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Adana A. M. Llanos

Amber Rockson

Kylie Getz

Patricia Greenberg

Eva Portillo

See next page for additional authors

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Comments

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The authors

Authors

Adana A. M. Llanos, Amber Rockson, Kylie Getz, Patricia Greenberg, Eva Portillo, James A. McDonald, Dede K. Teteh, Justin Villasenor, Carolina Lozada, Jamirra Franklin, Vaishnavi More, Zorimar Rivera-Núñez, Carolyn W. Kinkade, and Emily S. Barrett



Assessment of personal care product use and perceptions of use in a sample of US adults affiliated with a university in the Northeast

Adana A.M. Llanos^{a,b,*}, Amber Rockson^a, Kylie Getz^c, Patricia Greenberg^c, Eva Portillo^d, Jasmine A. McDonald^{a,b}, Dede K. Teteh^e, Justin Villasenor^d, Carolina Lozada^f, Jamirra Franklin^g, Vaishnavi More^h, Zorimar Rivera-Núñez^{c,i}, Carolyn W. Kinkadeⁱ, Emily S. Barrett^{c,i}

^a Department of Epidemiology, Mailman School of Public Health, Columbia University Irving Medical Center, New York, NY, USA

^b Herbert Irving Comprehensive Cancer Center, Columbia University Irving Medical Center, New York, NY, USA

^c Department of Biostatistics & Epidemiology, Rutgers School of Public Health, Piscataway, NJ, USA

^d Biostatistics Epidemiology Summer Training (BEST) Diversity Program, Mailman School of Public Health, Columbia University Irving Medical Center, New York, NY, USA

^e Department of Health Sciences, Crean College of Health and Behavioral Sciences, Chapman University, Orange, CA, USA

^f Rutgers Cancer Institute of New Jersey, New Brunswick, NJ, USA

^g Environmental and Health Sciences Department, Spelman College, Atlanta, GA, USA

^h Department of Nursing and Health Sciences, The College of New Jersey, Ewing, NJ, USA

ⁱ Environmental and Occupational Health Sciences Institute, Rutgers University, Piscataway, NJ, USA

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ABSTRACT

Evidence supports unequal burdens of chemical exposures from personal care products (PCPs) among some groups, namely femme-identifying and racial and ethnic minorities. In this study, we implemented an online questionnaire to assess PCP purchasing and usage behaviors and perceptions of use among a sample of US adults recruited at a Northeastern university. We collected PCP use across seven product categories (hair, beauty, skincare, perfumes/colognes, feminine hygiene, oral care, other), and behaviors, attitudes, and perceptions of use and safety across sociodemographic factors to evaluate relationships between sociodemographic factors and the total number of products used within the prior 24–48 h using multivariable models. We also summarized participants' perceptions and attitudes. Among 591 adults (20.0% Asian American/Pacific Islander [AAPI], 5.9% Hispanic, 9.6% non-Hispanic Black [NHB], 54.6% non-Hispanic White [NHW], and 9.9% multiracial or other), the average number of PCPs used within the prior 24–48 h was 15.6 ± 7.7 . PCP use was greater among females than males (19.0 vs. 7.9, $P < 0.01$) and varied by race and ethnicity among females. Relative to NHWs, AAPI females used fewer hair products (2.5 vs. 3.1) and more feminine hygiene products (1.5 vs. 1.1), NHB females used more hair products (3.8 vs. 3.1), perfumes (1.0 vs. 0.6), oral care (2.3 vs. 1.9), and feminine hygiene products (1.8 vs. 1.1), and multiracial or other females used more oral care (2.2 vs. 1.9) and feminine hygiene products (1.5 vs. 1.1) (P -values < 0.05). Generally, study participants reported moderate concern about exposures and health effects from using PCPs, with few differences by gender, race, and ethnicity. These findings add to the extant literature on PCP use across sociodemographic characteristics. Improving the understanding of patterns of use for specific products and their chemical ingredients is critical for developing interventions to reduce these exposures, especially in vulnerable groups with an unequal burden of exposure.

1. Introduction

Use of certain personal care products (PCPs) has been linked with

adverse health outcomes among women including breast cancer (Eberle et al., 2020; Llanos et al., 2017; Rao et al., 2022), ovarian cancer (White et al., 2021a), uterine cancer (Chang et al., 2022), and reproductive

* Corresponding author. Department of Epidemiology, Mailman School of Public Health, Columbia University Irving Medical Center, 722 West 168th Street, New York, NY, 10032, USA.

E-mail address: al4248@cumc.columbia.edu (A.A.M. Llanos).

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outcomes including earlier pubertal onset, miscarriage, infertility, and uterine fibroids (James-Todd et al., 2016; Bariani et al., 2020; Collins et al., 2023; Gaston et al., 2020; Wright et al., 2021; Fruh et al., 2022). Emerging evidence also suggests that PCP use, namely hair dye, among men is associated with prostate cancer risk (Lim et al., 2022). Further, an unequal burden of exposure to environmental chemicals from PCPs has been documented for racial and ethnic minority groups relative to their non-Hispanic White (NHW) counterparts (White et al., 2021a; Collins et al., 2023; Branch et al., 2015; Chan et al., 2021; Chesney and Duderstadt, 2022; Zota and Shamasunder, 2017), though much of the prior work in this area has focused on femme-identifying individuals. Given the potential health implications of chemical exposures from PCPs, a growing number of studies have sought to better understand use of specific products, their chemical ingredients, and perceptions about PCP use, particularly among diverse populations. Of these, many studies have been small (e.g., <150 participants) and focused on very specific populations such as Latina adolescents (Berger et al., 2019; Harley et al., 2016), pregnant people (Lang et al., 2016), or predominantly White university students (Hart et al., 2020; Chan et al., 2015). Other studies have focused narrowly on specific types of products (e.g., hair products commonly used by Black women) (Gaston et al., 2020).

There is an increasing interest in surveying PCP use more broadly, including PCP-related behaviors and perceptions. Several recent projects have taken this approach, including two recent community-based studies in California that reported on PCP use by race and ethnicity with an emphasis on targeted enrollment of women from underrepresented racial and ethnic minority groups (Collins et al., 2023; Dodson et al., 2021). To date, few studies on this topic have included more general recruitment among inherently diverse populations and few studies have investigated PCP use among men (Lim et al., 2022; Nassan et al., 2017).

To begin addressing some of the current gaps in knowledge, we recruited a sample of adults at a large, public academic institution in New Jersey. We surveyed PCP purchasing and use behaviors including prevalence of PCP use (overall and by product type) and where products are typically purchased. To begin exploring the role of environmental health literacy in the context of PCP use (Finn and O'Fallon, 2017; Madrigal et al., 2016), we additionally examined perceptions and attitudes around PCP use among participants and explored variation by sociodemographic characteristics.

2. Methods

2.1. Participants and Setting

This study collected self-reported information on sociodemographic characteristics, PCP use, perceptions and attitudes about PCP use, and PCP purchasing behaviors in a sample of adults (age ≥ 18 years) at an academic institution in New Jersey (Rutgers University). Prospective study participants were contacted via email over a five-week period between September 13, 2019, and October 18, 2019 – using email blasts and listservs targeting students, staff, and faculty – and invited to participate in an online questionnaire about PCP use and perceptions. The initial email included an eligibility screener, with two questions – (1) *What is your age?* (Response options: *Younger than 18, 18 years old or older*); and (2) *Are you a student, staff member, or faculty member at Rutgers University?* (Response options: Yes, No) – to confirm eligibility for study participation (i.e., ≥ 18 years old and a member of the Rutgers University community). Ineligible individuals immediately received a thank you message and were informed they were not eligible to participate. Eligible individuals were informed of their eligibility and asked to provide their email address so they could be sent a personal link to complete the online questionnaire. The consent form and study questionnaire were programmed in Qualtrics (Provo, UT). After completing the electronic consent form, participants were instructed to proceed to the questionnaire – with instructions to first gather the PCPs they used in the

last 24–48 h so that they could be on hand during questionnaire completion. The online questionnaire took approximately 30–40 min to complete, and participants had the option of closing it and coming back to complete it later (until the survey closure date). Upon completion of the questionnaire, participants were invited to enter a drawing to win one of ten \$100 electronic Amazon gift cards. The study was reviewed and approved by the Rutgers University Institutional Review Board (Pro2019000563).

