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Associations between Personal Care Product Use Patterns and Breast Cancer Risk among White and Black Women in the Sister Study

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Background: Many personal care products include chemicals that might act as endocrine disruptors and thus increase the risk of breast cancer.

Objective: We examined the association between usage patterns of beauty, hair, and skin-related personal care products and breast cancer incidence in the Sister Study, a national prospective cohort study (enrollment 2003–2009).

Methods: Non-Hispanic black (4,452) and white women ($n = 42,453$) were examined separately using latent class analysis (LCA) to identify groups of individuals with similar patterns of self-reported product use in three categories (beauty, skin, hair). Multivariable Cox proportional hazards models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for associations between product use and breast cancer incidence.

Results: A total of 2,326 women developed breast cancer during follow-up (average follow-up = 5.4 y). Among black women, none of the latent class hazard ratios was elevated, but there were <100 cases in any category, limiting power. Among white women, those classified as "moderate" and "frequent" users of beauty products had increased risk of breast cancer relative to "infrequent" users [HR = 1.13 (95% CI: 1.00, 1.27) and HR = 1.15 (95% CI: 1.02, 1.30), respectively]. Frequent users of skincare products also had increased risk of breast cancer relative to infrequent users [HR = 1.13 (95% CI: 1.00, 1.29)]. None of the hair product classes was associated with increased breast cancer risk. The associations with beauty and skin products were stronger in postmenopausal women than in premenopausal women, but not significantly so.

Conclusions: This work generates novel hypotheses about personal care product use and breast cancer risk. Whether these results are due to specific chemicals or to other correlated behaviors needs to be evaluated. https://doi.org/10.1289/EHP1480

Introduction

There is concern that use of personal care products (e.g., cosmetics, lotions, and fragrances) may be associated with breast cancer risk (Brody et al. 2007). These products are a possible source of human exposure to endocrine-disrupting chemicals, such as phthalates, parabens, and phenols (Braun et al. 2014; Dodson et al. 2012; Meeker et al. 2013). Endocrine-disrupting chemicals have been hypothesized to mimic the carcinogenic effects of estrogenic exposures (Chen 2008; Morgan et al. 1998). For example, phthalates, an ingredient commonly used in personal care products, have been associated with risk of breast cancer (López-Carrillo et al. 2010; Shanle and Xu 2011). However, endocrine-disrupting chemicals have a much lower affinity to the estrogen receptor (ER) than does estradiol (Shanle and Xu 2011).

Women are the primary consumers of many personal care products and are disproportionately exposed to the chemicals within these products (CDC 2012). A national survey of >2,300 U.S. women reported that the average adult woman uses approximately 12 individual personal care products each day and that more than a quarter of all women use ≥15 products per day (EWG 2004). A cross-sectional analysis of women in northern Mexico reported that increased personal care product use was associated with higher urinary concentrations of monoethyl phthalate (MEP) (Romero-Franco et al. 2011), a metabolite of phthalates that are used in a range of personal care products (Koo and Lee 2004). The Environmental and Reproductive Health (EARTH) Study, a cohort study of women attending fertility clinics (18–45 y old), reported evidence of a monotonic dose–response relationship between the number of products used and urinary paraben and phthalate metabolite concentrations (Braun et al. 2014). Few studies have evaluated the association between individual personal care products, or components of products, and breast cancer risk. In addition, the studies focused on deodorant/antiperspirant and hair dye use have generally not supported an increase in risk of breast cancer (Fakri et al. 2006; López-Carrillo et al. 2010; McGrath 2003; Mirick et al. 2002; Rollison et al. 2006; Takkouche et al. 2005, 2009). One population based case–control study of women residing in northern Mexico, with 233 histopathologically confirmed breast cancer cases and 221 age-matched controls, did report that exposure to MEP may be associated with increased risk of breast cancer (López-Carrillo et al. 2010). However, the same study also reported that exposure to other phthalates used in personal care products [i.e., monobenzyl phthalate (MBzP) and mono (3-carboxypropyl) phthalate (MCPP)] was inversely associated with breast cancer (López-Carrillo et al. 2010).

