5 (0.33, 7.5)	0.52 (0.1, 2.3)
Health	Some chemicals from pollution, food, or everyday products can remain in a person's body for years.	TRUE	127 (94.1)	—	—
Health	Some of the chemicals tested in CHDS can affect fertility (the ability of a man or woman to have children).	TRUE	125 (92.6)	—	—
Health	Whether or not a chemical exposure affects your health depends partly on how much you are exposed to.	TRUE	124 (91.9)	1.5 (0.43, 6.2)	0.49 (0.12, 1.8)
Health	Scientists are not sure about all the health implications of the chemicals tested by the CHDS.	TRUE	119 (88.1)	1.6 (0.54, 5)	0.68 (0.22, 2)
Health	A doctor will be able to tell me how the chemical results in MyCHDSReport will affect my health in the future.	FALSE	41 (30.4)	2.6 (1.2, 5.8)*	0.79 (0.36, 1.7)
Regulation	Some of the chemicals used in beauty products in the U.S. are banned in Europe.	TRUE	102 (75.6)	1.2 (0.52, 2.6)	2.1 (0.91, 4.9)
Regulation	Chemicals have to be tested for safety before they can be used in products in the U.S.	FALSE	32 (23.7)	3.2 (1.4, 8)**	1.6 (0.68, 3.7)

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. —, odds ratios could not be computed because of quasi-separation in the data. CHDS, Child Health and Development Studies; CI, confidence interval; DDT, dichlorodiphenyltrichloroethane; OR, odds ratio; PCBs, polychlorinated biphenyls; Ref, reference.

[a]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).

[b]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.

Table 4. Multiple regression model evaluating associations between race and education and baseline environmental health knowledge index score ($n = 135$).

Term	Coefficient (95% CI)	p-Value
Intercept	15 (14.3, 15.8)	<0.001
Education[a] (Ref: no bachelor's degree)	1.1 (0.2, 1.9)	0.012
Race[b] (Ref: non-Black race)	−0.3 (−1.1, 0.6)	0.51

Note: CI, confidence interval; Ref, reference.
[a]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).
[b]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.

participants who received personal reports were the only subgroup who showed a significant increase in knowledge index after report-back ($p < 0.001$). Participants in this group had an average increase in knowledge index of 1.4 points; all other groups had average changes between 0.13 and 0.32 points. Out of 11 questions where participants scored <90% at baseline, four questions showed significant increases in the proportion of participants to answer correctly, one question showed a marginally significant increase ($p = 0.063$), and no questions showed significant decreases (Table 6). The greatest increase in proportion of participants answering correctly (12.6 percentage points, $p = 0.008$) was for the question, "The U.S. Centers for Disease Control has found many chemical contaminants in blood samples from everyone they tested." The two biggest misconceptions both showed substantial improvement: an 8.4-percentage point increase in the question about chemicals safety testing in the United States ($p = 0.063$) and an 11.1-percentage point increase ($p = 0.016$) in the question about what doctors know about chemicals and health.

Concern

Overall, participants in the MyCHDSReport Study had more concern at baseline about health effects from traditional chemical hazards (banned and current-use pesticides, older industrial chemicals) than consumer product chemicals, with the greatest fraction of participants ($n = 108$, 80%) having concern about banned pesticides like DDT (Table 7). Fewer than half of all participants had concern about any of the chemical groups used in consumer products (i.e., flame retardants in electronics and furniture; products likely to contain PFAS, including stain-resistant textiles, nonstick cookware, and grease-resistant food packaging; chemicals in cosmetics; and vinyl products), ranging from 25% to 41% ($n = 34$–55) overall (Table 7).

We then tested whether education and race were associated with concern about each chemical group at baseline. There was no significant interaction between education and race for any chemical group (Table S3), so we report here on the regression models including main effects only. Participants with a bachelor's degree were significantly less likely to have concern about some traditional pollutants (banned pesticides, and to a lesser extent current-use pesticides) and chemicals that collect in house dust, but there was no relationship between education and concern for any of the consumer product chemicals (Table 8). In contrast, Black participants were significantly more likely to be concerned about chemicals in consumer products than non-Black participants for five out of seven chemical groups; Black participants were also more likely to be concerned about chemicals in house dust (Table 8).

We next examined changes in concern after report-back stratified by report type and race (Table 9). Non-Black participants who received personal reports showed the greatest increase in concern index after report-back, with a mean increase of 6.0 points ($p < 0.001$). All other groups had mean increases between 2.0 and 2.7 points. These increases did not close the gap between Black and non-Black participants; after report-back, Black participants still had higher mean concern index than non-Black participants, independent of report type. Concern increased after report-back for five consumer product chemical groups and for chemicals that collect in house dust, whereas concern about banned pesticides decreased after report-back (Table 10). The greatest increases in concern were about products containing PFAS, including nonstick cookware (20.7 percentage points), stain-resistant textiles (19.3 percentage points), and grease-resistant food packaging (13.3 percentage points).

