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Evaluating Neighborhood-Level Differences in Hair Product Safety by Environmental Working Group Ratings among Retailers in Boston, Massachusetts

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Background: Personal care products are a notable source of exposure to endocrine-disrupting chemicals (EDCs). Racial/ethnic differences in the use of hair products containing EDCs are reported, with women and children of color more commonly using hair products that are hormonally active and contain EDCs than other racial/ethnic groups. There is limited research examining the neighborhood-level social and economic factors that may contribute to these reported disparities.

Objectives: We aimed to examine the safety of hair products across sociodemographically diverse neighborhoods in Boston, Massachusetts.

Methods: Eight neighborhoods were identified based on indicators of race/ethnicity and socioeconomic status (SES). We randomly selected 50 stores and collected data on the hair products for sale and their corresponding Environmental Working Group (EWG) Skin Deep hazard score. The association between neighborhood and EWG hazard category (low, moderate, high) was examined using a multinomial logistic regression.

Results: A total of 14,019 hair products were identified in the eight neighborhoods. When considering products with EWG hazard scores, Roxbury, a lower income community of color, and Mission Hill, a lower income community, were reported to have a higher percentage of high-hazard hair products in comparison with Beacon Hill [12.2% (163/1,332), 11.4% (65/571) vs. 7.9% (30/382), respectively]. Differences between the safety of hair products were observed, with Roxbury and Mission Hill reporting more than a 2-fold higher risk ratio (RR) of finding hair products with high vs. low EWG scores in comparison with that of Beacon Hill [RR for Roxbury: 2.3, 95% confidence interval (CI): 1.1, 4.6; RR for Mission Hill: 2.3, 95% CI: 1.0, 5.4]. Other neighborhoods were also observed to have an increased RR in comparison with Beacon Hill, however, with 95% CIs that extended beyond the null.

Discussion: Retail stores in neighborhoods with a higher percentage of residents of color and lower SES were found to be more likely to sell products with high hazard scores than stores in a higher SES and predominately non-Hispanic White neighborhood. https://doi.org/10.1289/EHP10653

Introduction

Personal care products (PCPs) are a notable source of chemical exposure.[1–3] Beauty products can contain a variety of endocrine-disrupting chemicals (EDCs), including phthalates and parabens.[1,3–5] Consequently, the use of PCPs may increase exposure to EDCs.[6,7]

PCP use is typically viewed as an individual-level behavior, and as a result, product use or availability of products is not often considered to be a potential contributor to community-level exposures. However, PCP use is driven by sociocontextual variables, including culture and beauty standards.[2,6,8] Although factors relating to neighborhood-level drivers of PCP use are less explored, research has identified differences in product use based on sociodemographic characteristics. Racial/ethnic disparities in exposure to PCP-associated EDCs are reported.[7,9–12] Specifically, hair product use patterns vary by race/ethnicity.[6,7,13] For instance, non-Hispanic Black women are more likely to use certain hair products (hair oil, hair lotion, leave-in conditioner, perm/relaxer, and pomade),[6,14–16] and less likely to use others (shampoo, conditioner)[17,18] in comparison with other racial/ethnic groups. In addition, the use of hair products containing hormones and EDCs is more common among women and children of color.[6,19,20] There is limited literature examining how hair product use may vary by socioeconomic status (SES).[21] More broadly, the findings on PCP use by SES are mixed, with some studies reporting greater product use among higher SES participants, and others finding greater product use among lower SES participants.[7,22,23]

Identifying the factors that may impact safer product availability and whether the safety of products differs by community composition is an important environmental justice (EJ) issue. Such differences in availability and subsequent exposure may contribute to well-documented disparities in women and children's health outcomes.[6,20,24,25] Yet, no study to our knowledge has considered the association between neighborhood-level social and economic factors with the safety of hair products. Through this study, we examined whether the safety of hair products was associated with socio-demographically diverse neighborhoods in Boston, Massachusetts. Because product use is a modifiable risk factor, determining differences in hair product safety by neighborhood may present opportunities for intervention to reduce disparities in environmental chemical exposures and related health outcomes.

Methods

Study Area: Neighborhood Selection

The study area included the following neighborhoods in the city of Boston, as designated by the City of Boston's Office of Neighborhood Services: Beacon Hill, Chinatown, Dorchester, Downtown, East Boston, Mattapan, Mission Hill, and Roxbury. These eight neighborhoods were selected out of the 24 neighborhoods in Boston based on racial/ethnic composition and percentage below the poverty line reported in the 2010 United States (U.S.) Census and American Community Survey 2014–2018 5-y estimates at the ZIP code level (Table 1; Table S1). Although we selected neighborhoods based on ZIP code–level data, we switched to census block group-level data for our

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results and interpretation (the smallest administrative unit with available socioeconomic data) to reflect the sociodemographic composition of the neighborhoods more accurately. We selected four neighborhoods that had the highest percentage of non-Hispanic White residents, non-Hispanic Black residents, Hispanic residents, and Asian residents (the largest racial/ethnic groups in the city of Boston), respectively. We also selected two neighborhoods with the highest and lowest percentage below the poverty line, respectively, as a proxy for higher and lower SES. In addition, two neighborhoods were selected based on their diversity, meaning that they did not have the highest percentage of residents of any racial/ethnic group or the highest/lowest percentage below the poverty line. The selection criteria for the eight neighborhoods are outlined in Table 1 and Figure 1. Data on neighborhoods not selected can be found in Table S1.

Store Identification and Selection

Figure S1 presents a flowchart of the store identification, selection/visitation, and hair product data collection process. Within the selected neighborhoods, hair product retailers were identified using North American Industry Classification System (NAICS) codes from ArcGIS Business Analyst.[26] NAICS codes were selected based on empirical data from U.S. market research identifying national retailers, such as CVS (pharmacies), Target (department stores), and Kroger (grocery stores), as the most common category of stores where consumers in the United States shop for personal care products and cosmetics.[27,28] Furthermore, we included beauty supply stores, which culturally serve as major retailers for consumers of color, notably non-Hispanic Black consumers, for purchasing personal care products, per market research.[29] The codes that identified department stores (NAICS code: 45221001), pharmacies (44611009), grocery stores (44511003), and beauty supply stores (44612004) were included. After identifying 198 stores in the 8 neighborhoods, an initial search was conducted to investigate whether the stores were open and located at the provided addresses, because NAICS codes are updated every 5 y. Stores were excluded if they were considered unlikely to sell hair products (e.g., seafood market, butcher, deli). After these exclusions, 109 stores remained and were included in our target population prior to stratified random selection.