A challenge facing epidemiologic studies of personal care products lies in the fact that individual chemical exposures or personal care product usage will not capture overarching patterns of use across multiple products. We have previously shown that latent class analysis could identify mutually exclusive groups of women with differing patterns of personal care product use among participants in the Sister Study (Taylor et al. 2017). We also found racial differences in population distribution across product classes. For example, we observed race-related patterns of hair product use

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Table 1. Descriptive statistics of sample population by race and number of breast cancer cases.

Characteristic	White women		Black women	
	Total *n* (%)	Cases *n* (%)	Total *n* (%)	Cases *n* (%)
Age (y)				
Total	42,447	2,146	4,450	180
35–39	1,601 (4)	49 (2)	237 (5)	8 (4)
40–44	3,536 (8)	142 (7)	480 (11)	15 (8)
45–49	6,248 (15)	293 (14)	783 (18)	27 (15)
50–54	8,022 (19)	384 (18)	993 (22)	30 (17)
55–59	8,436 (20)	418 (19)	960 (22)	48 (27)
60–64	6,631 (16)	384 (18)	596 (13)	27 (15)
64–69	5,209 (12)	308 (14)	280 (6)	21 (12)
70–74	2,764 (7)	168 (8)	121 (3)	4 (2)
Menopausal status[a]				
Total	42,432	2,145	4,447	180
Premenopausal	14,755 (35)	691 (32)	1,937 (44)	67 (37)
Postmenopausal	27,677 (65)	1,454 (68)	2,510 (56)	113 (63)
Missing or unknown	15	1	3	0
Education				
Total	42,444	2,146	4,449	180
<High school	324 (1)	15 (1)	44 (1)	14 (8)
≥High school	42,120 (99)	2,131 (99)	4,405 (99)	166 (92)
Missing	3	0	1	0
Geographic location				
Total	42,424	2,145	4,447	180
Northeast	7,744 (18)	292 (18)	420 (9)	17 (9)
Midwest	12,237 (29)	597 (28)	996 (22)	39 (22)
South	12,885 (30)	672 (31)	2,685 (60)	106 (59)
West	9,558 (23)	484 (23)	346 (8)	18 (10)
Missing, don't know, refused, or PR	23	1	3	0
Adult BMI kg/m^2				
Total	42,447	2,146	4,450	180
<25	2,253 (5)	833 (39)	737 (17)	32 (18)
25 to <30	13,282 (31)	690 (32)	1,406 (32)	55 (31)
≥30	11,612 (27)	623 (29)	2,307 (52)	93 (52)
Oral contraceptive use				
Total	42,413	2,145	4,448	180
Ever	6,538 (15)	363 (17)	621 (14)	23 (13)
Never	35,875 (85)	1,782 (83)	3,827 (86)	157 (87)
Missing	34	1	2	0
Hormone replacement therapy use				
Total	42,301	2,143	4,441	179
Ever	20,645 (49)	989 (46)	2,895 (65)	110 (61)
Never	21,655 (51)	1,154 (54)	1,546 (35)	69 (38)
Missing	146	3	9	1
Age at menarche (y)				
Total	42,447	2,146	4,339	180
<12	8,315 (20)	438 (20)	3,339 (75)	47 (26)
≥12	34,132 (80)	1,708 (80)	1,000 (25)	133 (74)
Missing	0	0	111	0
Parity				
Total	42,427	2,146	4,436	180
Nulliparous	7,782 (18)	419 (20)	831 (19)	19 (11)
1–2 children	21,783 (51)	1,108 (52)	2,512 (56)	111 (62)
≥3 children	12,862 (30)	611 (28)	1,093 (25)	50 (28)
Missing	20	0	14	0
Age at first live birth (y)				
Total	42,427	2,146	4,436	180
Nulliparous	7,782 (18)	419 (20)	831 (19)	19 (11)
<26	23,004 (54)	1,116 (52)	2,729 (61)	122 (68)
≥26	11,641 (27)	611 (28)	876 (20)	39 (22)
Missing	20	0	14	0
Total months breastfeeding				
Total	42,447	2,146	4,450	180
<12	31,550 (74)	1,643 (77)	3,881 (87)	154 (86)
≥12	10,897 (26)	503 (23)	569 (13)	26 (14)
Family history				
Total	41,333	2,102	4,089	170
One sister with breast cancer	29,986 (71)	1,343 (63)	3,061 (69)	115 (64)
≥1 sister and/or a mother with breast cancer	11,347 (27)	759 (35)	1,028 (23)	55 (31)
Missing	1,114	44	361	10