3. Data collection

The Personal Care Product (PCP) Use Questionnaire included a total of 65 questions in eleven sections and was designed to assess specific details about PCPs used in the past 24–48 h (including specific products and brand names) across seven categories: *hair products* (shampoos, conditioners, hair styling products, hair loss treatments); *beauty products* (makeup, nail products); *skin care products* (facial skin care products, body cleansing and bath products, skin moisturizing products, hair removal products, deodorants and antiperspirants, sunscreen and sunless tanning products); *perfumes and colognes*; *feminine hygiene products* (among participants self-identifying as female: sanitary pads, panty liners, tampons, feminine washes and wipes, douche); *oral care products* (toothpaste, mouthwash, dental floss, teeth whitening products); and “*other*” PCPs used (e.g., essential oils, hand sanitizer gels, eye drops, petroleum jelly) that were not captured in any of the previous categories and/or additional products that are used at least once per week that were not captured previously. In addition to hair products used in the last 24–48 h, the hair products section also assessed use of permanent hair dyes, semi-permanent hair dyes, chemical relaxers and straightening products, and deep conditioning products that contain cholesterol or placenta at ages <10, 10–14, 15–19, and ≥ 20 years to assess past hair product use.

The PCP Use Questionnaire queried participants' sociodemographic characteristics (e.g., age, race and ethnicity, gender identity, income, education, marital status), where they purchase their PCPs (major pharmacy, regular grocery store, natural food market, cosmetics specialty store, clothing and accessory store, department store, dollar store, online retailer, salon, or other), if they experienced allergic skin reactions or any health effects following the use of PCPs in the past 12 months (yes, no, don't know/don't remember), if they avoid using certain PCPs (yes, no, don't know/don't remember), and frequency of salon visits for professional hair and nail services (did not receive professional services in the past 12 months, less than once per month, 1–3 times per month, or more than 3 times per month).

The PCP Use Questionnaire was also designed to query participants' frequency of using healthy product apps or websites, reading PCP ingredients lists, and specifically looking for products labeled as natural, non-toxic, or eco-friendly (5-point Likert scale: 1, never; 2, rarely; 3, sometimes; 4, usually; and 5, always) when selecting products to use at home. Perceptions and attitudes about PCPs were assessed by asking a series of questions about participants' concern about health effects from ingredients in PCPs used in hair and nail salons (5-point Likert scale: 1, not at all concerned; 2, slightly concerned; 3, somewhat concerned; 4, moderately concerned; and 5, extremely concerned) and level of agreement (5-point Likert scale: 1, strongly disagree; 2, disagree; 3, neither disagree nor agree; 4, agree; and 5, strongly agree) with the following statements: (1) “*The personal care products I use affect my health.*” (2) “*Organic, natural, non-toxic or eco-friendly personal care products have fewer toxic chemicals than regular products.*” (3) “*Consumers should be concerned about the health effects of personal care products.*” (4) “*There is no reason to worry about the health effects from chemicals that might be in personal care products.*” (5) “*Overall, the benefits of using personal care products outweigh any risks from exposure to toxic chemicals that might be in these products.*” (6) “*Organic, natural, non-toxic or eco-friendly personal care products are just as effective as regular products.*” (7) “*The Food and Drug Administration (FDA) and other government agencies do a*

good job of regulating personal care products to ensure they are safe for consumers.”

A total of 656 individuals completed the PCP Use Questionnaire. Among them, 9 (1.4%) did not self-identify as female or male (1 identified as gender non-binary and 8 refused to answer the question) and were excluded from the remaining analysis due to insufficient sample size. Of the 647 remaining participants, 591 participants had complete PCP use data available for analysis and comprised the analytic dataset. For the excluded 56 study participants, we were unable to tally the number of PCPs used in the prior 24–48 h due to incomplete responses to the product use questions. Here, we focused on evaluating relationships between sociodemographic factors and the total number of products used within the prior 24–48 h and summarizing perceptions and attitudes about PCP use in our study sample. While the larger study collected data on specific products (i.e., brand and product names), the current work does not include analysis related to specific products or product chemicals as this is the subject of future work.

3.1. Data analysis

Participant characteristics, product choices, purchasing behaviors, perceptions, and attitudes related to personal care products were summarized and differences between gender, race and ethnicity categories were examined. All categorical measures were first summarized using frequencies and percentages, while continuous measures were summarized using means and standard deviations. The level of concern about health effects is represented as an average score (ranging from 1 to 5), which we categorized/interpreted as low concern (1–2), moderate concern (3–4), and high concern (5). The level of agreement with perceptions statements is represented as an average score (ranging from 1 to 5), which we categorized/interpreted as low agreement (1–2), moderate agreement (3), and high agreement (4–5). We tallied the total number of products reported within each product category (hair, beauty, skin, perfume and cologne, feminine hygiene, oral care, other) as well as across all categories. Product usage, overall and by product category, were compared by gender (using Student's t-tests) and by race and ethnicity among females only (using Kruskal-Wallis tests). Among females, if a Kruskal-Wallis test resulted in a P-value <0.05, then Dunn tests were used post-hoc to identify pairwise differences – comparing racial and ethnic minority groups to NHW females – with Bonferroni adjustment for multiple comparisons. Additionally, differences in perceptions were explored between males and females using Wilcoxon Rank Sum tests.

A series of Poisson and negative binomial models were fit for each product type to determine the relationship between race and ethnicity and the number of products reported, while also adjusting for respondent age, income, education, and marital status using data from only those who reported at least one specific product within that type. Due to large overdispersion, rather than using Poisson models, negative binomial models were fit. Secondly, sensitivity analyses using quasi-Poisson models were also fit as another approach to correct for overdispersion. The primary negative binomial models were fit using data from females only (n = 499), given the smaller number of male respondents in the analytic dataset (n = 82). We hypothesized that females who had a prior history of experiencing allergic reactions or health effects due to PCP use may use less products, so we also performed sensitivity analyses excluding female participants who reported having experienced any health effects following the use of any personal care products in the past 12 months (n = 81) (Supplementary Table 2). Secondary analysis including both males and females with PCP use data were also performed (Supplementary Table 3).

4. Results

4.1. Description of study sample and PCP use behaviors

Summary data on the 656 respondents who completed the questionnaires were included in the descriptive statistics, representing adults self-identifying as Asian American/Pacific Islander (AAPI, 131 [20.0%]), Hispanic (39 [5.9%]), non-Hispanic Black (NHB, 63 [9.6%]), non-Hispanic White (NHW, 358 [54.6%]), and multiracial or other (65 [9.9%]) (Table 1). Most participants self-identified as female (84.9%) and the mean age was 37 ± 16 years. Participants were primarily US-born (82.2%), single/never married (51.4%), and held more than a bachelor's degree (42.4%). More than half reported a household income \geq \$100,000 (52.4%) and approximately 40% identified themselves as students (undergraduate or graduate), 15% as faculty, 41% as staff, and approximately 4% as other university affiliate. Finally, 1.1% of female participants reported being pregnant at the completion of the questionnaire and 3.5% of participants reported having a previous cancer diagnosis.

Overall, the average number of PCPs used in the past 24–48 h across all product categories was 15.6 ± 7.7 , with the number of skin care products being highest (5.1 ± 2.8), followed by beauty products (3.6 ± 3.7), hair products (2.9 ± 1.8), oral care (2.0 ± 1.0), and perfumes and colognes (0.7 ± 0.9) (Table 2). Significant differences were observed in product use between males and females ($P < 0.01$) for all applicable categories except oral care products. Total product usage across all categories in the past 24–48 h averaged 15.8 ± 6.9 among AAPI women, 19.2 ± 7.9 products among NHB women, 16.4 ± 8.5 among Hispanic women, 26.9 ± 7.3 among NHW women, 16.9 ± 7.1 among women self-identifying as multiracial or other, and 7.9 ± 4.7 among males of all races and ethnicities. Using Dunn tests for pairwise comparisons in product usage by race and ethnicity among females, we found that relative to NHWs, AAPI females reported using fewer hair products (2.5 ± 1.4 vs. 3.1 ± 1.7) and more feminine hygiene products (1.5 ± 1.1 vs. 1.1 ± 1.3), NHB females reported using more hair products (3.8 ± 2.6 vs. 3.1 ± 1.7), perfumes (1.0 ± 0.9 vs. 0.6 ± 0.9), oral care products (2.3 ± 0.9 vs. 1.9 ± 1.0), and feminine hygiene products (1.8 ± 1.5 vs. 1.1 ± 1.3), and females identifying as multiracial or other reported using more oral care (2.2 ± 0.9 vs. 1.9 ± 1.0) and feminine hygiene products (1.8 ± 1.2 vs. 1.1 ± 1.3).