Behavior

We observed changes in frequency for 5 out of 15 behaviors after report-back (Figure 1; Table S4). After report-back, participants decreased the frequency of three behaviors associated with sources of PFAS: eating microwave popcorn ($z = 2.48$, $p = 0.016$), eating food prepared with nonstick cookware ($z = 2.35$, $p = 0.019$), and using Oral-B Glide dental floss ($z = 3.34$, $p < 0.001$). Participants did not tend to increase how often they performed dust-reducing behaviors, and, unexpectedly, one behavior was less frequent after report-back (damp-wiping windowsills or other surfaces: $z = 2.28$, $p = 0.022$). After report-back, 25% ($n = 34$) of participants reported having added or removed an item from their home in the past month due to concern about chemicals, in comparison with 10% ($n = 14$) prior to report-back ($X^2 = 10.5$, $p = 0.001$).

We next examined changes in behavior index after report-back, stratified by report type and race (Table 11). Non-Black participants who received personal reports and Black participants who received aggregate reports both showed significant increases in behavior index; however, these effects were small, with mean increases of 0.75 and 0.73 points, respectively. Behavior index

Table 5. Mean environmental health knowledge index at baseline and after report-back by report type and participant race.

Report type[b]	Race[c]	n	Mean knowledge index[a] (standard deviation): Baseline	Mean knowledge index[a] (standard deviation): After report-back	Mean of the differences	t	p-Value[d]
Personal	non-Black	34	15.4 (2.5)	16.9 (1.9)	1.40	4.70	<0.001
Personal	Black	31	15.3 (2)	15.4 (1.8)	0.13	0.29	0.78
Aggregate	non-Black	38	15.8 (2.1)	16.1 (1.8)	0.29	0.83	0.41
Aggregate	Black	31	15 (3.3)	15.4 (1.8)	0.32	0.62	0.54

[a]Knowledge index was calculated as the sum of correct answers (range of possible scores = 0–20).
[b]Personal reports included individual-level exposure results in comparison with the study population and national benchmarks. Aggregate reports did not include individual-level exposure results.
[c]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.
[d]Paired t-tests were used to test for change in knowledge index within each report type by race subgroup.

Table 6. Proportion of participants ($n = 135$) who correctly answered each knowledge question at baseline and after report-back, for questions with a baseline percent correct <90%.

Category	Question	Answer	n (%) correct: Baseline	n (%) correct: After report-back	X^2	p-Value
Health	Scientists are not sure about all the health implications of the chemicals tested by the CHDS.	TRUE	119 (88.1)	124 (91.9)	1.1	0.30
Exposure	People can get chemicals in their blood from the dust in their home.	TRUE	115 (85.2)	127 (94.1)	6.0	0.014
Exposure	Most people do not have any industrial chemicals in their blood.	FALSE	114 (84.4)	115 (85.2)	0.0	0.87
Exposure	The pesticide DDT was banned years ago, so people are not exposed anymore.	FALSE	109 (80.7)	106 (78.5)	0.3	0.60
Regulation	Some of the chemicals used in beauty products in the U.S. are banned in Europe.	TRUE	102 (75.6)	113 (83.7)	4.2	0.041
Exposure	The U.S. Centers for Disease Control has found many chemical contaminants in blood samples from everyone they tested.	TRUE	100 (74.1)	117 (86.7)	7.0	0.008
Exposure	Californians have the same levels of flame retardants in their blood as other Americans.	FALSE	82 (60.7)	74 (54.8)	1.1	0.29
Exposure	Washing your hands removes germs but has no effect on a person's exposures to harmful chemicals.	FALSE	62 (45.9)	63 (46.7)	0.0	0.89
Exposure	Leafy vegetables are more likely than meat, cheese, or whole milk to contain residues of long-lasting chemical contaminants.	FALSE	62 (45.9)	67 (49.6)	0.6	0.46
Health	A doctor will be able to tell me how the chemical results in MyCHDSReport will affect my health in the future.	FALSE	41 (30.4)	56 (41.5)	5.8	0.016
Regulation	Chemicals have to be tested for safety before they can be used in products in the U.S.	FALSE	32 (23.7)	43 (32.1)	3.5	0.063

Note: McNemar's test was used to test for differences in proportion correct before and after report-back. CHDS, Child Health and Development Studies; DDT, dichlorodiphenyltrichloroethane.

after report-back was associated with participants' levels of concern and knowledge at that time (Table 12). We did not observe an association with race, report type, or education level.

Finally, we analyzed open-ended responses about changes participants planned to take (reported in the pop-up survey) and items that they added or removed from their home after report-back (reported in the post-interview). Of the 70 participants who completed the pop-up survey, 62 (89%) responded that they planned to make changes because of learning their results. At the post-interview, 34 out of 135 participants (25%) reported adding or removing something from their home in the past month because of concern about chemicals. By far the most frequently reported change involved removing or replacing nonstick cookware: At the time of report-back, 23 participants planned to make this change, and during the post-interview 18 participants stated having made this change (Table 13). These responses are consistent with the structured data reported above showing a decrease in eating food prepared with nonstick cookware (Figure 1). In the pop-up survey, 15 participants planned to alter a cleaning behavior, and many tied this to reducing dust levels in the home; however, in this case the structured data do not support that participants carried through on these intentions (Figure 1). Overall, participants reported in the pop-up survey a wide range of changes they intended to make, spanning food/diet, pesticide use, cleaning

Table 7. Proportion of participants at baseline ($n = 135$) who were concerned or very concerned about health effects of certain chemicals, stratified by participant race and education.