Table 1. (*Continued.*)

Characteristic	White women		Black women	
	Total *n* (%)	Cases *n* (%)	Total *n* (%)	Cases *n* (%)
Alcohol consumption				
Total	42,392	2,143	4,434	180
Never drinker	1,303 (3)	61 (3)	238 (5)	11 (6)
Former drinker	5,855 (14)	278 (13)	1,101 (25)	49 (27)
Currently drink <1 drink/d	28,905 (68)	1,458 (68)	2,861 (64)	112 (62)
Currently drink ≥1 drink/d	6,329 (15)	346 (16)	234 (5)	8 (4)
Missing	55	3	16	0
Smoking				
Total	42,391	2,144	4448	180
Never smoker	22,180 (52)	1,068 (50)	2747 (62)	113 (63)
Former smoker	16,774 (40)	914 (43)	1252 (28)	57 (32)
Current smoker	3,437 (8)	162 (8)	449 (10)	10 (6)
Missing	56	2	2	0

Note: Data are complete unless numbers of missing observations are shown. BMI, body mass index; PR, Puerto Rico.
[a]Menopausal status as assigned at baseline.

consistent with findings from previous, smaller studies (James-Todd et al. 2011; Silva et al. 2004; Tiwary 1998; Tiwary and Ward 2003). Breast cancer incidence and mortality rates also vary by race. Research has shown that black women have higher breast cancer mortality than white women even though current mammography screening rates are similar, or even slightly higher, in black women than in white women (DeSantis et al. 2016). Therefore, in the present work, we stratified by race when we evaluated patterns of beauty-, hair-, and skin-related personal care product use in association with breast cancer risk.

Methods

The Sister Study is directed at identifying environmental and genetic risk factors for breast cancer in a cohort of 50,884 women in the continental United States and Puerto Rico, enrolled during 2003–2009. Women eligible for enrollment were 35–74 y of age and had at least one sister diagnosed with breast cancer but were cancer-free themselves. Enrollment activities included a computer-assisted telephone interview and self-administered questionnaires that elicited information about environmental and reproductive exposures. This analysis includes breast cancers diagnosed as of June 1, 2014 (data release 4.1, updated July 2014). The Sister Study was approved by the institutional review boards at the National Institute of Environmental Health Sciences and Copernicus Group. All study participants provided written informed consent.

Breast Cancer Ascertainment

Participants reported breast cancer diagnoses on annual and biennial health questionnaires or by calling the Sister Study helpline. Women who reported an incident breast cancer during follow-up were asked to authorize release of pertinent medical records. Response rates were >94% over follow-up (Nichols et al. 2013). Among participants in our sample population, 2,326 breast cancers were reported for 304,034 person-years (average follow-up ~5.4 years). At the time of the present analysis, pathology reports or medical records had been obtained for >80% of these cases ($n = 1{,}923$). Confirmation of self-reported breast cancer diagnoses by medical record was very high [positive predictivevalue (PPV) = 99.5%] (NIEHS 2010). After medical record review, self-reported ER status information was confirmed for 99% of ER-positive cases and 85% of ER-negative cases. Because agreement between self-reported and medically abstracted data was high, we used self-reported tumor information when medical records were not available.

Personal Care Product Exposure

Information on the use of 48 personal care products was self-reported during the enrollment phase of the study (see Table S1) by inquiring about frequency of use (five-level response option) during the previous 12 months. The five response options in the questionnaire varied according to intended use of the product. For example, the response options for a product intended to be used regularly (e.g., hand lotion) included: *a*) did not use, *b*) used less than once a month, *c*) used 1–3 times per month, *d*) 1–5 times per week, *e*) >5 times per week. Response options for products that are used less often (e.g., hair dye) included: *a*) did not use, *b*) 1–2 times a year, *c*) every 3–4 months, *d*) every 5–8 weeks, *e*) once a month or more. Because PROC LCA requires the same number of response options for each item (i.e., each personal care product), and to ensure that each of the response options had an adequate sample size (≥10% of the sample population), the five original response options were condensed into three (rarely/never used, moderate use, and frequent use); this was done for each product individually (see Figure S1) and was based on the distribution of participants who fell into each frequency-of-use option. Products were then categorized as beauty ($n = 14$), hair ($n = 15$), or skincare ($n = 19$) products, and separate latent classes were defined for each product category. As described in more detail in our previous paper (Taylor et al. 2017), we performed latent class analyses (LCAs) using PROC LCA (Lanza et al. 2015) and SAS statistical software (version 9.3; SAS Institute Inc.). PROC LCA is an SAS procedure for latent class analysis (LCA) developed by the Methodology Center at Penn State (https://methodology.psu.edu/downloads/proclcalta). It allows the user to preprocess data, fit a variety of latent class models, and postprocess the results, all within SAS.