Table 3 shows the summary of PCP use behaviors among females (by race and ethnicity) and males (overall). Almost 20% of participants reported any use of homemade PCPs; this behavior appeared to be more prevalent among NHB, Hispanic, and multiracial or other females relative to NHW and AAPI females and males. Overall, hair and skin care products were the most frequently used types of homemade PCPs. Approximately 16% reported experiencing any type of allergic health effects following the use of a PCP in the past 12 months and 45% reported that they avoid using certain PCPs due to concerns about allergic reactions or other health effects. Most participants (82.2%) reported receiving professional hair care or hair styling services in the past 12 months and almost three quarters of the sample (73.3%) reported being at least slightly concerned about health effects from ingredients used in hair salons. Additionally, more than half of the sample (55.3%) reported receiving professional nail care services in a salon in the past 12 months and most participants (80.5%) responded that they had at least some concern about the health effects from ingredients used in nail salons.

As shown in Fig. 1, respondents reported buying their PCPs from various types of retailers (participants had the option of selecting more than one retailer type for each PCP category), with a majority reporting that they purchase the hair products (65%), beauty products (61%), skincare products (67%), and feminine hygiene products (64%) mostly at big box stores (e.g., Target, Walmart) or major pharmacies (e.g., CVS, Walgreens, Rite Aid). Many respondents also reported buying beauty products and skincare products at cosmetics specialty stores (e.g., Sephora, Ulta) (>180 participants for these product types at these

Table 1

Descriptive statistics of PCP use questionnaire respondents, overall and by race and ethnicity, N = 656.

Characteristic	Overall N = 656	AAPI n = 131	Hispanic n = 39	NHB n = 63	NHW n = 358	Multiracial or other ^a n = 65
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Age (years), mean ± SD	37 ± 16	27 ± 11	33 ± 11	35 ± 13	42 ± 16	35 ± 15
Missing/unknown ^b	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.5)
Gender identity						
Female	557 (84.9)	112 (85.5)	33 (84.6)	59 (93.7)	299 (83.5)	54 (83.1)
Male	90 (13.7)	17 (13.0)	5 (12.8)	4 (6.3)	55 (15.4)	9 (13.8)
Other or unknown ^c	9 (1.4)	2 (1.5)	1 (2.6)	0 (0.0)	4 (1.1)	2 (3.1)
Hispanic ethnicity						
Yes	68 (10.4)	0 (0.0)	39 (100.0)	0 (0.0)	0 (0.0)	30 (46.2)
No	579 (88.3)	130 (99.2)	0 (0.0)	63 (100.0)	356 (99.4)	29 (44.6)
Missing/unknown ^b	9 (1.4)	1 (0.8)	0 (0.0)	0 (0.0)	2 (0.6)	6 (9.2)
US-born						
Yes	539 (82.2)	78 (59.5)	30 (76.9)	52 (82.5)	337 (94.1)	42 (64.6)
No	110 (16.8)	52 (39.7)	9 (23.1)	11 (17.5)	20 (5.6)	18 (27.7)
Missing/unknown ^b	7 (1.1)	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.3)	5 (7.7)
Marital status						
Married	248 (37.8)	30 (22.9)	12 (30.8)	16 (25.4)	175 (48.9)	15 (23.1)
Previously married ^d	69 (10.5)	5 (3.8)	3 (7.7)	10 (15.9)	41 (11.5)	10 (15.4)
Single/never married	337 (51.4)	96 (73.3)	24 (61.5)	37 (58.7)	141 (39.4)	39 (60.0)
Missing/unknown	2 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	1 (1.5)
Education						
Less than bachelor's degree	167 (25.5)	50 (38.2)	12 (30.8)	21 (33.3)	67 (18.7)	17 (26.2)
Bachelor's degree	207 (31.6)	42 (32.1)	13 (33.3)	18 (28.6)	111 (31.0)	17 (35.4)
More than bachelor's degree	278 (42.4)	39 (29.8)	14 (35.9)	24 (38.1)	178 (49.7)	23 (35.4)
Missing/unknown ^b	4 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.6)	2 (3.1)
Household income						
<\$50,000	99 (15.1)	29 (22.1)	8 (20.5)	17 (27.0)	34 (9.5)	11 (16.9)
\$50,000 - \$74,999	100 (15.2)	14 (10.7)	11 (28.2)	13 (20.6)	48 (13.4)	14 (21.5)
\$75,000 - \$99,999	98 (14.9)	9 (6.9)	9 (23.1)	9 (14.3)	60 (16.8)	11 (16.9)
≥\$100,000	344 (52.4)	76 (58)	11 (28.2)	23 (36.5)	207 (57.8)	27 (41.5)
Missing/unknown ^b	15 (2.3)	3 (2.3)	0 (0.0)	1 (1.6)	9 (2.5)	2 (3.1)
Role at university						
Undergraduate student	98 (14.9)	44 (33.6)	8 (20.5)	10 (15.9)	25 (7.0)	11 (16.9)
Graduate student	164 (25.0)	44 (33.6)	9 (23.1)	18 (28.6)	78 (21.8)	15 (23.1)
Faculty	98 (14.9)	8 (6.1)	3 (7.7)	5 (7.9)	79 (22.1)	3 (4.6)
Staff	268 (40.9)	32 (24.4)	16 (41.0)	30 (47.6)	157 (43.9)	33 (50.8)
Other or unknown	28 (4.3)	3 (2.3)	3 (7.7)	0 (0.0)	19 (5.3)	3 (4.6)
Currently pregnant	7 (1.1)	1 (0.8)	0 (0.0)	2 (3.2)	3 (0.8)	1 (1.5)
Missing/unknown ^b	99 (15.1)	19 (14.5)	6 (15.4)	4 (6.3)	59 (16.5)	11 (16.9)
Personal history of cancer	23 (3.5)	0 (0.0)	1 (2.6)	0 (0.0)	21 (5.9)	1 (1.9)
Missing/unknown ^b	7 (1.1)	2 (1.5)	0 (0.0)	0 (0.0)	3 (0.8)	2 (3.1)

Abbreviations: AAPI, Asian American/Pacific Islander; NHB, non-Hispanic Black; NHW, non-Hispanic White.

^a Multiracial or other race and ethnicity category included those reporting more than one race or multiracial (52 [7.9%]), American Indian or Alaska Native (2 [3.1%]), and unknown (those who provided no response to race and/or ethnicity or responded, 'prefer not to answer' (11 [1.69%])).^b Missing/unknown included those who provided no response and/or responded, 'prefer not to answer'.^c Other or unknown gender category included those who self-identified as non-binary gender identity (n = 1) or responded, 'prefer not to answer' (n = 8).^d Previously married category included those who reported being widowed, separated, or divorced.

retailers). Very few participants reported purchasing PCPs at dollar stores or salons.

4.2. Perceptions and attitudes about PCP use

Generally, respondents reported neither a low nor high level of agreement with statements suggesting that PCPs are worrisome in terms of health effects (Fig. 2). On average, participants moderately agreed with the statement "The PCPs I use affect my health" (mean ± SD, 3.4 ± 1.1), and agreement with this statement was slightly higher among females than males (3.4 vs. 3.2; P = 0.05). Participants generally agreed that "Consumers should be concerned about the health effects of personal care products" (4.1 ± 0.7), with males agreeing slightly less than females (4.1 vs. 3.9; P = 0.01). In line with this finding, for the statement "There is no reason to worry about the health effects from chemicals that might be in personal care products," participants generally reported a low level of agreement (1.9 ± 0.8), with females agreeing less so than males (1.8 vs. 2.1; P = 0.001). Notably, among females, we observed a low level of agreement with this perception among NHBs than NHW (1.5 vs. 1.8; P < 0.01 with adjustment for multiple comparisons). For the statement

"Overall, the benefits of using personal care products outweigh any risks from exposure to toxic chemicals that might be in these products," again, participants generally reported low agreement (2.5 ± 1.0) and the level of agreement was slightly lower among females than males (2.5 vs. 2.7; P = 0.008). For the statement "The Food and Drug Administration (FDA) and other government agencies do a good job of regulating personal care products to ensure they are safe for consumers," participants trended towards moderate agreement (2.6 ± 1.0), with females agreeing slightly less than males (2.6 vs. 2.8; P = 0.02). AAPI females appeared to agree slightly more with this statement than NHWs (2.9 vs. 2.5; P < 0.05 with adjustment for multiple comparisons). No racial and ethnic or gender differences were observed in the level of agreement with "Organic, natural, non-toxic or eco-friendly personal care products have fewer toxic chemicals than regular products" (3.7 ± 0.9) and "Organic, natural, non-toxic or eco-friendly personal care products are just as effective as regular products" (3.3 ± 0.9).