Four stores of each type were randomly selected from each of the eight neighborhoods using a random number generator. A maximum of 16 stores could be randomly selected from each neighborhood. We chose to use stratified random sampling to capture the variation of products sold in stores visited by diverse populations—as an example, although there are fewer beauty supply stores in comparison with pharmacies in Boston, these stores are important in terms of the purchasing behaviors of consumers of color.[29,30] In neighborhoods where there were fewer than four stores, all stores of that type were included in our analysis (e.g., if a neighborhood had two grocery stores, both were included in the analysis). In addition, if there were more than one of the same store (at different locations) in a neighborhood (i.e., a chain or store with multiple branches), a separate random selection was conducted to ensure that only one of each duplicate store was included in the analysis. In total, 52 stores were identified and selected to be visited for data collection. The final data set consisted of hair products found in a selection of stores that represent the majority of store types used for purchasing personal care products and accounts for potential heterogeneity in purchasing behaviors by race/ethnicity, where non-Hispanic Black individuals more commonly visit beauty supply stores.[29,30]

Table 1. The neighborhood and residential characteristics of selected neighborhoods in the study area of Boston, Massachusetts ($n = 8$).

	1: Beacon Hill[a]	2: Chinatown	3: Dorchester	4: Downtown	5: East Boston	6: Mattapan	7: Mission Hill	8: Roxbury	Boston (all)
Total population	9,023	3,695	114,249	12,297	39,781	22,494	15,378	50,795	616,113
Area (square miles)	0.28	0.06	7.28	0.70	4.44	2.08	0.49	3.50	45.8
Population density[b]	31,943.4	57,967.3	15,688.0	17,555.6	8,953.0	10,792.2	31,068.5	14,504.5	13,448.4
% Below poverty line	7.6	32.1	22.8	18.6	19.3	20.2	41.3	34.2	20.1
% High school/GED and below	4.9	53.3	49.3	22.2	59.5	50.6	32.8	51.7	33.6
% Some college	3.5	4.2	17.3	7.7	10.9	22.7	17.7	18.1	13.1
% College degree[c]	46.6	22.7	23.9	31.7	20.3	18.6	27.5	20.6	31.1
% Graduate degree[d]	44.9	19.7	9.5	38.5	9.3	8.1	22.1	9.6	22.1
% White[e]	86.8	18.5	22.2	69.8	37.4	6.4	46.9	11.7	47.0
% Black	2.0	3.1	43.0	4.8	3.1	76.4	15.4	51.3	22.4
% Asian	5.3	73.3	9.3	18.0	3.5	1.7	15.1	2.6	8.9
% Hispanic	4.1	3.2	17.0	5.2	52.7	12.1	19.9	27.8	17.4
Selection criteria	High % White and lower % below poverty	High % Asian	Mixed race/ethnicity and higher % below poverty	Lower % below the poverty	High % Hispanic	High % Black	Higher % below the poverty	Mixed race/ethnicity and higher % below poverty	—

Note: The neighborhoods were selected based on ZIP code–level data. The count and percentages presented are based on the approximate boundaries of each neighborhood based on census block group—the smallest spatial unit with socioeconomic data from the American Community Survey (2014–2018) 5-y estimates. Total population, neighborhood size (area in square miles), population density, percentage below the poverty line, percentage of educational attainment, percentage of each racial/ethnic group, and study selection criteria for the eight neighborhoods and overall in Boston. —, no data; GED, general equivalency diploma.
[a]Each neighborhood was assigned a number from 1 to 8.
[b]Total population/area (square miles).
[c]Associate's and/or bachelor's degree.
[d]Master's, professional school, and/or doctoral degree.
[e]Racial/ethnic categories based on the 2010 Census.