Chemical group	Black participants[b]: No bachelor's degree[c] ($n = 38$)	Black participants[b]: Bachelor's degree ($n = 24$)	non-Black participants: No bachelor's degree ($n = 31$)	non-Black participants: Bachelor's degree ($n = 42$)	All ($n = 135$)
	n (%) concerned[a]				
Banned pesticides (like DDT)	35 (92.1)	17 (70.8)	26 (83.9)	30 (71.4)	108 (80)
Pesticides used to kill bugs or weeds in and around homes	29 (76.3)	16 (66.7)	23 (74.2)	23 (54.8)	91 (67.4)
Older industrial chemicals (like PCBs)	23 (60.5)	14 (58.3)	20 (64.5)	24 (57.1)	81 (60)
Chemicals that collect in your house dust	28 (73.7)	12 (50)	16 (51.6)	12 (28.6)	68 (50.4)
Flame retardants in electronic equipment like computers, TVs, printers, and phones	23 (60.5)	11 (45.8)	11 (35.5)	10 (23.8)	55 (40.7)
Nonstick cookware (like Teflon pans)	16 (42.1)	13 (54.2)	11 (35.5)	13 (31)	53 (39.3)
Flame retardants in furniture	23 (60.5)	10 (41.7)	6 (19.4)	11 (26.2)	50 (37)
Chemicals in cosmetics	19 (50)	8 (33.3)	11 (35.5)	10 (23.8)	48 (35.6)
Stain-resistant clothing and furnishings (such as rugs)	17 (44.7)	8 (33.3)	5 (16.1)	8 (19)	38 (28.1)
Vinyl products (like shower curtains or flooring)	18 (47.4)	7 (29.2)	6 (19.4)	6 (14.3)	37 (27.4)
Grease-resistant food packaging	18 (47.4)	9 (37.5)	3 (9.7)	4 (9.5)	34 (25.2)

Note: DDT, dichlorodiphenyltrichloroethane; PCBs, polychlorinated biphenyls; TV, television.
[a]Percent concerned includes participants who responded that they were concerned or very concerned (versus not at all concerned, slightly concerned, or somewhat concerned).
[b]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.
[c]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).

Table 8. Odds ratios from logistic regressions evaluating whether education and race were associated with concern about health effects of certain chemicals at baseline ($n = 135$).

Chemical group	n (%) concerned[a]	OR (95% CI)	
		Education[b] (Ref: no bachelor's degree)	Race[c] (Ref: non-Black race)
Banned pesticides (like DDT)	108 (80)	0.34 (0.13, 0.83)*	1.3 (0.54, 3.3)
Pesticides used to kill bugs or weeds in and around homes	91 (67.4)	0.5 (0.23, 1)+	1.4 (0.65, 2.9)
Older industrial chemicals (like PCBs)	81 (60)	0.81 (0.4, 1.6)	0.94 (0.46, 1.9)
Chemicals that collect in your house dust	68 (50.4)	0.37 (0.18, 0.75)**	2.6 (1.2, 5.4)*
Flame retardants in electronic equipment like computers, TVs, printers, and phones	55 (40.7)	0.56 (0.27, 1.2)	2.8 (1.3, 5.7)**
Nonstick cookware (like Teflon pans)	53 (39.3)	1.1 (0.56, 2.3)	1.8 (0.91, 3.8)
Flame retardants in furniture	50 (37)	0.8 (0.38, 1.7)	3.6 (1.7, 7.7)***
Chemicals in cosmetics	48 (35.6)	0.53 (0.25, 1.1)	1.7 (0.83, 3.6)
Stain-resistant clothing and furnishings (such as rugs)	38 (28.1)	0.83 (0.37, 1.8)	3 (1.4, 6.9)**
Vinyl products (like shower curtains or flooring)	37 (27.4)	0.55 (0.24, 1.2)	3.1 (1.4, 7.2)**
Grease-resistant food packaging	34 (25.2)	0.75 (0.31, 1.8)	6.9 (2.8, 19)***

Note: $^{+}p < 0.07$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. CI, confidence interval; DDT, dichlorodiphenyltrichloroethane; OR, odds ratio; PCBs, polychlorinated biphenyls; Ref, reference; TV, television.
[a]Percent concerned includes participants who responded that they were concerned or very concerned (vs. not at all concerned, slightly concerned, or somewhat concerned).
[b]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).
[c]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.

products, and more. Four participants planned to help or inform others. Many actions that were mentioned in the pop-up survey closely echoed specific exposure-reduction tips included in MyCHDSReport. However, participants sometimes named sources of chemicals mentioned only in the context of the pre- and post-interview itself and not in MyCHDSReport—for example, Oral-B Glide dental floss, air freshener, and vinyl shower curtains. This type of response occurred both in the pop-up survey and post-interview but was somewhat more frequent in the post-interview.