Latent classes within each product category were defined by item-response probabilities (Dean and Raftery 2010) for the products driving each class (Lanza et al. 2007). To identify the classes, we fit a sequence of LCA models starting with two classes and increasing up to six for each model, and we used Akaike's information criterion (AIC), the Bayesian information criterion (BIC), and entropy (Lanza et al. 2007) to select the optimum number of classes. We used a common classify-analyze approach (the maximum-probability assignment rule) to assign each participant to the class in which she had the highest posterior probability of membership (Bray et al. 2012). To reduce dimensionality and improve interpretability, classification, and precision, each product category included in our model was limited to the personal care products that were most useful for distinguishing between latent classes (i.e., ≥10% difference in posterior probabilities between classes), as described by Dean and Raftery (2010).

Table 2. Latent class descriptions by product category and distribution of breast cancer events among white and black women at time of follow-up.

Product category/class	Class description[a]	White women		Black women	
		n (%)	BC events [*n* (%)]	*n* (%)	BC events [*n* (%)]
Beauty product classes					
A. Infrequent users	Likely to have infrequent use of eye shadow, eyeliner, mascara, foundation, makeup remover, nail polish, perfume, blush and lipstick.	9,208 (22)	448 (21)	1,276 (31)	53 (32)
B. Moderate users	Likely to have moderate use of eye shadow, eyeliner, mascara, foundation, makeup remover, nail polish, perfume, blush and lipstick.	15,967 (38)	816 (38)	2,153 (52)	86 (52)
C. Frequent users	Likely to have frequent use of eye shadow, eyeliner, mascara, foundation, makeup remover, nail polish, perfume, blush and lipstick.	16,720 (40)	859 (41)	744 (18)	26 (16)
Total in analyses		41,895	2,123	4,173	165
Missing		552	23	277	15
Hair product classes					
A. Infrequent users of hair spray	Likely to have infrequent use of hair spray, hair gel, pomade and hair straightener); frequent use of shampoo, conditioner	20,896 (50)	1,059 (50)	1,006 (24)	42 (25)
B. Moderate users of pomade, hair straightener, hair spray, and conditioner	Likely to have infrequent use of shampoo, hair gel; moderate use of hair spray, conditioner, pomade, and hair straightener	1,178 (3)	61 (3)	2,984 (72)	118 (72)
C. Frequent users of hair spray and hair gel	Likely to have frequent use of hair spray, hair gel, shampoo, conditioner; infrequent use of pomade and hair straightener	19,609 (47)	997 (47)	172 (4)	5 (3)
Total in analyses		41,683	2,117	4,162	165
Missing		764	29	288	15
Skincare product classes					
A. Infrequent users	Likely to have infrequent use of face cream, cleansing cream, antiaging cream, foot cream, body lotion and hand lotion, petroleum jelly, and talcum powder[b]	7,936 (19)	404 (19)	810 (19)	39 (24)
B. Moderate users	Likely to have moderate use of face cream, cleansing cream, antiaging cream, foot cream, body lotion and hand lotion; infrequent use of petroleum jelly and talcum powder[b]	18,572 (44)	930 (44)	2,186 (52)	88 (53)
C. Frequent users	Likely to have frequent use of face cream, cleansing cream, antiaging cream, foot cream body lotion, and hand lotion; infrequent use of petroleum jelly and talcum powder[b]	10,236 (25)	548 (26)	551 (13)	23 (14)
D. Talcum powder users	Likely to have frequent use of face cream, cleansing cream, antiaging cream, foot cream body lotion, and hand lotion; most frequent use of petroleum jelly, hand lotion, and talcum powder[b]	5,148 (12)	242 (11)	625 (15)	15 (9)
Total in analyses		41,892	2,124	4,172	165
Missing		555	22	278	15

Note: BC, breast cancer.
[a]Class labels and descriptions are based on likely item-response probabilities for each product, but all responses for individual women may not fit these parameters; each class is described relative to the other classes in each product category (Taylor et al. 2017).
[b]Refers to two different uses of talcum powder: talcum powder applied under arms and talcum powder applied elsewhere.