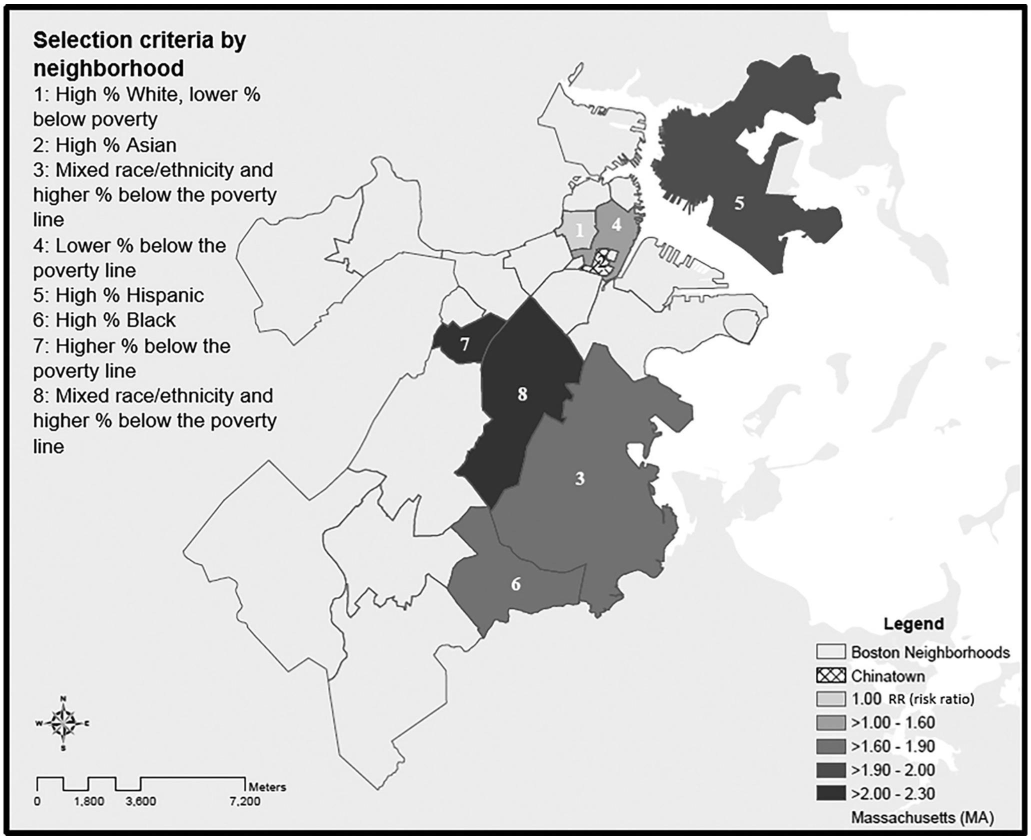

Figure 1. A map of the study area in Boston, Massachusetts, presenting RRs of hair products with high EWG hazard scores (7–10) vs. hair products with low EWG hazard scores (0–2), comparing each neighborhood to Beacon Hill estimated by multinomial logistic regression. (A complete case analysis was used; $n = 8{,}478$). These results visually present the RRs of finding hair products with high EWG hazard scores vs. low EWG hazard scores that are outlined in Table 3. Neighborhood 1 = Beacon Hill, 2 = Chinatown (excluded from the analysis because of the large number of missing EWG scores), 3 = Dorchester, 4 = Downtown, 5 = East Boston, 6 = Mattapan, 7 = Mission Hill, 8 = Roxbury. The neighborhood selection criteria are listed. This map was created using ESRI ArcMap (version 10.8.2). RR, risk ratio; EWG, Environmental Working Group.

Cataloguing Hair Products

From 31 January to 12 March 2021, 50 out of the 52 stores were visited, and their hair products were photographed (two beauty supply stores in Dorchester were not visited because of COVID-19–related challenges). We visited each store once and did not validate the product's availability over time. Once the hair products were photographed, the product's information (brand, name, and price), as well as the store's information (name, neighborhood, and date of data collection) were entered into our database. As the hair products were entered, they were categorized based on product type (e.g., shampoo, hair oils, leave-in conditioner; see Table S2 for the full list of product types), which has been done in previous research.[6] Prior to the analysis, the hair products were recategorized into leave-in products, rinse-off products, and hair products marketed to children/kids (e.g., children's leave-in conditioner, shampoo, conditioner, and hair relaxers). Leave-in products may result in a higher absorbed dose of EDCs because of the extended time the product is on the skin and scalp.[5,31] All products marketed to women and children were entered into the database (these were identified based on the product labels and branding—for example, Mixed Texture HairCare Curly Gel from CurlyKids was categorized as "hair products marketed to children/kids"). Hair products marketed to women and children were included based on previous exposure assessment research identifying the presence of EDCs and the hormonal activity of commonly used hair products.[1,6]

We excluded hair dyes/temporary hair color, kits of multiple hair products, essential oils, hair supplements, lice products, and travel- or sample-sized products. Products marketed for men were identified and excluded based on the product labels and branding (e.g., "for Men," " Men + Care," "Men"). Hair dyes/temporary hair color were excluded based on previous research using a validated questionnaire that classified "colored cosmetics" as a category that included other product types such as blush and eye shadow.[32] Furthermore, this group of products may not have the same sociohistorical context—where certain product types (such as hair products—notably hair relaxers—and skin-bleaching products, as well as vaginal douching or care products) are more commonly used by communities of color based on societal drivers, including racism and colorism.[2] We excluded kits of multiple products based on the knowledge that we could not identify the hazard scores of a kit and generally products included in kits are sold separately. In addition, travel-sized or sample-sized products were excluded because these products would be captured by the inclusion of full-sized products. Essential oils were excluded based on the knowledge that these products are typically used in do-it-yourself (DIY) products (including eye, skin, or hair care, cleaning products, and aromatherapy) and thus are not strictly used in hair products.[33,34] Furthermore, in DIY products, essential oils are generally added as one ingredient and at different concentrations than in store-bought products. Hair supplements were excluded based on the knowledge that beauty supplements that do not contain active ingredients are regulated as food and not classified as cosmetics (the category that includes personal care products) by the U.S. Food and Drug Administration (U.S. FDA), despite being located in the personal care products section of stores.[35,36] Similarly, some lice products are regulated by the U.S. FDA as over-the-counter drugs and are not classified as cosmetics/personal care products.[37,38] Last, products marketed to men were excluded for a few reasons. First, in the United States, individuals identifying as women are reported to use more personal care products and be more highly exposed to personal care product chemicals in comparison with individuals identifying as men.[12,39,40] Research has also examined the association between exposure to personal care products and personal care product–associated chemicals with a variety of women and children's health outcomes across the life course.[15,24,41,42] However, there is limited research into personal care product use patterns and their associated chemical exposure among individuals identifying as men.[43] Thus, this is an important area for future research, and additional studies are needed first to fully characterize potential disparities in exposure and associated health outcomes experienced by men.

Environmental Working Group (EWG) Hazard Score

Finally, the product's hazard score was identified using the EWG Skin Deep Cosmetics Database (https://www.ewg.org/skindeep/). The Skin Deep database is an online consumer tool that allows individuals to assess the safety of their products through a hazard score. To date, there are >80,000 products from almost 2,500 brands listed. The product hazard scores are developed by *a*) categorizing (based on 17 hazard categories: cancer, reproductive/developmental toxicity, neurotoxicity, endocrine disruption potential, allergies/immunotoxicity, restrictions/warnings, organ system toxicity, persistence/bioaccumulation, multiple/additive exposure, mutations, cellular/biochemical changes, ecotoxicity, occupational hazards, irritation, absorption, impurities, and miscellaneous) and scoring available data/studies based on the weight of evidence; *b*) calculating ingredient scores by taking the weight of each category score and the sum of the weighted factors (based on the relative importance of the category to health); *c*) calculating the product scores by adding the highest scoring ingredient to the average score for the other ingredients and taking the weighted sum of the category scores; and *d*) scaling the hazard scores from 1 to 10 (top 5% hazardous products and ingredients are assigned a 10). More information on the development of the hazard ratings is reported elsewhere.[44] The final hazard score is categorized from low hazard to high hazard, respectively. In addition, EWG has its own score, called EWG Verified, positioned below a score of 1, which is given to products that are free of chemicals on EWG's Unacceptable List (chemicals linked to adverse health outcomes, ecotoxicity, and contamination concerns), provides full ingredient transparency, and follows good manufacturing practices.[45] We replaced the EWG Verified score with a score of 0 to complete the numeric hazard scale and included it in the low hazard category. Thus, we used the following scoring based on EWG's categorization and our inclusion of the EWG Verified score: low (0–2), moderate (3–6), and high hazard (7–10). The inclusion of ingredients such as parabens (ingredient hazard score of 9) and fragrance (ingredient hazard score of 8) (which may contain phthalates) may contribute to a high overall product hazard score. The absence of these same ingredients may also contribute to a low overall or EWG Verified product score. Hazard scores were entered for the corresponding products. Products not found using the Skin Deep database were assigned a missing value. We evaluated the total number of products with unavailable hazard score information across neighborhoods. In addition, these products were excluded from other analyses.