Discussion

Participants in the MyCHDSReport Study generally understood basic principles about exposure pathways and health outcomes related to environmental endocrine disruptors but lacked critical understanding of how chemicals are regulated in the United States. Prior to report-back of the study's chemical exposure results, participants were primarily concerned about traditional and legacy pollutants. After report-back, participants' concern about chemicals in everyday consumer products increased, and they changed certain exposure-related behaviors, especially those suspected to increase PFAS exposure. These results demonstrate that report-back of chemical exposure results can increase understanding and empower participants to take action to lower exposures to EDCs. This larger-scale, quantitative study adds to findings from earlier research that show study participants learn from receiving individual results reports, express intentions to change their behaviors, and sometimes do take action to reduce exposures.[15,28,30,32,33]

Participants in the MyCHDSReport Study were knowledgeable at the outset of the study about routes of chemical exposures and health effects, key components of EDC-EHL. For example, >90% of participants understood the concept of *in utero* exposure ($n = 124$) and the connection between chemicals and children's cognitive development ($n = 127$). Women in this study have been enrolled in the CHDS since birth, and a primary research focus of the CHDS is the effect of early-life environmental exposures on adult health outcomes. Thus, the women in the study may have greater knowledge about environmental chemicals due their lifelong participation in the CHDS.

Despite their long-term involvement in the CHDS, participants had poor knowledge of chemicals regulation in the United States. Over three-quarters of participants ($n = 103$) wrongly believed that chemicals must be tested for safety before they can be used in products in the United States. In fact, the Toxics Substances Control Act (TSCA),[34] promulgated in 1976 and amended in 2016, does not require manufacturers to conduct any toxicity or safety testing prior to submitting notice to the U.S. Environmental Protection Agency (U.S. EPA) of intent to use a new chemical in commerce, nor was testing required for the >62,000 chemicals in use at the time the TSCA became law.

Participants also misjudged what doctors know about chemical exposures. Most participants wrongly believed that doctors can

Table 9. Mean concern index at baseline and after report-back by report type and participant race.

Report type[b]	Race[c]	n	Mean concern index[a] (standard deviation)		Mean of the differences	t	p-Value[d]
			Baseline	After report-back			
Personal	Non-Black	35	30.1 (10.2)	36.1 (10.1)	6.0	3.7	<0.001
Personal	Black	31	39.4 (9.9)	42.1 (10.8)	2.7	1.6	0.12
Aggregate	Non-Black	38	34.1 (8.9)	36.2 (10.5)	2.1	1.8	0.084
Aggregate	Black	31	38 (12.2)	40 (11)	2.0	1.1	0.28

[a]Concern index was calculated as the sum of all 5-point concern variables (range of possible scores = 11–55). Concern was rated as not at all concerned (1), slightly concerned (2), somewhat concerned (3), concerned (4), or very concerned (5).
[b]Personal reports included individual-level exposure results in comparison with the study population and national benchmarks. Aggregate reports did not include individual-level exposure results.
[c]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.
[d]Paired t-tests were used to test for change in concern index within each report type by race subgroup.

Table 10. Proportion of participants ($n = 135$) concerned or very concerned about certain chemical groups at baseline and after report-back.

	n (%) concerned[a]			
Chemical group	Baseline	After report-back	X^2	*p*-Value[b]
Banned pesticides (like DDT)	108 (80)	97 (71.9)	3.9	0.048
Pesticides used to kill bugs or weeds in and around homes	91 (67.4)	98 (72.6)	1.3	0.25
Older industrial chemicals (like PCBs)	81 (60)	90 (66.7)	2.3	0.13
Chemicals that collect in your house dust	68 (50.4)	81 (60)	4.3	0.037
Flame retardants in electronic equipment like computers, TVs, printers, and phones	55 (40.7)	59 (43.7)	0.4	0.54
Nonstick cookware (like Teflon pans)	53 (39.3)	81 (60)	14.0	<0.001
Flame retardants in furniture	50 (37)	67 (49.6)	7.4	0.006
Chemicals in cosmetics	48 (35.6)	58 (43)	2.6	0.10
Stain-resistant clothing and furnishings (such as rugs)	38 (28.1)	64 (47.4)	15.4	<0.001
Vinyl products (like shower curtains or flooring)	37 (27.4)	54 (40)	7.8	0.005
Grease-resistant food packaging	34 (25.2)	52 (38.5)	8.5	0.004

Note: DDT, dichlorodiphenyltrichloroethane; PCBs, polychlorinated biphenyls; TV, television.
[a]Percent concerned includes participants who responded that they were concerned or very concerned (vs. not at all concerned, slightly concerned, or somewhat concerned).
[b]McNemar's test was used to test for differences in proportion concerned before and after report-back.

predict future health impacts based on a person's chemical levels, even though most participants agreed that "Scientists are not sure about all the health implications" of the chemicals in the study. Results show that participants do recognize a general relationship between amount of exposure and health effects; however, participants may not realize that levels that cause harm are not known for most environmental chemicals. In addition, most doctors have little environmental health training and are not likely to be familiar with the chemicals measured in the study.[35,36] Participants' belief in doctors may rather reflect cultural norms that elevate doctors as trustworthy sources of health information.[37] In contrast, participants associated scientists with uncertainty. We recommend that future reports acknowledge that doctors usually have limited training in environmental chemicals and also provide resources to help participants constructively engage with their health care provider.

Education and race were not important predictors of people's baseline knowledge, with one exception: Both key misconceptions were more common among participants who did not have a bachelor's degree.

Participants showed large improvements on certain knowledge questions. Participants performed better after report-back on two core concepts about exposure—that household dust is a source of chemicals, and that everyone in the United States has chemicals in their blood—and on the two key misconceptions—that chemicals are tested for safety before use and that doctors can infer future health impacts from EDC exposure results. However, even after report-back, more than half of participants still held these wrong beliefs. We observed small gains in overall knowledge after report-back among non-Black participants receiving a personal report but not other groups. We encourage strengthening communication about these topics in future reports with the aim of correcting these and other misconceptions.