Within each product category, latent classes were described and considered as exposure groups. Women with missing data for any of the individual products included in the corresponding product category (i.e., beauty products, hair products, and skincare products) were classified as missing for a latent class assignment in that product category and were not included in statistical analyses.

Statistical Analysis

The present analysis was limited to non-Hispanic white ($n = 42{,}447$, 91%) and non-Hispanic black ($n = 4{,}450$, 9%) women (Table 1). Multivariable Cox proportional hazards models were used to estimate adjusted hazard ratios (adjHRs) and 95% confidence intervals (CIs) for associations between the personal care product latent classes and breast cancer risk. Statistical models used age as the time scale, where participants entered the analysis at their enrollment age (left-truncation) and accrued person-time until they exited at their cancer diagnosis or were administratively censored at their age at last follow-up. Women who reported that they had undergone natural menopause, bilateral oophorectomy, irradiation to the ovaries, or otherwise reported cessation of menstruation were classified as postmenopausal; women who reported that they were still cycling were classified as premenopausal. In analyses investigating associations by menopausal status at the time of breast cancer diagnosis, the person-time of women who became postmenopausal during the follow-up period was counted as premenopausal time at risk up until menopause (after which it was censored for the premenopausal analysis), and subsequent person-time after menopause was counted as postmenopausal person-time at risk. The proportional hazards assumption was visually assessed using ln-ln survival plots; there was no suggestion of time-variant associations.

Models were stratified by race, menopausal status, or both at time of diagnosis or follow-up. The following covariates, measured at baseline, were included in adjusted models: menopausal status (premenopausal or postmenopausal), age at menarche (<12 y or ≥12 y), age at first birth (nulliparous, <26 y, or ≥26 y), parity (nulliparous, 1–2 children, or ≥3 children), duration of breastfeeding (<12 mo or ≥12 mo), oral contraceptive (OC) use (ever or never), hormone therapy (HT) use (ever or never), education (<high school or ≥high school), alcohol consumption (never drinker, former drinker, currently drink <1 drink/d, or currently drink ≥1 drink/d), adult body mass index (BMI) (<25 kg/m^2, 25 to <30 kg/m^2, or ≥30 kg/m^2), family history (having one sister with breast cancer or ≥1 sister and/or a mother with breast cancer), smoking status (never

Table 3. Hazard ratios and 95% confidence intervals for the association between personal care product latent classes and overall breast cancer risk among white and black women.

	White women				Black women			
Exposure	Person-years[a]	BC events[a]	HR (95% CI)[b]	adjHR (95% CI)[c]	Person-years[a]	BC events[a]	HR (95% CI)[b]	adjHR (95% CI)[c]
Beauty classes								
Infrequent user	60,484	448	1	1	7,066	53	1	1
Moderate user	104,790	816	1.13 (1.01, 1.27)	1.13 (1.00, 1.27)	11,782	86	1.00 (0.71, 1.40)	0.95 (0.66, 1.36)
Frequent user	111,191	859	1.12 (1.00, 1.26)	1.15 (1.02, 1.30)	4,171	26	0.85 (0.53, 1.36)	0.86 (0.53, 1.39)
Totals	276,464	2,123			23,019	165		
Hair classes								
Infrequent users of hair spray	137,672	1,059	1	1	5,615	42	1	1
Moderate users of pomade, hair straightener, hair spray, and conditioner	7,686	61	0.91 (0.70, 1.18)	0.91 (0.70, 1.19)	16,333	118	0.93 (0.65, 1.32)	0.90 (0.63, 1.28)
Frequent users of hair spray and hair gel	129,205	997	1.01 (0.93, 1.10)	1.02 (0.93, 1.11)	998	5	—	—
Totals	274,563	2,117			22,946	165		
Skincare classes								
Infrequent user	52,506	404	1	1	4,311	39	1	1
Moderate user	123,010	930	1.00 (0.89, 1.12)	1.03 (0.91, 1.17)	12,124	88	0.76 (0.52, 1.11)	0.75 (0.51, 1.10)
Frequent user	66,346	548	1.11(0.98, 1.27)	1.13 (1.00, 1.29)	3,032	23	0.82 (0.49, 1.38)	0.79 (0.47, 1.34)
Talcum powder user	34,582	242	0.90 (0.77, 1.06)	0.92 (0.78, 1.08)	3,542	15	—	—
Totals	276,444	2,124			23,009	165		