Statistical Analyses

We assessed the total count of hair products, store types, and hair product types in each of the eight neighborhoods. The percentage of products with a hazard score greater than or equal to 7 (high hazard) was calculated for each neighborhood. We examined whether there was a statistically significant difference between the hazard categories in each neighborhood in comparison with that in Beacon Hill—the reference neighborhood with a high percentage of non-Hispanic White residents and the lowest percentage of individuals living below the poverty line—using Pearson's chi-squared tests. The median price of hair products, mean price by product type, and the percentage of products with missing EWG scores and prices were calculated for each neighborhood.

For our primary analysis, we examined the association between neighborhood (categorical) and EWG hazard categories (low, moderate, high) using a multinomial logistic regression. Beacon Hill, which has a high percentage of non-Hispanic White residents and higher SES, was the reference neighborhood. Beacon Hill was selected as the reference neighborhood based on the residents' racial/ethnic composition and SES, which were identified as important characteristics when considering the availability and accessibility of safer products in neighborhoods. Furthermore, to begin to explore whether there were differences in the hazard scores of hair products available in the same store in different neighborhoods, as a secondary analysis, we examined the association between neighborhood and EWG hazard category in a pharmacy chain with branches nationwide that was present in six neighborhoods (the pharmacy was not located in Mission Hill and Chinatown). In addition, we examined the associations between neighborhood and EWG hazard category by product type (leave-in and rinse-off products) using stratified multinomial logistic regressions. Children's products were excluded from this secondary analysis because of the small sample size.

Finally, to investigate presumptions that higher-priced products were safer and more commonly found in higher-SES communities, we examined the associations between equal quintiles of product price and EWG hazard category, as well as neighborhood and equal quintiles of product price using multinomial logistic regressions. Price quintiles were developed by equally dividing the hair product data with price into five categories that represented 20% of the total sample size across the distribution of price (first quintile, $n = 2{,}116$: USD \$0.49–\$5.29; second quintile, $n = 2{,}116$: \$5.29–\$6.99; third quintile, $n = 2{,}116$: \$6.99–8.99; fourth quintile, $n = 2{,}116$: \$8.99–\$11.99; fifth quintile, $n = 2{,}115$: \$11.99–\$73.99). In addition, we stratified the analysis examining the association between neighborhood and quintiles of product price by product type. We used a complete case analysis approach (i.e., we excluded products with missing EWG scores) for all models. The statistical analyses were conducted using R (version 4.1.1; R Development Core Team), and mapping was completed using ESRI ArcMap (version 10.8.2).

Results

Neighborhood Characteristics

The eight neighborhoods had a range of sociodemographic and geographic characteristics (Table 1). Beacon Hill, Chinatown, Downtown, and Mission Hill were all less than 1 sq mi in size and had the fewest stores. Comparatively, Dorchester, East Boston, Mattapan, and Roxbury were between 2 and 8 sq mi in size and had more stores. In terms of racial/ethnic composition, residents of Beacon Hill, Downtown, and Mission Hill were predominately non-Hispanic White; residents of Dorchester, Mattapan, and Roxbury were predominately non-Hispanic Black. Residents of Chinatown were predominantly Asian, and residents of East Boston were predominantly of Hispanic ethnicity. In terms of SES, Beacon Hill and Downtown were higher-SES neighborhoods (lower percentage below the poverty line of 7.6% and 18.6%, respectively), whereas Mission Hill and Chinatown were lower-SES neighborhoods (higher percentage below the poverty line of 41.3% and 32.1%, respectively).

Store and Hair Product Characteristics

Table S2 presents information on the store and hair product characteristics across the eight neighborhoods in our study area. A total of 14,019 hair products were found in the eight neighborhoods—and 46 of the 50 randomly selected stores sold hair products marketed to women and children (three grocery stores in Dorchester and one department store in East Boston did not have hair products for sale that were marketed to women and children). Certain store types were not located in Beacon Hill, Chinatown, and Mission Hill, three smaller neighborhoods (Table S2). Dorchester had the highest total count of hair products ($n = 3{,}958$ products), and Chinatown had the lowest ($n = 159$). The most common product type found across neighborhoods was shampoo, followed by conditioners. The availability of product types differed across neighborhoods (Table S2); for example, around $\sim 22\%$ of hair products in Beacon Hill ($n = 108$) and Downtown ($n = 451$) were hair spray/mousse vs. only 14%–15% in Roxbury ($n = 417$) and Mattapan ($n = 303$). Hair gels were $\sim 7\%$ of hair products in Roxbury ($n = 223$) and Mattapan ($n = 146$), whereas hair gels were only $\sim 3\%$–4% in Beacon Hill ($n = 14$) and Downtown ($n = 71$) and 0.6% in Chinatown ($n = 1$). Furthermore, $\sim 4\%$–5% of hair products in Roxbury ($n = 134$) and Mattapan ($n = 79$) were hair relaxers, whereas no relaxers were found in Beacon Hill and Chinatown.

Across neighborhoods, the highest mean EWG score was in Chinatown (5.9), and the lowest was in Dorchester, Downtown, East Boston, Mattapan, and Roxbury (5). In addition, 12.2% and 11.4% of hair products available in Roxbury ($n = 163$) and Mission Hill ($n = 65$) had hazard scores ≥ 7 (indicating high hazard) in comparison with 7.9% in Beacon Hill ($n = 30$). Of the hair products found in Chinatown, EWG scores were found for only 9 out of the 159 products cataloged; of these, 33.3% ($n = 3$) had hazard scores ≥ 7. Pearson's chi-square test presented a significant difference between the hazard categories of hair products found in Roxbury in comparison with Beacon Hill at the 0.05 significance level ($p = 0.03$) (Table 2). Across neighborhoods, there were low counts of low-hazard hair products. In the moderate hazard category, a higher percentage of products were rinse-off vs. leave-in, whereas the opposite was observed in the high-hazard category in which a higher percentage of products were leave-in vs. rinse-off (Table 2). The highest median price of a hair product was found in Chinatown ($18.5), and the lowest median price was in Mattapan ($7.5) (Table S2); 23.5% of the price data were missing or illegible on the price tags/stickers ($n = 3{,}290$). Roxbury had the highest percentage of missing price data (51%; $n = 1{,}679$) because of the large number of products cataloged at beauty supply stores where price tag stickers were not legible, and Mission Hill had the lowest (0%).