Prior to report-back, participants had high levels of concern about traditional and legacy pollutants, such as pesticides and older industrial chemicals. The highest level of concern was for banned pesticides like DDT. These are the types of pollutants that catalyzed the modern environmental movement, so it is not surprising that they have become embedded in the United States collective consciousness. In addition, participants in our study may have known about research results from the CHDS on the health impacts of early-life DDT exposures. The CHDS regularly communicates with participants through the publication of a newsletter. At baseline, participants had lower levels of concern about chemicals found in everyday products in comparison with traditional chemical hazards. This lower level of concern could arise from participants' misconception about United States chemicals regulation, because believing that chemicals in everyday products are tested for safety would serve to limit concern for these chemicals.

Differences in concern by chemical source extended across all subgroups, but Black participants and participants without a bachelor's degree tended to have greater concern about some chemicals prior to report-back. Participants without a bachelor's degree were more likely to be concerned than those with a bachelor's degree about some traditional pollutants (banned and current-use pesticides) and chemicals in house dust. Black participants were more likely to be concerned in comparison with non-Black participants about several types of consumer product chemicals (such as flame retardants in electronics and furnishings, vinyl products, and grease-resistant food packaging) and chemicals in house dust. These results are consistent with our prediction of higher levels of concern among Black participants, considering their experience of environmental racism.

Concern increased after report-back for five consumer product chemical groups, with the greatest increases in concern for products containing PFAS. Greater increases in concern about PFAS might reflect participants' lack of familiarity with these chemicals prior to report-back, because these reports were disseminated before the increase in media attention to PFAS that has occurred in recent years. Concern also increased for some chemical sources that were not included in the results report: chemicals in cosmetics and vinyl products. By educating participants about specific chemicals tested in the study, report-back may also produce heightened awareness of—or sensitivity to—the presence of chemical contaminants in everyday products more generally. This shift is consistent with changes in understanding previously documented in interviews after environmental chemical report-back.[27,28] A surprising finding was a reported decrease in concern about banned pesticides. It is possible that people's newfound concern about consumer product chemicals began to overshadow some of their previous concerns about traditional pollutants.

A goal of EDC-EHL is to support action; thus, we were interested in whether report-back led to behavior change. Behaviors with the best uptake involved replacing a particular product, such as nonstick cookware. Several participants noted replacing their dental floss; an interesting aspect was that the pre-interview asked about use of Oral-B Glide dental floss, but information about floss was not included as an exposure-reduction tip in the report. Making product changes did not require participants to adopt a different routine or increase their time spent on household chores.

When participants first opened their reports, those who completed the pop-up survey overwhelmingly expected to make changes in behavior. Participants described a wide variety of actions that they planned to take, and in many cases, their answers closely mirrored exposure-reduction tips found in the report, suggesting immediate recall of information from the report. However, at the time of the post-interview several weeks later, observed changes were more muted. Participants reported reductions in several PFAS-related exposure behaviors, but there were no increases in any of the dust-reducing cleaning behaviors (such as vacuuming or mopping), despite being frequently mentioned in the pop-up survey. The discrepancy between the intentions expressed in the pop-