4.3. Associations between sociodemographic characteristics and PCP use

In multivariable adjusted analyses (adjusting for age, income,

Table 2
Distributions of PCP use (counts), overall and by gender and race and ethnicity, N = 591.

	Overall N = 591	AAPI Females n = 98	NHB Females n = = 55	Hispanic Females n = 31	NHW Females n = = 277	Multiracial or Other Females n = 47	Males n = 83	Gender comparisons (females vs. males) ^a	Race and ethnicity comparisons (females only) ^b
All product categories combined	Number of products (n)							P-value	P-value
Mean ± SD	15.6 ± 7.7	15.8 ± 6.9	19.2 ± 7.9	16.4 ± 8.5	26.9 ± 7.3	16.9 ± 7.11	7.9 ± 4.7	<0.01	0.12
Median (Min, Max)	15.0 (2, 46)	15.0 (4, 37)	18.0 (6, 40)	16.0 (3, 39)	16.0 (2, 46)	17.0 (2, 37)	7 (2, 38)		
Hair products	Number of products (n)							P-value	P-value
Mean ± SD	2.9 ± 1.8	2.5 ± 1.4 ^c	3.8 ± 2.6 ^c	3.0 ± 1.8	3.1 ± 1.7	3.1 ± 1.6	1.7 ± 1.7	<0.01	0.01
Median (Min, Max)	2 (0, 13)	2 (0, 7)	3 (0, 12)	3 (0, 7)	3 (0, 13)	3 (1, 7)	1 (0, 11)		
Beauty products	Number of products (n)							P-value	P-value
Mean ± SD	3.6 ± 3.7	3.8 ± 4.0	3.9 ± 3.9	4.1 ± 3.1	4.5 ± 3.8	3.3 ± 2.8	0.5 ± 0.9	<0.01	0.07
Median (Min, Max)	3 (0, 22)	3 (0, 16)	3 (0, 20)	4 (0, 11)	4 (0, 22)	3 (0, 11)	0 (0, 5)		
Skin care products	Number of products (n)							P-value	P-value
Mean ± SD	5.1 ± 2.8	5.1 ± 2.4	6.1 ± 2.8	5.1 ± 2.8	5.3 ± 2.9	5.6 ± 2.7	3.3 ± 2.1	<0.01	0.27
Median (Min, Max)	5 (0, 18)	5 (0, 13)	6 (0, 12)	5 (0, 12)	5 (0, 18)	5 (0, 13)	3 (0, 10)		
Perfumes and colognes	Number of products (n)							P-value	P-value
Mean ± SD	0.7 ± 0.9	0.7 ± 0.9	1.0 ± 0.9 ^c	0.7 ± 0.9	0.6 ± 0.9	0.8 ± 0.9	0.3 ± 0.6	<0.01	<0.01
Median (Min, Max)	0 (0, 7)	0.5 (0, 4)	1 (0, 4)	1 (0, 3)	0 (0, 7)	1 (0, 4)	0 (0, 2)		
Oral care products	Number of products (n)							P-value	P-value
Mean ± SD	2.0 ± 1	1.9 ± 0.9	2.3 ± 0.9 ^c	1.8 ± 1.2	1.9 ± 1.0	2.2 ± 0.9 ^c	1.9 ± 1.1	0.33	0.04
Median (Min, Max)	2 (0, 6)	2 (1, 5)	2 (0, 5)	2 (0, 4)	2 (0, 6)	2 (0, 4)	2 (0, 5)		
Feminine hygiene products	Number of products (n)							P-value	P-value
Mean ± SD	1.2 ± 1.3	1.5 ± 1.1 ^c	1.8 ± 1.5 ^c	1.4 ± 1.2	1.1 ± 1.3	1.8 ± 1.2 ^c	NA	NA	<0.01
Median (Min, Max)	1 (0, 9)	1 (0, 5)	2 (0, 6)	1 (0, 4)	1 (0, 9)	2 (0, 5)			

^a P-values for gender comparisons were generated from Student’s t-tests.

^b P-values for race and ethnicity comparisons among females were generated from Kruskal-Wallis rank sum tests.

^c Indicates a statistically significantly difference in the number of products used relative to non-Hispanic White women at the 0.05 level using the Dunn Test with Bonferroni adjustment for multiple comparisons.

education, and marital status) including female respondents with complete product data for each PCP type, we observed that NHB race was associated with use of significantly more PCPs in the past 24–48 h relative to NHW (all types combined, RR 1.16, 95% CI: 1.02, 1.31; hair products, RR 1.19, 95% CI: 1.01, 1.39; perfumes/colognes, RR 3.00, 95% CI: 1.59, 5.87; oral care products, 1.29, 95% CI 1.05, 1.58; and feminine hygiene products, 1.44, 95% CI: 1.13, 1.83) (Table 4). Relative to NHW, multiracial and other racial identity was associated with use of more perfumes/colognes (RR 2.04, 95% CI: 1.06, 4.04) and feminine hygiene products (RR 1.41, 95% CI: 1.09, 1.80). AAPI racial identity was associated with use of significantly fewer hair products relative to NHW (RR 0.83, 95% CI: 0.71, 0.96). Relative to being married, being previously married was associated with use of more hair products (RR 1.26, 95% CI: 1.07, 1.48) and feminine hygiene products (RR 1.41, 95% CI: 1.02, 1.90). Having less than a bachelor’s level of education (relative to having a bachelor’s degree) was associated with use of fewer PCPs overall (RR 0.90, 95% CI: 0.82, 1.00) – it is important to note that out of the 167 participants with less than a bachelor’s degree, 98 of them are current undergraduate students (data not shown). Having a household income <\$50,000 compared to ≥\$100,000 was also associated with use of fewer beauty products (including makeup) (RR 0.74, 95% CI: 0.57, 0.97) and skin care products (RR 0.84, 95% CI: 0.73, 0.96). Similarly, having a household income of \$75,000 - \$100,000 compared to ≥\$100,000 was associated with use of fewer feminine hygiene products

(RR 0.79, 95% CI: 0.62, 1.00). In sensitivity analysis restricted to female participants who did not report having any health effects following the use of PCPs in the past 12 months the risk estimates were consistent in both magnitude and direction (Supplementary Table 1). Additionally, the inclusion of males with complete product data for each PCP type the observed associations were generally consistent in magnitude and direction, and some were strengthened (Supplementary Table 2). For example, several of the associations observed in the analyses including females only became stronger with the inclusion of males such as the positive associations between being previously married and use of more PCPs overall (RR 1.16, 95% CI: 1.02, 1.32), being single/never married and use of fewer hair products (RR 0.84, 95% CI: 0.73, 0.98) and more skin care products (RR 1.16, 95% CI: 1.03, 1.32), and having a household income <\$50,000 and use of fewer PCPs overall (RR 0.87, 95% CI: 0.78, 0.97).

5. Discussion

In a convenience sample of adults at an academic institution, we collected information on and tallied the number of PCPs used in the past 24–48 h. Participants reported using approximately 16 products per day – approximately 19 products among women and 8 products among men. This reflects higher product use than a recent study showing a median of 8 products per day among a diverse sample of women in California

Table 3
Distribution of PCP use behaviors and concerns around these behaviors among females (by race and ethnicity) and males (overall).