Products found in certain neighborhoods were notably absent and, in total, 5,532 products did not have EWG scores. Of these products, 47.9% were categorized as rinse-out ($n = 2{,}649$), 49% were categorized as leave-in ($n = 2{,}708$), and 3.2% were categorized as products marketed to children/kids ($n = 175$). In Chinatown, 94.3% of the products entered did not have a corresponding score ($n = 150$). Mattapan ($n = 854$), Roxbury ($n = 1{,}603$), Dorchester ($n = 1{,}388$), and East Boston ($n = 575$) (neighborhoods consisting predominately of residents of color) had between 35% and 55% missing EWG scores. Alternatively, in Beacon Hill ($n = 121$), Mission Hill ($n = 191$), and Downtown ($n = 650$)—three predominately non-Hispanic White neighborhoods with different SESs—between 24% and 31% of EWG scores were not found. Because of the high percentage of missing data in Chinatown, we excluded Chinatown from the primary and secondary analyses.

Table 3 and Figure 1 present the risk ratios (RRs) of finding hair products with moderate or high EWG hazard scores vs. hair products with low EWG hazard scores in the stores selected and visited and with available information on hazard scores, comparing each neighborhood to Beacon Hill, the reference neighborhood ($n = 8{,}478$ total products). In Roxbury, the risk of finding hair products with high EWG hazard scores vs. low EWG hazard scores was over 2-fold higher in comparison with Beacon Hill (RR = 2.3; 95% CI:1.1, 4.6). In general, the risk of finding hair products with moderate or high EWG scores vs. low EWG scores was higher in all neighborhoods in comparison with Beacon Hill [for high hazard: neighborhoods included Mission Hill (RR = 2.3; 95% CI: 1.0, 5.4), Dorchester (RR = 1.9; 95% CI: 1.0, 3.6), East Boston (RR = 2.0; 95% CI: 0.9, 4.2), and Mattapan (RR = 1.9; 95% CI: 0.9, 3.9)]. However, other than Roxbury, all other neighborhoods reported 95% CIs that included the null.

Table 2. Count and percent [n (%)] of hair products grouped by EWG hazard categories (low, moderate, and high) and product type (rinse-out, leave-in, children's/kids') across the neighborhoods included in the analyses ($n = 7$).

EWG hazard grouping	1: Beacon Hill[a]	3: Dorchester	4: Downtown	5: East Boston	6: Mattapan	7: Mission Hill	8: Roxbury
Low: rinse-out	9 (60)[b]	40 (55.6)	26 (63.4)	9 (32.1)	17 (53.1)	3 (21.4)	16 (44.4)
Low: leave-in	6 (40)	31 (43.1)	1 (34.1)	18 (64.3)	15 (46.9)	10 (71.4)	19 (52.8)
Low: children's	0	1 (1.4)	1 (2.4)	1 (3.6)	0	1 (7.1)	1 (2.8)
Low: total	15 (3.9)[c]	72 (2.8)	41 (2.9)	28 (2.6)	32 (2.8)	14 (2.5)	36 (2.7)
Moderate: rinse-out	246 (73)	1,313 (58.9)	784 (64.2)	587 (62.6)	585 (58.4)	306 (62.2)	578 (51)
Moderate: leave-in	91 (27)	872 (39.1)	434 (35.5)	344 (36.7)	392 (39.1)	181 (36.8)	517 (45.6)
Moderate: children's	0	45 (2)	3 (0.2)	7 (0.7)	25 (2.5)	5 (1)	38 (3.4)
Moderate: total	337 (88.2)	2,230 (86.8)	1,221 (87.8)	938 (87.1)	1,002 (86.8)	492 (86.2)	1,133 (85.1)
High: rinse-out	6 (20)	57 (21.3)	16 (12.4)	28 (25.2)	36 (29.8)	10 (15.4)	47 (28.8)
High: leave-in	24 (80)	204 (76.1)	112 (86.8)	83 (74.8)	82 (67.8)	53 (81.5)	112 (68.7)
High: children's	0	7 (2.6)	1 (0.8)	0	3 (2.5)	2 (3.1)	4 (2.5)
High: total	30 (7.9)	268 (10.4)	129 (9.3)	111 (10.3)	121 (10.5)	65 (11.4)	163 (12.2)
Total products with hazard scores	382	2,570	1,391	1,077	1,155	571	1,332
Products with missing EWG score	121	1,388	650	575	854	191	1,603
—	Ref	$p = 0.16$[d]	$p = 0.45$	$p = 0.18$	$p = 0.19$	$p = 0.10$	$p = 0.03$*

Note: Differences in the hazard scores in each neighborhood in comparison with those in Beacon Hill were examined through Pearson's chi-squared tests. EWG hazard categories: low [scores EWG verified (classified as 0) through 2], moderate (3–6), and high (7–10). Products with missing EWG scores were excluded. —, no data; EWG, Environmental Working Group; Ref, reference. *indicates statistically significant at the 0.05 level.

[a]Each neighborhood was assigned a number from 1 to 8; neighborhood 2 represents Chinatown. Chinatown was excluded because of the large amount of missing EWG score data ($n = 150$ missing).

[b]Percentage of product type refers to within each hazard category; for example: 60% of the 15 low-hazard products in Beacon Hill were rinse-out.

[c]Percentage of total refers to all hair products in the neighborhood; for example: 3.9% of the hair products in Beacon Hill were found to have a low hazard score.

[d]Pearson's chi-squared tests comparing the difference in hazard categories for hair products found in each neighborhood to Beacon Hill.

Table 3. RR and 95% CI of finding hair products with moderate and high EWG hazard scores vs. hair products with low EWG hazard scores comparing each neighborhood to Beacon Hill.