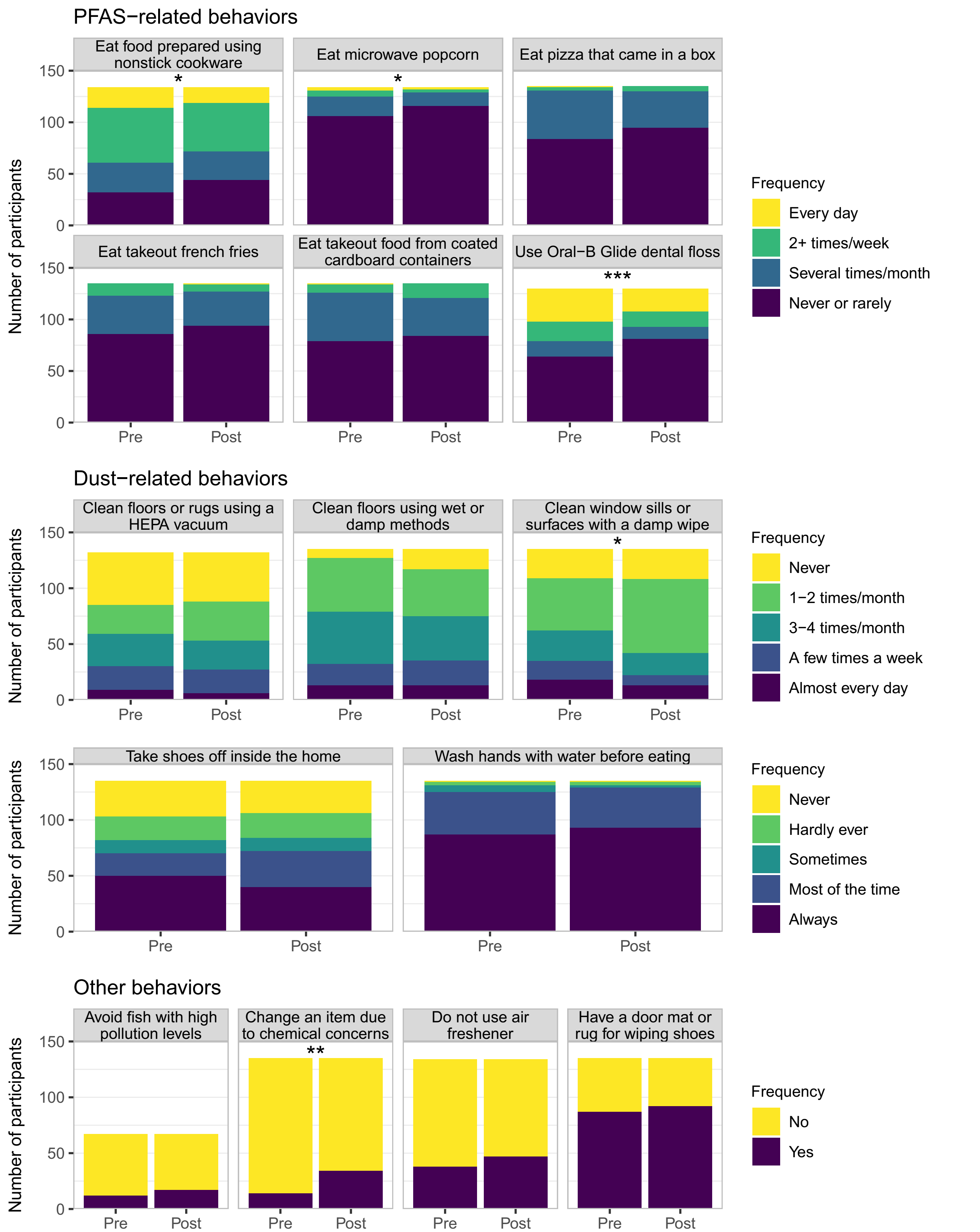

Figure 1. Frequency of performing exposure-related environmental health behaviors, before and after receiving report-back. Frequency of behavior was assessed for the previous month, except for taking shoes off and handwashing, which were assessed for the previous week. A total of 11 out of 135 participants had missing data for one behavior: using Oral-B Glide floss ($n = 5$), using a vacuum with a high-efficiency particulate air (HEPA) filter ($n = 3$), eating food prepared with nonstick cookware ($n = 1$), eating microwave popcorn ($n = 1$), and not using air freshener ($n = 1$). The question about avoiding fish with high pollution levels was asked only of participants who first indicated that they consumed fish or seafood ($n = 67$). All scales are ordered such that the darkest part of the scale is the protective environmental health action; in some cases, the protective action is not performing an exposure-related behavior (e.g., not eating microwave popcorn). Symbols indicate p-values from Wilcoxon-Pratt signed-rank tests (PFAS-related and dust-related behaviors) or McNemar's test (other behaviors): $^{*}<0.05$, $^{**}<0.01$, $^{***}<0.001$. Summary data are available in Table S4.

Table 11. Mean behavior index at baseline and after report-back by report type and participant race.

Report type[b]	Race[c]	n	Mean behavior index[a] (standard deviation)		Mean of the differences	t	p-Value[d]
			Baseline	After report-back			
Personal	Non-Black	35	8.2 (1.3)	8.9 (1.1)	0.750	4.10	<0.001
Personal	Black	31	8.3 (1.3)	8.4 (1.6)	0.075	0.25	0.81
Aggregate	Non-Black	38	8.5 (1.4)	8.6 (1.6)	0.140	0.77	0.45
Aggregate	Black	31	8.1 (1)	8.9 (1.5)	0.730	2.60	0.016

[a]Behavior index was calculated as the sum of behaviors asked of all participants, where each behavior was rescaled to span from 0 to 1, with 1 representing the most protective environmental health action (range of possible scores = 0–14). When a response to a behavior question was missing at one interview only, we substituted the participant's response from the alternate interview during the calculation of the behavior index.
[b]Personal reports included individual-level exposure results in comparison with the study population and national benchmarks. Aggregate reports did not include individual-level exposure results.
[c]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.
[d]Paired t-tests were used to test for change in behavior index within each report type by race subgroup.

up survey and post-interview cleaning behaviors could result from the broader participation in the post-interview (which was required to complete the study), or it could represent a breakdown in converting behavioral intentions into realized habits. Future research can investigate barriers to implementing exposure-reducing behaviors, such as a lack of time for household cleaning.

After report-back, total behavior index was associated with knowledge and concern and not with report type, education, or race. These results suggest that components of EDC-EHL are interacting as expected, with knowledge and concern bolstering people's ability to act on exposures to environmental chemicals, and that race and education did not impact people's willingness or ability to perform the environmental health behaviors measured in this study. Although social norms can be influential drivers of change in beliefs and behaviors,[38] in this study, participants who received their individual results, including comparisons to the study population and national benchmarks, did not differ in total behavior index from those who only received study-wide results.