	Overall N = 647 n (%)	AAPI Females n = 112 n (%)	NHB Females n = 59 n (%)	Hispanic Females n = 33 n (%)	NHW Females n = 299 n (%)	Multiracial or Other ^a Females n = 54 n (%)	Males n = 90 n (%)
Ever use homemade PCP	125 (19.3)	24 (21.4)	22 (37.3)	10 (30.3)	45 (15.1)	16 (29.6)	8 (8.9)
Missing	4 (0.6)	1 (0.9)	0 (0.0)	0 (0.0)	2 (0.7)	1 (1.9)	0 (0.0)
Types of homemade PCPs used							
Hair products	68 (10.5)	11 (9.8)	13 (22.0)	6 (18.2)	20 (6.7)	13 (24.1)	5 (5.6)
Beauty products	10 (1.5)	1 (0.9)	1 (1.7)	0 (0.0)	5 (1.7)	2 (3.6)	1 (1.1)
Skin care products	105 (16.2)	21 (18.8)	18 (30.5)	10 (30.3)	37 (12.4)	13 (24.1)	6 (6.7)
Feminine hygiene products	6 (0.9)	1 (0.9)	1 (1.7)	0 (0.0)	2 (0.7)	2 (3.7)	0 (0.0)
None reported	458 (70.8)	78 (69.6)	26 (44.1)	17 (51.5)	235 (78.6)	24 (44.4)	78 (86.7)
Experienced any health effects following the use of any PCP in the past 12 months ^b	102 (15.8)	20 (17.9)	14 (23.7)	5 (15.2)	39 (13.0)	11 (20.4)	13 (14.4)
Missing	24 (3.7)	8 (7.1)	3 (5.1)	3 (9.1)	7 (2.3)	1 (1.9)	2 (2.2)
Avoid use of certain PCPs due to concerns about allergic reactions or other adverse health effects	293 (45.3)	54 (48.2)	33 (55.9)	21 (63.6)	140 (46.8)	19 (35.2)	26 (28.9)
Missing	21 (3.2)	6 (5.4)	3 (5.1)	1 (3.0)	8 (2.7)	2 (3.7)	1 (1.1)
Frequency of receiving professional hair care or styling services in the past 12 months							
Did not receive	115 (17.8)	26 (23.2)	14 (23.7)	5 (15.2)	30 (10.0)	8 (14.8)	32 (35.6)
<1 time per month	469 (72.5)	82 (73.2)	29 (49.2)	23 (69.7)	249 (83.3)	40 (74.1)	46 (51.1)
1-3 times per month	49 (7.6)	3 (2.7)	12 (20.3)	4 (12.1)	15 (5.0)	4 (7.4)	11 (12.2)
>3 times per month	8 (1.2)	0 (0.0)	3 (5.1)	0 (0.0)	3 (1.0)	1 (1.9)	1 (1.1)
Level of concern about the health effects from ingredients used in hair salons							
Not at all concerned	161 (24.9)	7 (11.9)	20 (17.9)	78 (26.1)	13 (24.1)	5 (15.2)	38 (42.2)
Slightly concerned	153 (23.6)	14 (23.7)	31 (27.7)	71 (23.7)	9 (16.7)	8 (24.2)	20 (22.2)
Somewhat concerned	140 (21.6)	10 (16.9)	28 (25.0)	64 (21.4)	10 (18.5)	10 (30.3)	18 (20.0)
Moderately concerned	119 (18.4)	14 (23.7)	21 (18.8)	62 (20.7)	9 (16.7)	4 (12.1)	9 (10.0)
Extremely concerned	63 (9.7)	13 (22.0)	9 (8.0)	20 (6.7)	12 (22.2)	5 (15.2)	4 (4.4)
Missing	11 (1.7)	1 (1.7)	3 (2.7)	4 (1.3)	1 (1.9)	1 (3.0)	1 (1.1)
Frequency of receiving professional nail care in the past 12 months							
Did not receive	282 (43.6)	56 (50.0)	10 (16.9)	8 (24.2)	109 (36.5)	22 (40.7)	282 (43.6)
<1 time per month	252 (38.9)	45 (40.2)	21 (35.6)	18 (54.5)	132 (44.1)	25 (46.3)	252 (38.9)
1-3 times per month	106 (16.4)	10 (8.9)	27 (45.8)	6 (18.2)	55 (18.4)	6 (11.1)	106 (16.4)
>3 times per month	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	0 (0.0)	1 (0.2)
Missing	6 (0.9)	1 (0.9)	1 (1.7)	1 (3.0)	2 (0.7)	1 (1.9)	6 (0.9)
Level of concern about health effects from ingredients in products used in nail salons							
Not at all concerned	126 (19.5)	4 (6.8)	16 (14.3)	48 (16.1)	10 (18.5)	2 (6.1)	46 (51.1)
Slightly concerned	122 (18.9)	13 (22.0)	25 (22.3)	61 (20.4)	2 (3.7)	4 (12.1)	17 (18.9)
Somewhat concerned	147 (22.7)	16 (27.1)	30 (26.8)	64 (21.4)	16 (29.6)	11 (33.3)	10 (11.1)
Moderately concerned	144 (22.3)	12 (20.3)	22 (19.6)	79 (26.4)	10 (18.5)	10 (30.3)	11 (12.2)
Extremely concerned	97 (15.0)	16 (14.3)	43 (14.4)	15 (27.8)	5 (15.2)	5 (5.6)	16 (14.3)
Missing	11 (1.7)	1 (1.7)	3 (2.7)	4 (1.3)	1 (1.9)	1 (3.0)	1 (1.1)

^a Multiracial or other race and ethnicity category included those reporting more than one race or multiracial and unknown (those who provided no response to race and/or ethnicity or responded, 'prefer not to answer').

^b This variable assesses respondents' reported experience of any health effects (including allergic reactions) following the use of a personal care product in the past 12 months.

(Dodson et al., 2021). Consistent with prior studies (Collins et al., 2023; Dodson et al., 2021; White et al., 2021b), we observed that socio-demographic characteristics were associated with the number of PCPs used within the last 24–48 h. Race and ethnicity were particularly associated with product use, but we also observed evidence of associations with marital status, income, and education. These findings add to the growing body of evidence indicating a greater burden of chemical exposures due to differences in PCP use among some groups (e.g., NHB

women and other women of color). Participants reported making most PCP purchases at Big Box stores (e.g., Walmart, Target) and grocery stores, which is consistent with national consumer behavior data and indicates the importance of making safer products widely available through major retailers (Cosmetics Consumer Behavior in the U.S. - Statistics & Facts). Our examination of perceptions, attitudes, and PCP purchasing behaviors in this study showed that both males and females have at least some awareness about the potential risks associated with

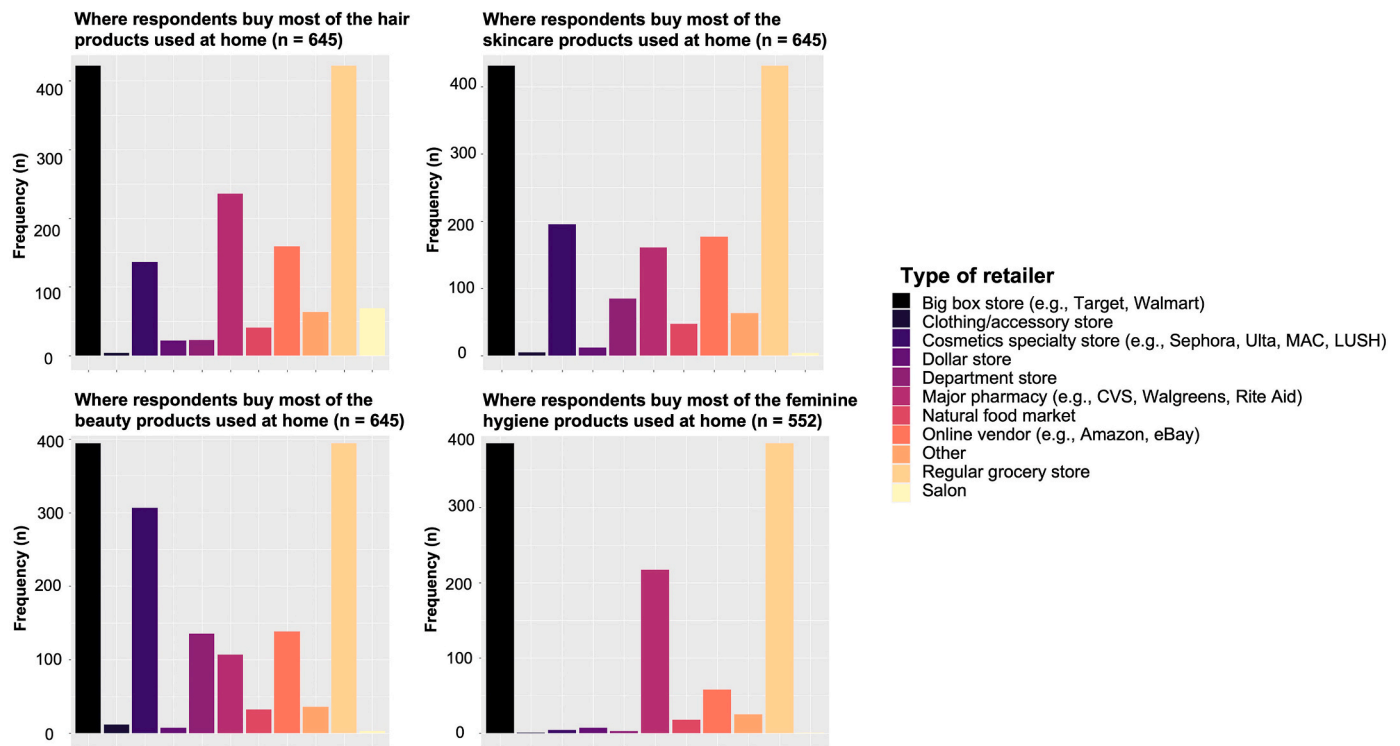


Fig. 1. Distributions of retailer types that respondents reported buying the PCPs they typically use at home. NOTE: Participants had the option of selecting more than one retailer type for each PCP category, so percentages may be less meaningful.

using PCPs and moderate levels of concern about health effects from ingredients used in professional salons – both nail salons and hair salons. These findings may highlight the growing evidence supporting significant associations between PCP use and hormone-mediated conditions including reproductive outcomes (James-Todd et al., 2016; Bariani et al., 2020; Collins et al., 2023; Gaston et al., 2020; Wright et al., 2021) and cancers of the breast, ovarian, uterine, and prostate (Eberle et al., 2020; Llanos et al., 2017; Rao et al., 2022; White et al., 2021a; Chang et al., 2022), along with increasing science communication and media coverage about the potential risks.