EWG hazard category	Neighborhood[a]	RR (95% CI)
Low[b]	—	Ref
Moderate	1: Beacon Hill[c] ($n=337$)	Ref
	3: Dorchester ($n=2{,}230$)	1.4 (0.8, 2.4)
	4: Downtown ($n=1{,}221$)	1.3 (0.7, 2.4)
	5: East Boston ($n=938$)	1.5 (0.8, 2.8)
	6: Mattapan ($n=1{,}002$)	1.4 (0.7, 2.6)
	7: Mission Hill ($n=492$)	1.6 (0.7, 3.3)
	8: Roxbury ($n=1{,}113$)	1.4 (0.8, 2.6)
High	1: Beacon Hill ($n=30$)	Ref
	3: Dorchester ($n=268$)	1.9 (1.0, 3.6)
	4: Downtown ($n=129$)	1.6 (0.8, 3.2)
	5: East Boston ($n=111$)	2.0 (0.9 4.2)
	6: Mattapan ($n=121$)	1.9 (0.9, 3.9)
	7: Mission Hill ($n=65$)	2.3 (1.0, 5.4)
	8: Roxbury ($n=163$)	2.3 (1.1, 4.6)

Note: RR with 95% CIs of finding hair products with moderate (3–6) and high (7–10) EWG hazard scores in comparison with hair products with a low (0–2) EWG hazard scores comparing each neighborhood to Beacon Hill, estimated by multinomial logistic regression. (A complete case analysis was used; $n=8{,}478$). The results presenting the RR of finding high-hazard hair products vs. low-hazard hair products comparing each neighborhood to Beacon Hill is visually presented in Figure 1. —, no data; CI, confidence interval; EWG, Environmental Working Group; Ref, reference; RR, risk ratio; SES, socioeconomic status.
[a]Each neighborhood was assigned a number from 1 to 8; neighborhood 2 represents Chinatown. Chinatown was excluded because of the large amount of missing EWG score data.
[b]The low hazard category (0–2) was the reference group.
[c]Beacon Hill, which is predominantly non-Hispanic White and higher SES, was the reference neighborhood.

Table S3 presents the RRs of finding hair products with moderate or high EWG hazard scores vs. hair products with low EWG hazard scores in the selected and visited branches of the pharmacy chain and with available information on hazard scores, comparing each neighborhood (except for Mission Hill and Chinatown) to Beacon Hill ($n=2{,}488$ total products). Downtown (RR = 1.8; 95% CI: 0.7, 5.0) and Mattapan (RR = 1.5; 95% CI: 0.5, 4.5) presented the largest RRs comparing high hazard to low hazard hair products; however, all estimates were imprecise, and the 95% CIs included the null. These results may indicate that store types, other than pharmacy chains, and their associated products could be important contributors to differences in hair product safety observed in the main analysis. When comparing the mean EWG score of all of the beauty supply stores in communities of color ($n=3$ stores; 765/2,307 hair products with EWG scores in Mattapan and Roxbury) to the beauty supply store in Beacon Hill ($n=1$; 6/34 products with EWG scores), the mean scores were 5.0 and 3.0, respectively. However, it is important to note the small sample size of hair products with EWG scores identified in the beauty supply store in Beacon Hill.

Tables S4–S7 present the results of the additional secondary analyses among stores selected and visited with available information on hazard scores and/or price. Secondary analyses evaluating the association between neighborhood and EWG hazard category stratified by product type ($n=4{,}719$) presented the highest risk of finding rinse-off products with high EWG hazard scores in East Boston (RR = 4.7; 95% CI: 1.3, 16.7) and Roxbury (RR = 4.4; 95% CI: 1.4, 14.3), in comparison with Beacon Hill (Table S4). Furthermore, Downtown (RR = 2.0; 95% CI: 0.7, 5.7), Dorchester (RR = 1.6; 95% CI: 0.6, 4.3), and Roxbury (RR = 1.5; 95% CI: 0.5, 4.1) had the largest RRs of finding leave-in products with high vs. low EWG hazard scores in comparison with Beacon Hill ($n=3{,}614$ total). The secondary analyses also revealed that products with higher quintiles of price had a lower risk of moderate and high EWG hazard scores in comparison with products with the lowest quintile of price ($n=7{,}181$) (Table S5). In addition, lower-SES neighborhoods (Dorchester, Mattapan, Mission Hill, and Roxbury) had a lower risk of finding higher-priced hair products ($n=10{,}579$) (Table S6). When stratifying by product type (rinse-off $n=5{,}699$ and leave-in $n=4{,}693$), Downtown and East Boston neighborhoods were observed to have a higher RR of finding higher-priced rinse-off and leave-in hair products (notably fourth quintile and fifth quintile vs. first quintile) in comparison with Beacon Hill (Table S7). Of note, the 95% CIs crossed the null for a number of the estimates from the secondary analyses.

Discussion

In this study, we observed differences in the safety of hair products in the stores visited between neighborhoods in Boston based on EWG hazard scores. Overall, Roxbury, a lower-SES community of color, was found to have a 2-fold greater risk of finding hair products with high vs. low EWG scores in comparison with those of Beacon Hill, a higher-SES and predominately non-Hispanic White community. Based on a number of imprecise estimates in the secondary analyses, potentially driven by smaller sample sizes, we cautiously interpret these findings. One secondary analysis observed that East Boston and Roxbury (two lower-SES communities of color) had the highest risk of finding rinse-off products with high hazard scores in comparison with low hazard scores. Furthermore, the analyses incorporating price presented evidence that lower-SES neighborhoods may have a higher chance of finding lower-priced products, whereas higher-priced products may have lower hazard scores.