This study focused on knowledge as one important component of EHL because little is known about public understanding of EDCs and report-back directly offers information to increase understanding. However, knowledge is known to be a limited driver of behaviors. We also measured concern as an influence on behavior, but we did not measure other socioeconomic, biological, or psychosocial factors that could affect motivation and ability to change behavior. We expect that the effect of these unmeasured variables was likely to be limited in this study, because the behaviors that we asked about were mostly low- or zero-cost (mitigating socioeconomic effects) and the study population was homogeneous with respect to sex, age, birthplace, and self-reported general health (mitigating effects due to differences in susceptibility). We also note that report-back is a sensitive context for knowledge-based communications to motivate behavior because it makes invisible chemical contaminants material and personal. In our earlier semistructured interviews, participants described the "exposure experience" of report-back creating embodied knowledge about their chemical levels.[28] This embodied knowledge is a salient feature of report-back that is distinct from other risk communication contexts, such as climate change and conservation, which are often seen as temporally or geographically distant threats.

Table 12. Multiple regression model evaluating associations between knowledge, concern, and other participant characteristics with total behavior index after receiving report-back ($n = 135$).

Term	Coefficient (95% CI)	p-Value
Intercept	4.6 (2, 7.2)	<0.001
Race[a] (Ref: non-Black race)	−0.04 (−0.56, 0.48)	0.88
Report type[b] (Ref: personal report)	0.17 (−0.32, 0.65)	0.50
Education[c] (Ref: no bachelor's degree)	0.33 (−0.2, 0.85)	0.22
Post-report–back concern index	0.031 (0.0073, 0.055)	0.011
Post-report–back knowledge index	0.17 (0.027, 0.31)	0.02

Note: CI, confidence interval; Ref, reference.
[a]Self-reported race/ethnicity was categorized as Black if the participant indicated African American/Black as one of her races in answer to a question allowing multiple response categories for race and ethnicity. Non-Black participants indicated that their race was non-Hispanic White, Hispanic, Asian, or mixed race and not Black.
[b]Personal reports included individual-level exposure results in comparison with the study population and national benchmarks. Aggregate reports did not include individual-level exposure results.
[c]Highest level of education was categorized into "no bachelor's degree" (high school or less, associate degree, technical or vocational training) or "bachelor's degree" (bachelor's, master's, doctoral, or professional degree).

Because most environmental health hazards impact communities and populations and cannot be controlled solely through individual action, EHL inherently requires consideration of community context,[7] and report-back can be influential in social settings because change may ripple out from activated participants. The design of MyCHDSReport incorporated social context by including the Participant Advisory Council in report development and providing actions for prosocial engagement, such as joining an advocacy group working to restrict exposures to toxic chemicals or telling a family member, friend, or neighbor something that they learned from their report about chemicals and health. Earlier case studies have shown that report-back can be highly impactful at stimulating collective action.[39,40] Report-back aligns with previous research showing that communications in smaller, interconnected groups are more effective than mass-media strategies.[41] Although we only assessed individual behavior in this study, future work is needed to examine how participants receiving report-back further disseminate knowledge among their social networks and engage in collective action.

Non-Black participants who received a personal report showed the greatest increases in overall knowledge, concern, and behavior. This finding is consistent with the group having spent the greatest amount of time on the MyCHDSReport website,[16] affording them greater opportunity to learn from report, and with our expectation that personal reports are more motivating than aggregate reports. Despite larger increases in concern among non-Black participants, mean overall concern remained higher among Black participants after report-back because of greater concern at the outset. Disparities in knowledge and behavior change by race likely arise from the previously documented differences in the amount of time participants spent viewing their reports, which in turn may be influenced by effects of structural racism on time resources and lack of trust in research as well as by characteristics of the report.[16] The CHDS Participant Advisory Committee, which represented the diversity of the study population, provided detailed input to the design and content of reports. Future inquiry engaging less-involved participants may also be helpful.

Table 13. Self-reported changes in behavior or product use after report-back among participants who reported a change or plan to change.

	Pop-up survey[a]		Post-interview[b]		
Category	n (%)	Example quotes	n (%)	Removed examples	Added examples
Non-stick cookware	23 (37.1)	"Threw out Teflon pans." "Replace pans with non-stick coating."	18 (52.9)	Teflon pans, nonstick pans	Cast iron pans, stainless cookware
Cleaning behaviors	15 (24.2)	"Maintain a cleaner, dust free, home." "Dust/vacuum more frequently."	—	—	—
Food or diet	10 (16.1)	"Purchasing less canned goods and buying even more vegetables." "I will not eat any more fish or animal skins."	3 (8.8)	Canned vegetables	—
Pesticide use	8 (12.9)	"Will now wear gloves when using flea repellent on my cat." "Let the weeds grow."	1 (2.9)	Items that might have been contaminated with pesticides	—
Cleaning products	6 (9.7)	"Making a conscious effort to purchase safer products to clean my home and clothes." "Stop using chemical cleaners and use more natural."	9 (26.5)	Window cleaner, all-purpose surface cleansers, Pine-Sol	More white vinegar for cleaning
Help or inform others	4 (6.5)	"I will educate my children and extended family and friends what these chemical exposures can cause." "I'm going to go out and buy my sister, who has young children a new ceramic pan to cook."	—	—	—
PFAS-related products (not cookware)	4 (6.5)	"Avoid grease free packaging."	—	—	—
Plastic food storage	4 (6.5)	"Never using plastic to store food or drink." "Avoid the plastic containers that heat up in the microwave."	2 (5.9)	Plastic food storage container	—
Take off shoes at the door	4 (6.5)	"Instead of sometimes taking off shoes at the door do it all the time."	—	—	—
Doormat	3 (4.8)	"Get a rubber doormat." "At least a rug to wipe feet at all doors."	—	—	—
Reduce chemical use (generic)	3 (4.8)	"Use less chemicals in my home."	—	—	—
Read labels	3 (4.8)	"Check my furniture for flame retardants." "More aware of purchase, to read labels on everything."	—	—	—
Choose natural materials	2 (3.2)	"When buying new furniture, look for natural materials."	—	—	—
Microwave popcorn	2 (3.2)	"Toss the microwave popcorn."	1 (2.9)	Microwave popcorn	—
Dental floss	1 (1.6)	"I want to read more about the Glide floss, that might be my 'Teflon' exposure."	2 (5.9)	Four packages Oral-B Glide dental floss	—
Furnishings	1 (1.6)	"Buy a new mattress for my daughter! She has a foam mattress that I bought at an estate sale that is very comfortable but is probably from the 1960's looking at the label!"	1 (2.9)	Throw rugs	—
Handwashing	1 (1.6)	"Washing my hands (even with plain water) before dinner."	—	—	—
Personal care products	1 (1.6)	"Slowly weaning out many household soaps, body washes, lotions that have toxins."	3 (8.8)	Lotion, cosmetics, Cetaphil soap	—
Chemicals (miscellaneous)	—	—	5 (14.7)	Chemicals in garage, hazard materials, spray paint	—
Shower curtain	—	—	3 (8.8)	Vinyl shower curtain	Cloth shower curtain
Air freshener	—	—	2 (5.9)	Plug-in air freshener	—