The beauty industry overwhelmingly targets femme-identifying individuals through idealizing Eurocentric beauty standards in marketing and advertising (Black representation in the beauty), driving PCP sales among women, particularly NHB and other women of color (Collins et al., 2023; Zota and Shamasunder, 2017; Raley et al., 2021). When examined by race and ethnicity, NHB women reported greater use of many categories of PCPs, including hair, feminine care, and fragrance products than other groups including NHW women. Higher use of PCPs, particularly hair products, is linked to higher exposure to endocrine-disrupting chemicals (EDCs) and carcinogens (Collins et al., 2023; Fruh et al., 2022; Branch et al., 2015; Chan et al., 2021; Dodson et al., 2021; Preston et al., 2021; Berger et al., 2021; Johnson et al., 2022; Santaliz Casiano et al., 2022) and a disproportionate chemical burden (Zota and Shamasunder, 2017) among populations that already disproportionately suffer poorer health outcomes (Chinn et al., 2021). These disparate exposures tend to start early in life during potentially critical windows of early susceptibility and continue throughout the life course. For example, data show that certain hair care products (e.g., chemical relaxers, hair oils, anti-frizz serums and treatments) are commonly used among NHB girls starting as young as age 5 (Gaston et al., 2020; Raley et al., 2021).

Feminine hygiene products are another class of PCPs that are widely used despite associations with a range of adverse health effects. Studies have examined the prevalence of use of feminine hygiene products including douches and perineal/genital talc (Wright et al., 2021;

O'Brien et al., 2021), which have been linked to alterations to the vaginal microbiome, fibroid development, and ovarian cancer, and uterine fibroids (Bariani et al., 2020). We found that NHB, Hispanic, and multiracial/other females had significantly greater use of feminine hygiene products relative to NHW females. In review studies, douching has been associated with outcomes including greater risk of human papillomavirus (HPV) infection and susceptibility (O'Brien et al., 2021; Museba et al., 2021), higher cervical cancer risk, and moderately increased risk of ectopic pregnancy (Martino and Vermund, 2002; Zhang et al., 1997). In the National Survey for Family Growth (Martino and Vermund, 2002), while 36% of Hispanic/Latina women and 27% of White women reported douching within the past 12 months, the prevalence of use among Black women was significantly higher at 59%. Similarly, NHB women also report greater prevalence of feminine powder and feminine spray use relative to their NHW counterparts (Wright et al., 2021; Martino and Vermund, 2002). Vaginal douching can serve as an important source of phthalate exposure among reproductive aged women in the US (Branch et al., 2015). Thus, greater use of these products in combination with greater use of PCPs from other categories might contribute to increased exposures to harmful chemicals and processes that are implicated in increased health risks among women of color.

The range of chemical exposures from PCP use is not limited to hair products and feminine hygiene products, but also includes makeup and cosmetics, skin moisturizing products, sunscreen, nail polish, perfumes, and colognes, among others – each with varying concentrations of chemicals linked to adverse health outcomes. Few studies have examined detailed PCP use, particularly in diverse study samples. The Taking Stock Study (Dodson et al., 2021), which recently surveyed 357 women in California, reported that study participants used a median of 8 products daily. The study reported significant differences by race and ethnicity, however, did not examine socioeconomic differences in product use. One interesting finding from that study was the high correlation between the number of products used overall with the number of cosmetics products used (Dodson et al., 2021). As a result, many

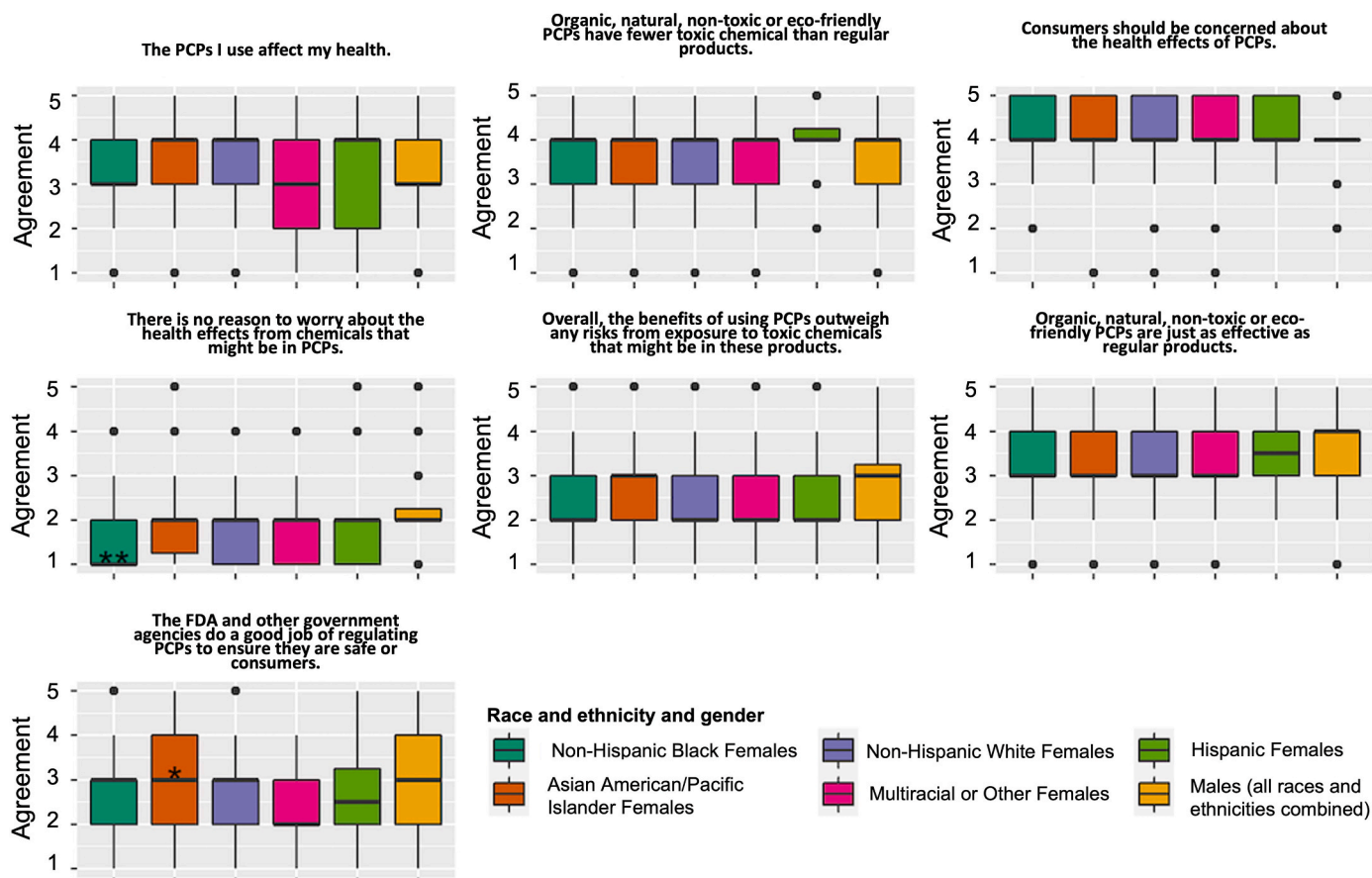


Fig. 2. Distributions of participants' level of agreement with statements regarding perceptions and attitudes about PCP use. NOTE: Level of agreement was assessed on a 5-point Likert scale: 1, strongly disagree; 2, disagree; 3, neither disagree nor agree; 4, agree; and 5, strongly agree.