This differential patterning in the safety of hair products observed in this study may be driven by the same policies and practices that contribute to the burden of place-based exposures in cumulatively burdened EJ communities.[46] Complex sociohistorical processes, including structural racism (historic residential redlining, restrictive covenants, and discriminatory zoning practices), have shaped and continue to shape which businesses, residents, and resources are in or not in certain neighborhoods.[47] One practice that shapes the retail landscape in low-income communities and communities of color is retailer redlining, which is the spatially discriminatory business practice of not serving certain communities or providing differential treatment or product quality based on the demographic composition of the customers or neighborhood.[48] This practice has been framed as both the absence of certain health-affirming businesses, oversaturation of businesses offering products that are more detrimental to health.[48,49] The differential patterning of businesses may impact product availability and ultimately health. For example, businesses such as fast-food restaurants, dollar stores, and liquor stores are more frequently located in lower-SES communities and communities of color, resulting in residents being limited to a retail environment that offers a greater proportion of unsafe or unhealthy products.[49–52] Stores that sell PCPs may follow similar patterns of burden, and hair products containing EDCs may be more commonly marketed to and found in lower income communities of color because of both structural and neighborhood/community-level drivers of product use (Figure 2).[1,6,17]

Prior research explored a similar framing of retailer redlining by examining the expansion of dollar stores (e.g., Dollar General, Dollar Tree, and Family Dollar) in relation to neighborhood demographic characteristics. Shannon presented evidence of an association between dollar store proximity and neighborhoods with a greater proportion of non-White residents after controlling for income, population, and retailer density.[49] In addition, Kwate et al. examined retailer redlining in the context of proximity to health-related stores in New York City, finding in one of their

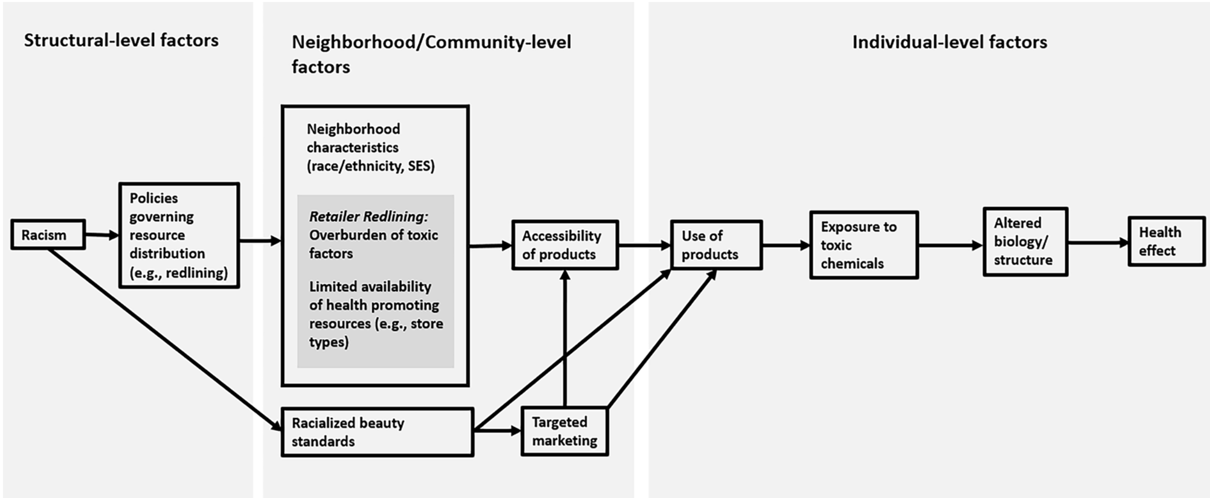

Figure 2. Conceptual diagram of the upstream drivers (structural and neighborhood/community level) of personal care product use and the downstream individual-level factors including exposure to toxic chemicals and health outcomes. "Neighborhood characteristics," "Accessibility of products," and "Exposure to toxic chemicals" are factors measured directly or indirectly through study design and statistical analysis in the present paper.

analyses that regardless of the high prevalence of pharmacies, residents in predominately Black areas had to travel farther to access them.[53] Our results presented a suggested greater risk of finding high-hazard hair products in the same pharmacy across almost all neighborhoods in the study area in comparison with Beacon Hill—however, the 95% CIs encompassed the null for all estimates.

Although these analyses were some of the few to consider the disproportionate burden or absence of retail stores in certain communities, differences in the chemical content of PCPs sold across neighborhoods remain unexplored. Furthermore, differences in access to hair products—a category of products that have documented differences in use by race/ethnicity[6,7]—have not been examined, specifically how the greater burden of unsafe hair products relates to neighborhood-level factors. In our exploratory analysis, the distribution of hair product types differed by neighborhood. A slightly greater proportion of hair spray/mousses were found in higher-SES and predominantly non-Hispanic White neighborhoods, in comparison with lower income neighborhoods of color. Hair relaxers and hair gels, which are more commonly used by non-Hispanic Black women and may contain EDCs,[1,14] were found to compose a greater proportion of hair products in lower-SES communities of color (except for Chinatown) in comparison with the higher-SES, non-Hispanic White neighborhoods. Hair product availability in different neighborhoods throughout Boston may be driven by market demand and/or targeted marketing practices.

Although the neighborhood-level social and economic dimensions of hair product accessibility have not been previously examined, racial/ethnic differences in exposure to hair product–associated EDCs are better documented. A study by Tiwary found that the majority of African-American participants used hair products containing hormones or placenta in comparison with few non-Hispanic White participants.[19] These findings were supported by James-Todd et al.[6] In addition, Helm et al. tested hair products marketed to and used by non-Hispanic Black women from the Greater New York Hair Product study[6] and found phthalates and parabens, along with cyclosiloxanes and diethanolamine (two suspected EDCs) in hair relaxers, antifrizz products, and leave-in conditioners.[1] The literature on hair product–associated chemical exposure among other racial/ethnic groups is limited. However, studies examining urinary phthalate metabolites and parabens—chemicals used to hold fragrance and as preservatives in PCPs—reported high concentrations among Hispanic, Puerto Rican, and "Other" race/ethnicity–identifying women.[9,12,39,54] Our study suggests that the availability of unsafe products may be an important contributor to these exposure disparities.

The limited literature examining the differences in PCP use by SES is heterogeneous. Studies in Canada and the United States reported that women with higher incomes/SES were more likely to have higher total product use.[7,22] In contrast, a recent study among pregnant people from the LIFECODES cohort in Boston found that women with lower SES reported higher total product use.[23] In addition, a study by Kobrosly et al. examined differences in PCP-associated phthalate metabolite concentrations by SES and reported that the lowest quartile of SES was associated with 1.83 times the concentration of monobenzyl phthalate among participants.[11] It is worth noting that phthalate and paraben content is connected to higher EWG scores because of their associations with adverse health outcomes.[55,56] The current study demonstrated a greater risk of finding more harmful products based on EWG scores in the lower-SES neighborhood of Roxbury in comparison with the higher SES neighborhood of Beacon Hill.