Note: —, no responses.
[a]Participants responded to the pop-up survey immediately after viewing their report. Pop-up survey data are from participants who indicated that they planned to make changes because of learning their results ($n = 62$).
[b]Participants completed the post-interview 3 or more weeks after report-back. Data from the post-interview are open-ended responses from participants who said that they added or removed items from the home because of concern about the chemicals that were in them ($n = 34$).

Our survey methods were vulnerable to systematic biases that limited interpretation of these data. Among those assigned to the structured survey, 59% ($n = 135/227$) had complete data after applying exclusion criteria to collected data, and our results may not be representative of nonparticipants. As we previously reported,[16] participants in the MyCHDSReport Study did not differ in education level from those we were unable to recruit, but, among the available pool, Black women were somewhat less likely to participate than non-Black women. We made efforts to minimize common sources of self-report bias, but these factors likely had some influence on our results. Because earlier questions in the survey may influence responses to questions asked later, we randomized question order within key survey sections, but we cannot rule out bias due to the order of the sections. To mitigate affirmation bias, the tendency to answer questions affirmatively, we aimed to balance the number of "true" and "false" knowledge statements, and our final data analysis included 11 true statements and 9 false. Answers may also be influenced by social desirability biases. For example, participants may have overstated behaviors or opinions that they regard as socially desirable to their peers or the research team. Further, as they learned more about environmental health from their reports, their views on social desirability may have changed, influencing answers on the post-interview. However, we did not see evidence of this bias in our results, given that some recommended behaviors changed at the post-interview, but others, including cleaning behaviors that might be considered socially desirable, did not.

This study is one of the first quantitative assessments of what people know about EDCs, providing important baseline information about EDC-EHL. Participants initially knew more than we expected, with many questions having high correct rates at baseline. These results add confidence that study participants have important foundational information for understanding their personal results. However, high baseline knowledge for the questions we asked also represents a limitation for some of our research questions. Because our instrument was not well-calibrated to the EDC-EHL of our population, there was little room for scores to increase, limiting our ability to evaluate the potential for report-back to increase knowledge. Another limitation was that the survey instrument did not have perfect correspondence with the content in the report. Future studies will be able to build from this study's findings to construct better measurements. Being biomonitored alone (without report-back) could heighten awareness of chemical contaminants, but we think this effect is unlikely to be substantial in our study, given that that sample was collected to address a range of research questions in the CHDS and the years-long gap between blood collection and report-back. However, the CHDS is a unique population of women participating in a long-term, multigenerational research study that includes environmental exposures and health, and study communications over the years may have influenced baseline knowledge. Strengths of this population are that about half of the participants identify as Black and only about half of participants held a bachelor's degree. However, to learn about EDC-EHL in other contexts, we plan to extend this research to populations who have additional diversity in age, race, gender, and geography.

Supporting EHL about endocrine-disrupting compounds poses challenges because these chemicals have diverse sources, and exposures cannot be directly linked to individual health effects, which sometimes have long latencies. Yet public understanding is vital to enable people to make decisions about their own exposures and participate in policy decisions. This study of knowledge, concerns, and behaviors before and after participants received reports about 42 EDCs measured in the CHDS shows that participants generally understood exposure pathways and health effects, providing a good foundation for additional communications about EDCs. Report-back significantly increased awareness of consumer product chemicals as a possible health concern. Although report-back increased awareness of regulatory gaps, most people still did not know about lack of safety testing after receiving their reports, making this topic an important area for EHL messaging. Although participants took certain actions to lower their exposure to chemicals measured in the study, much additional work remains to learn how report-back can support the adoption of healthy behaviors. As more investigators seek to return individual biomonitoring results for EDCs, this study adds to the evidence that participants can understand and benefit from these reports.

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