*Significantly different perception relative to NHW females at the 0.05 level using the Dunn Test with Bonferroni adjustment for multiple comparisons.

**Significantly different perception relative to NHW females at the 0.01 level using the Dunn Test with Bonferroni adjustment for multiple comparisons.

women have substantial aggregate exposure to chemicals found in cosmetics. Further, 70% of women reported at least half of the products used contained fragrance ingredients, which frequently contain a myriad of undisclosed chemicals, such as phthalates, that have been linked to adverse human health outcomes (Dodson et al., 2021; Right to know: Exposing toxic fragrance chemicals in beauty et al). The Taking Stock Study also reported significant differences in product use by race and ethnicity for approximately half of the product types – Hispanic/Latina and AAPI women reported greater use of cosmetics than Black and White women, and Black women reported using significantly more hair products and certain feminine hygiene products (Dodson et al., 2021). Like our study, these prior findings highlight differences in product use and frequency, which clearly support the notion of unequal burdens of exposure among racial and ethnic minority women relative to NHW women.

In another California study, investigators showed that on average, women used 12 different PCPs each day, similar to our findings, and that 65% of the products contained chemicals of concern, with almost three quarters of the product labels including undisclosed ingredients (Johnson et al., 2022). These chemicals of concern include suspected EDCs (e.g., such as phthalates, parabens, triclosan, benzophenone-3), carcinogens (e.g., 1,4-dioxane, formaldehyde, diethanolamine, and cyclic volatile methyl siloxanes (Collins et al., 2023; Chan et al., 2021; Johnson et al., 2022). Differences in PCP use across product category were analyzed by race and ethnicity, but not by socioeconomic factors. In that study, Vietnamese and Latina women were the least likely to report intentionally avoiding certain ingredients (15.4% and 13.9%, respectively). While we did not query avoidance of specific ingredients in PCPs

in the current study, nearly half of AAPI women and nearly two-thirds of Hispanic women reported avoiding certain PCPs due to health concerns. This discrepancy between our results and those of the prior study by Collins et al. may reflect differences in the questions asked as well as underlying differences in the samples studied. For example, Vietnamese participants in the California study were recruited through organizations focused on health among Vietnamese nail salon workers, whereas our participants were derived from a university community and two thirds of the AAPI women participating were undergraduate or graduate students. Norms around PCP use and beauty standards likely vary by sociodemographic and geographic factors as well, highlighting the need for future work in larger, more diverse and inclusive samples.

To date, few studies focusing on PCP use have specifically recruited participants who self-identify as male (Lim et al., 2022; Nassan et al., 2017) and, to our knowledge, none have considered variation in product use and/or perceptions in this population as described herein. In the EARTH study (Nassan et al., 2017), Nassan and colleagues assessed the use of 14 PCPs in a sample of 400 men and the associated change in urinary phthalate metabolites and parabens following PCP use. Use of PCPs, especially fragrance products, deodorant, and some hair products, significantly correlated with increases in urinary concentrations of EDCs within 6 h of urine collection (Nassan et al., 2017). Another study examined the prospective association between hair dye use and prostate cancer in a subset of men enrolled in a randomized-controlled trial and showed that hair dye users had a significant 77% increased risk of prostate cancer relative to non-users (Lim et al., 2022). These studies highlight the necessity of more research on PCP use in the context of health outcomes among men, who have been largely understudied in

Table 4

Associations between sociodemographic characteristics and average number of PCPs used in the last 24–48 h (counts) among females, overall and by product category, N = 499.

	Total products (All categories combined)	Hair products	Beauty products	Skin care products	Perfumes and colognes	Oral care products	Feminine hygiene products
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
Intercept	19.93 (16.46, 24.14)	3.72 (2.89, 4.79)	4.74 (3.13, 7.20)	5.97 (4.78, 7.44)	1.35 (0.54, 3.42)	1.78 (1.29, 2.43)	3.25 (2.13, 4.93)
Age (years)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.01)	1.00 (0.99, 1.00)	0.99 (0.97, 1.00)	1.00 (1.00, 1.01)	0.97 (0.96, 0.98)^c
Race and ethnicity							
AAPI	0.92 (0.83, 1.03)	0.83 (0.71, 0.96)^b	0.88 (0.69, 1.11)	0.92 (0.81, 1.05)	1.17 (0.70, 1.93)	1.12 (0.94, 1.34)	1.03 (0.83, 1.28)
Hispanic	0.97 (0.82, 1.14)	0.97 (0.78, 1.20)	0.93 (0.66, 1.32)	0.95 (0.79, 1.15)	1.22 (0.56, 2.64)	1.00 (0.74, 1.31)	1.06 (0.75, 1.46)
NHB	1.16 (1.02, 1.31)^b	1.19 (1.01, 1.39)^b	0.91 (0.69, 1.21)	1.15 (1.00, 1.32)	3.00 (1.59, 5.87)^c	1.29 (1.05, 1.58)^b	1.44 (1.13, 1.83)^c
NHW	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Multiracial/other	1.01 (0.88, 1.16)	1.00 (0.83, 1.19)	0.74 (0.55, 1.01)	1.06 (0.91, 1.24)	2.04 (1.06, 4.04)^b	1.22 (0.97, 1.51)	1.41 (1.09, 1.80)^c
Marital status							
Married	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Previously married ^a	1.07 (0.93, 1.22)	1.26 (1.07, 1.48)^c	1.01 (0.76, 1.37)	1.01 (0.86, 1.19)	0.74 (0.38, 1.43)	0.86 (0.69, 1.08)	1.40 (1.02, 1.90)^b
Single/never married	1.01 (0.91, 1.13)	0.82 (0.70, 0.95)	1.06 (0.83, 1.35)	1.14 (1.00, 1.29)	0.79 (0.46, 1.36)	0.89 (0.74, 1.08)	1.07 (0.84, 1.36)
Education							
Less than bachelor's degree	0.90 (0.82, 1.00)^b	1.01 (0.89, 1.15)	0.84 (0.68, 1.05)	0.90 (0.80, 1.01)	1.29 (0.80, 2.08)	0.86 (0.73, 1.02)	0.88 (0.72, 1.07)
Bachelor's degree	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
More than bachelor's degree	0.93 (0.85, 1.02)	0.90 (0.80, 1.02)	0.88 (0.72, 1.07)	1.00 (0.90, 1.11)	0.83 (0.53, 1.31)	0.97 (0.83, 1.13)	0.94 (0.77, 1.14)
Household income							
<\$50,000	0.86 (0.76, 0.96)	1.05 (0.90, 1.23)	0.74 (0.57, 0.97)^b	0.84 (0.73, 0.96)^b	1.05 (0.60, 1.87)	0.90 (0.73, 1.11)	0.88 (0.70, 1.09)
\$50,000 - \$74,999	1.01 (0.90, 1.14)	0.96 (0.82, 1.12)	1.05 (0.82, 1.36)	1.01 (0.88, 1.15)	1.35 (0.76, 2.41)	0.98 (0.80, 1.20)	0.96 (0.75, 1.20)
\$75,000 - \$100,000	0.96 (0.86, 1.07)	0.95 (0.82, 1.09)	0.96 (0.76, 1.21)	0.95 (0.83, 1.07)	1.14 (0.67, 1.93)	1.12 (0.94, 1.33)	0.79 (0.62, 1.00)^b
≥\$100,000	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)

NOTE: Risk estimates generated using negative binomial regression models among female study participants with complete product data for each PCP type.

^a Previously married category included those who reported being widowed, separated, or divorced.

^b P < 0.05.

^c P < 0.01.

this context.