Note: —, <20 cases; adjHR, adjusted hazard ratio; BC, breast cancer; CI, confidence interval; HR, hazard ratio.
[a]Numbers of person-years and BC events are for women with complete data for each product class only; after accounting for missing data, total numbers of person-years and BC events were 279,699 and 2,146, respectively, for white women and 24,336 and 180, respectively, for black women; results were not reported if <20 BC events.
[b]Models accounted for age by using age as the time scale, where participants entered the analysis at their enrollment age (left-truncation) and accrued person-time until they exited at their cancer diagnosis or were administratively censored at their age at last follow-up.
[c]In addition to the adjustments described in [b], models were adjusted for baseline menopausal status, parity, age at first live birth, duration of breastfeeding, adult body mass index, alcohol use, oral contraceptive use, hormone therapy use, education, family history, region of residence, age at menarche, and smoking status.

smoker, former smoker, current smoker), and current region of residence (West, South, North, East). Interaction by menopausal status was tested by adding an interaction term for menopausal status and latent class into the Cox proportional hazard models stratified by race. In sensitivity analyses among postmenopausal white women only (the only subgroup with sufficient numbers for this analysis), models were stratified by ER status (ER positive or ER negative according to the clinical record) and breast cancer type (*in situ* or invasive).

For all analyses, results are presented only for the personal care product latent classes that included ≥20 exposed breast cancer cases.

Results

During the 304,034 person-years contributed by 46,897 black and white non-Hispanic women, 2,326 breast cancers were diagnosed (average follow-up ∼5.4 years). Characteristics of the women included in the present study population are provided in Table 1. As previously reported (Taylor et al. 2017), our final LCA model included nine beauty products (mascara, lipstick, foundation, nail polish, perfume, eye shadow, eyeliner, blush, and makeup remover), six hair products (pomade, hair straightener, conditioner, hair spray, hair gel, and shampoo), and nine skincare products (cleansing cream, antiaging cream, body lotion, hand lotion, face cream, foot cream, petroleum jelly, talcum powder applied under arms, and talcum powder applied elsewhere) (see Table S1).

Latent classes within each category of products were described (Table 2) based on the item response probabilities for frequency of use of the different products (see Figure S1). Although women within any given class are more likely than women in the other classes to have frequencies of product use as described in Table 2, all the individual responses may not fit those parameters. Our final model included three latent classes for beauty products, three for hair products, and four for skincare products, as described in detail in Table 2. Associations between product use latent classes and breast cancer are shown in Table 3. With only 165 incident breast cancer cases in black women, some latent classes lacked the 20 exposed cases we required for analysis, and those that were analyzed showed no evidence of association with breast cancer incidence.

Among white women, "moderate" and "frequent" users of beauty products had increased risk of breast cancer relative to "infrequent" users [moderate users, adjHR = 1.13 (95% CI: 1.00, 1.27) and frequent users, adjHR = 1.15 (95% CI: 1.02, 1.30)] (Table 3). Similarly, among white women, frequent users of skincare products had increased risk of breast cancer relative to infrequent users [adjHR = 1.13 (95% CI: 1.00, 1.29)]. Patterns of hair product use were not associated with breast cancer incidence.

In analyses stratified by menopausal status (conducted in white women only), HRs for breast cancer associated with the frequent (compared with the infrequent) users of beauty or skincare products were higher among postmenopausal women [adjHR = 1.18 (95% CI: 1.14, 1.21) and 1.12 (95% CI: 1.09, 1.16), respectively] than premenopausal women [adjHR = 1.01 (95% CI: 0.76, 1.33) and 1.06 (95% CI: 0.79, 1.42), respectively] but were not statistically different (p-interaction 0.33 and 0.65, respectively) (Table 4).