Although there are a variety of individual-level drivers of product use, exposure to PCP chemicals (specifically EDCs) may also be driven by a product's application type. The use of leave-in vs. rinse-off products may result in differing absorbed doses because of prolonged dermal contact. Hsieh et al. found that the more leave-in PCPs participants reported using, the higher the urinary concentrations of monoethyl phthalate.[31] In addition, Guo and Kannan reported that diethyl phthalate, dibutyl phthalate, and parabens (methyl-, ethyl-, propyl-) were more commonly found in leave-in products.[5] Our study's finding of a higher risk of high-hazard rinse-off products in East Boston and Roxbury suggests differences in the safety of hair products between neighborhoods based on application type.

This study has a number of limitations. First, we may have underestimated the complete range of products available if stores with NAICS codes other than the types considered in our study also sell PCPs. However, we visited 50 stores within these neighborhoods, which make up a significant share of the market for purchasing these products. Some store types were also not found in smaller neighborhoods. Furthermore, we did not include hair salons, based on our focus on market research identifying national retailers as the predominant locations where consumers shop for personal care products and cosmetics and beauty supply stores as important retailers for the Black community in the United States.[27–29] Another limitation is that there is unequal missingness across neighborhoods and, more broadly, missing data, which resulted in a complete case analysis approach. Specifically, there were a large number of products without EWG hazard scores in lower-income communities of color. Technically, bias could occur in either direction depending on whether those products missing EWG hazard scores are more likely to score as lower or higher in the communities of color and lower income communities in comparison with Beacon Hill. That said, there is evidence of racial/ethnic and socioeconomic disparities in exposure to personal care product–associated EDCs,[11,12,57,58] and previous studies have also shown that products marketed to people of color, particularly Black people, are more likely to contain harmful chemicals.[1,6] Future work is needed to better characterize products and reduce missingness as it relates to product hazards. The lack of data, particularly in Chinatown, raises important questions as to how diverse communities might have barriers not only to safer products but also to accessing consumer-facing information about products sold in their communities. Differences in the availability of information may impact the ability of consumers in communities of color to identify safer products, which could contribute to differences in higher exposure to EDCs. More information is needed to understand whether the availability and accessibility of this information could provide a modifiable way to reduce exposure disparities. In addition, we did not present information on which hair products were marketed to women of color; however, racialized geographies of targeted marketing have been documented in other contexts,[59] and product type may be a proxy for marketing because hair product use patterns by race/ethnicity are documented.[6,15,16] Next, we used the EWG Skin Deep database, which is not the only product safety database, and others exist that evaluate the risk score of products used by certain populations (e.g., CosDNA evaluates the ingredient risk score for a variety of products, notably those marketed to Asian populations[60]) However, as discussed, EWG incorporates 17 hazard categories in the creation of the hazard score that are key to understanding risk. The distribution of store types may also be driven by population density, urbanicity, land use, and other market variables. Because of the neighborhood-level data, we were unable to adjust for these covariates, and there was multicollinearity between these neighborhood-level covariates and the predictor neighborhoods. However, these factors are related to the distribution of store types in neighborhoods (and may be relevant for analyses examining all store locations and product counts) and are not hypothesized to be confounders or contribute greatly to our association of interest. In addition, although the direction of our parameter estimates supports our hypotheses, it would have been beneficial to collect more hair products across the neighborhoods to achieve adequate power for detecting the differences across the neighborhoods and increase the precision of our model estimates. Finally, although we captured which products are available through a stratified random sample of stores throughout the eight neighborhoods, this study did not aim to answer the questions of which PCPs community members in Boston use and where they shop; rather the focus was on product safety by neighborhood.

Despite these limitations, this study has a number of strengths. PCP use has generally been examined as a behavior. As a result, structural determinants such as policies and practices that have shaped and continue to shape neighborhoods have not been considered potential drivers of product availability or safety. Our study is the first to our knowledge to consider the disproportionate burden of unsafe hair products based on neighborhood sociodemographic characteristics. This study is unique because it examines differences in hair product availability, price, and safety among racially/ethnically and socioeconomically diverse neighborhoods. In addition, we included leave-in maintenance hair products, which are not commonly incorporated in PCP research but make up a significant proportion of hair products used by non-Hispanic Black women,[6,7] although our secondary results should be interpreted with caution because of the small sample sizes. Last, we cataloged more than 14,000 hair products in the city of Boston, which to our knowledge, is one of the largest data sets of products and product availability by neighborhood characteristics for future research. This study is one step toward better understanding how PCPs may fit into the cumulative EJ landscape of disparate exposures.[2,61,62]

Our study found that Roxbury, a lower-SES community of color, had the highest risk of finding hair products with high EWG hazard scores. These hazard scores indicate product safety based on ingredients, with many of these products containing EDCs that are associated with adverse health outcomes. Hair products are one source of EDCs that may contribute to the disproportionate burden of environmental chemical exposure in EJ communities. However, hair products and other PCPs are modifiable exposure sources. Further research is needed to examine the role of SES and the joint role of race/ethnicity and SES in safer product availability, accessibility, and use. Research should also further consider the potential differences in exposure to EDCs from leave-in and rinse-off products used by different communities. The role of price in product use among different communities should also be examined more extensively, because price may be a potential barrier to accessing safer products. Finally, research should further explore how product-based exposures may combine with placed-based factors to impact health disparities. If our results are replicated, future work should address the greater burden of unsafe hair products in lower-income communities of color through policies and interventions, including the equitable distribution of safe and affordable hair products across neighborhoods, supply chain and retailer education focused on product safety and the growing market for safer products among communities of color, and the elimination of targeted hair product marketing practices. Although this study was conducted in a stratified random selection of stores across Boston and there may be regional differences in product use patterns and product availability, any replication of our results in other regions may indicate that this issue extends beyond Boston. In the United States, there are persistent and increasing trends in disparities in exposure to PCP-associated EDCs.[57] We hypothesize that structural factors, including racism and historic policies[63] (e.g., historic redlining) that have guided resource distribution (e.g., placement of certain stores, products, and pricing), are potential upstream drivers of differences in product safety observed in our study and are not limited to Boston (Figure 2). Furthermore, exposure to less-safe products could contribute to disparities in exposure to EDCs and other chemicals of concern and associated health outcomes reported. Thus, there is also a need for updated national policies and regulations for ingredients in PCPs to ensure equitable access to safe products for all, regardless of place.

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