In the current study, we found that male and female participants moderately agreed with statements suggesting that consumers should be concerned about the health effects of PCPs, while they reported low agreement that there is no reason to worry about the health effects of PCPs. This suggests that there is at least some awareness about potential health risks from PCP use. Relative to men, women reported greater awareness of and more concern about PCP safety, health effects, and regulation, suggesting that women may have greater environmental health literacy related to exposures in PCPs and potential links to adverse health outcomes. The limited research on this topic among men and little to no science communication about potentially harmful exposures in PCPs in this population may explain these findings. Furthermore, we noted that relatively few men reported avoiding certain PCPs due to concerns about health impacts. Prior research suggests that among females, improving environmental health literacy – particularly around chemicals found in PCPs, how they are regulated, and potential health risks (Madrigal et al., 2016) – might contribute to the avoidance of certain PCPs and/or certain chemicals found in PCPs, which is associated with lower urinary concentrations of EDCs (Dodson et al., 2020). Interestingly, NHB women reported a significantly lower level of agreement with the statement “There is no reason to worry about the health effects from chemicals that might be in personal care products,” suggesting potentially greater recognition that chemicals in PCPs they use could be harmful. Over half of the NHB women (55.9%) and nearly two-thirds (63.6%) of the Hispanic women surveyed reported avoiding

certain PCPs due to concerns about their health impacts. This may reflect recent popular media reports citing disproportionate exposures to toxic chemicals through PCPs among women of color (StudyWomen of Color Exposed to More Toxic Chemicals in Personal Care Products; Beauty Products Marketed to Black Women May Contain More Hazardous Chemicals: Report, 1079; Neighmond, 2019). It may also reflect greater concern about allergic reactions and skin irritation resulting from use of certain products (DevaCurl Is Under Fire From Their Loyal Customers For Alleged Hair Loss And Damage -Here's What We Know, 2020). Yet this potentially enhanced environmental health literacy did not appear to correlate with use of fewer products. While NHB and NHW females in this study reported using a similar number of PCPs overall, NHB females used a greater number of hair products, perfumes, and feminine hygiene products. These findings are likely indicative of the narrative surrounding racially targeted marketing and advertising of PCPs (Black representation in the beauty), and that despite recent societal shifts towards natural beauty (Lee and Kwon, 2022) and efforts towards more inclusive policies (Lee and Nambudiri, 2021), high levels of PCP use persist due to a myriad of factors, including psychosocial (Lawson et al., 1999) and sociocultural factors (Teteh et al., 2019) that contribute to a conflict between awareness and continued patterns of high PCP purchasing and use among Black women.

It is also notable that a large majority of participants reported having at least some concern about health effects from ingredients used in hair and nails salons. Almost one quarter reported being slightly concerned, approximately 24% reported being somewhat concerned, 18% reported

moderately concerned, and almost 10% reported being extremely concerned about health effects from ingredients used in hair salons. The proportions of participants who reported being moderately and extremely concerned about ingredients used in nail salons (22% and 15%, respectively) were higher and a bit surprising given that more than half of participants reported receiving professional nail services in the past year. These findings might indicate that the awareness of potential harms in nail salons is now more widespread (possibly more so than for other types of PCPs) and might shed some light on how to increase environmental health literacy related to PCP use and potential chemical exposures from PCPs.

Nielson Consumer Data reported that NHB women spent more than \$7.4 billion on beauty products, with hair products accounting for almost \$2.3 billion (Attracting Black beauty consumers in, 2022). This is partly due to the impacts of structural racism that contribute to many NHB women feeling pressured to adapt to societal beauty norms, which are expressed within and outside Black communities (Teteh et al., 2017, 2020; Edwards et al., 2022). One interpretation of these findings is that having concern about safety and/or knowledge and awareness about potential harms related to PCP use insufficiently facilitates behavior change in this context (Arlinghaus and Johnston, 2018; Llanos et al., 2022). It is also possible that the individuals who express concern about chemical exposures in PCPs and yet report extensive use of PCPs are choosing cleaner, less toxic products that may result in lower chemical burden. Testing that hypothesis is outside the scope of the current project but is an important direction for future research. Clearly these issues are multifaceted, and potential solutions should be considered through partnerships with the communities that are primarily impacted.

This study had some notable strengths, including an in-depth assessment of PCP usage patterns across seven product categories, which allowed the quantification of PCP use overall and by product type. The assessment of perceptions and attitudes around PCP use in a socioeconomically diverse sample of adults, an area with limited research, was another strength. We also included men in our study because they are typically underrepresented in studies of PCP use. This study also has limitations that should be considered, including a cross-sectional study design and use of a convenience sample – more than half of whom were NHW – which was not a good representation of the general US population (e.g., affiliation with an institution of higher education increases the likelihood of higher socioeconomic status). There was underrepresentation of NHB and Hispanic participants compared to the NJ state population (which is 12.4% NHB and 18.7% Hispanic), and overrepresentation of AAPI participants (who make up 6.0% of the NJ population). Relatedly, the relatively small sample of Hispanic participants ($n = 39$) precluded our ability to estimate the associations of interest in this group with sufficient power. Overall, our participants were more diverse than those studied in prior work on this topic situated in other university communities (Hart et al., 2020; Chan et al., 2015), but less diverse than prior community-based samples (Collins et al., 2023; Dodson et al., 2021). As this study was also conducted in the Northeastern US, it is possible that participants have different PCP use patterns compared to other US regions. The PCP use survey also only focused on product use within the previous 24–48 h for most categories, limiting the ability to capture product use over longer periods of time such as monthly or quarterly. Relatedly, our focus here was on the overall number of products used and we did not evaluate the amount of product applied or differentiate between “leave on” and “rinse off” products. Studies have suggested that in some populations, use of rinse off products is greater, however leave on products likely present greater risks of chemical exposure potential due to their prolonged contact with skin (Lang et al., 2016; Dodson et al., 2021; Manova et al., 2013). Additionally, males ($n = 90$) and non-binary or transgender individuals ($n = 1$) were not well represented, limiting our ability to adequately assess PCP use patterns and perceptions in these groups. All PCP use was self-reported, which might increase the risk of recall bias when reporting product use – although this concern was minimized as

the questionnaire instructed respondents to gather PCPs typically used so they would be available at the time of questionnaire completion. Another point to consider is that individuals in our sample were willing to spend 30–40 min to complete a questionnaire about their PCP use and perceptions, and these individuals are more likely to have a preexisting interest in or concern about the impact of PCPs on their health. Finally, we did not evaluate the ingredients used in individual product formulations in this analysis, so we are unable to characterize the relative safety or toxicity of the PCPs used by participants, however there is a clear need for that work in the future.

Despite these limitations, our results add to the growing literature on sociodemographic differences in PCP use. Self-reported product use was equal to or greater than counts reported in prior studies and overall, participants reported moderate concern about chemical exposures in PCPs. With greater awareness about the availability of non-toxic or safer PCPs (Non-Toxic Black Beauty Project), enhanced campaigns to raise awareness, changes in federal policies around manufacturing processes and ensuring the safety of chemicals in PCPs (Safer Beauty Bill Package), and development of effective interventions for ultimately changing consumer purchasing practices and PCP use will be important public health measures, particularly among vulnerable populations. Our findings also highlight the fact that while analysis of PCP use patterns and factors associated with them are widely studied among women, similar work is warranted in men and non-binary and transgender individuals, who also use PCPs regularly and are thereby also exposed to potentially harmful chemicals from these products (McDonald et al., 2022).

CRediT author statement

Adana A. M. Llanos: Conceptualization, Methodology, Investigation, Resources, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Funding acquisition. **Amber Rockson:** Data curation, Project administration, Writing – Review & Editing. **Kylie Getz:** Formal analysis, Methodology, Software, Visualization, Writing – Review & Editing. **Patricia Greenberg:** Formal analysis, Methodology, Software, Visualization, Writing – Review & Editing, Supervision. **Eva Portillo:** Writing – Original Draft, Writing – Review & Editing. **Jasmine A. McDonald:** Writing – Review & Editing. **Dede K. Teteh:** Writing – Original Draft, Writing – Review & Editing. **Justin Villasenor:** Writing – Review & Editing. **Carolina Lozada:** Software, Investigation, Writing – Review & Editing. **Jamirra Franklin:** Data curation, Writing – Review & Editing. **Vaishnavi More:** Writing – Review & Editing. **Zorimar Rivera-Núñez:** Writing – Review & Editing. **Carolyn W. Kinkade:** Data curation, Writing – Review & Editing. **Emily S. Barrett:** Conceptualization, Methodology, Investigation, Resources, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Adana A. M. Llanos and Emily S. Barrett report financial support for this study was received from the National Institute of Environmental Health Sciences (pilot funding from the NIEHS Center for Environmental Exposure and Disease at Rutgers University [P30ES005022]). Adana A. M. Llanos reports serving as a member of the Breast Cancer Prevention Partners Science Advisory Panel and the Advisory Committee of the Campaign for Safe Cosmetics’ Non-Toxic Black Beauty Project. Adana A. M. Llanos also reports receiving consulting fees for serving as an expert witness in litigation matters related to hair product use and health outcomes. Jasmine McDonald reports a relationship with Breast Cancer Prevention Partners that includes board membership and non-financial support. Jasmine A. McDonald receives consulting fees to her company, Dr.MamaBoss LLC, for serving as an expert witness in litigation matters related to personal care products and health outcomes.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.envres.2023.116719>.

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