In exploratory analyses, ER status was available for 85% (n = 1,420) of white postmenopausal women with a breast cancer diagnosis (the only subgroup with sufficient numbers for this analysis). In this group (see Table S2), the association between breast cancer and moderate and frequent users (compared to infrequent users) of beauty products did not appear to differ substantially between ER+ [adjHR = 1.05 (95% CI: 0.90, 1.23) and adjHR = 1.10 (95% CI: 0.94, 1.28), respectively] and ER− [adjHR = 1.03 (95% CI: 0.69, 1.54) and adjHR = 0.72 (95% CI: 0.47, 1.10), respectively]. However, because the overall HRs

Table 4. Hazard ratios and 95% confidence intervals for the association between latent classes and breast cancer risk among postmenopausal and premenopausal white women at time of breast cancer diagnosis.

	Premenopausal				Postmenopausal				
Exposure	Person-years	BC events[a]	HR (95% CI)[b]	adjHR (95% CI)[c]	Person-years	BC events[a]	HR (95% CI)[b]	adjHR (95% CI)[c]	Interaction p-Value[d]
Beauty Classes									
Infrequent user	6,834	74	1	1	53,247	372	1	1	
Moderate user	19,586	177	0.99 (0.75, 1.30)	0.98 (0.74, 1.30)	84,289	631	1.13 (1.10, 1.16)	1.16 (1.12, 1.19)	0.26
Frequent user	19,861	191	1.01 (0.77, 1.33)	1.01 (0.76, 1.33)	90,181	656	1.14 (1.10, 1.17)	1.18 (1.14, 1.21)	0.33
Totals[e]	46,281	442			227,717	1,659			
Hair Classes									
Infrequent users of hair spray	21,377	208	1	1	115,014	841	1	1	
Moderate users of hair spray, conditioner, pomade and hair straightener	443	4	—	—	7,190	56	0.76 (0.71, 0.81)	0.76 (0.71, 0.81)	0.46
Frequent users of hair spray and hair gel	24,277	229	1.07 (0.89, 1.29)	1.04 (0.86, 1.26)	103,825	757	1.01 (0.99, 1.03)	1.03 (1.01, 1.06)	0.84
Totals[e]	46,097	441			226,029	1,654			
Skincare Classes									
Infrequent user	8,266	76	1	1	43,793	324	1	1	
Moderate user	20,031	200	1.09 (0.84, 1.42)	1.06 (0.81, 1.39)	101,807	721	1.05 (1.02, 1.08)	1.08 (1.05, 1.12)	0.51
Frequent user	13,152	122	1.07 (0.80, 1.42)	1.06 (0.79, 1.42)	52,621	420	1.11 (1.07, 1.14)	1.12 (1.09, 1.16)	0.65
Talcum powder user	4,853	44	0.88 (0.61, 1.29)	0.84 (0.57, 1.23)	29,453	195	0.99 (0.95, 1.03)	1.03 (0.99, 1.07)	0.91
Totals[e]	46,302	442			227,674	1,660			

Note: adjHR, adjusted hazard ratio; BC, breast cancer; CI, confidence interval; HR, hazard ratio.
[a]Total numbers of BC events and person-years are for women with complete data for each product class; after accounting for missing data, among women with known menopausal status, total numbers of person-years and BC events were 47,166 and 445, respectively, for premenopausal white women and 230,023 and 1,679, respectively, for postmenopausal white women; results were not reported if <20 BC events.
[b]Models accounted for age by using age as the time scale, where participants entered the analysis at their enrollment age (left-truncation) and accrued person-time until they exited at their cancer diagnosis or were administratively censored at their age at last follow-up.
[c]In addition to the adjustments described in [b], models were adjusted for baseline menopausal status, parity, age at first live birth, duration of breastfeeding, adult body mass index, alcohol use, oral contraceptive use, hormone therapy use, education, family history, region of residence, age at menarche, and smoking status. Results were not reported if <20 BC events.
[d]p-Value for interaction by menopausal status, derived by adding interaction term to adjusted Cox proportional hazard model for pre- and postmenopausal white women.
[e]Women with unknown or missing menopausal status at follow-up ($n = 346$) were excluded; $n = 22$ breast cancer cases were premenopausal at baseline and had an unknown menopausal status at follow-up.

for women with known ER status are not consistent with the stratum-specific hazard ratios, it is unlikely that women were missing ER status at random, so the HRs presented may be biased. When white postmenopausal women were stratified by breast cancer type, *in situ* ($n = 326$) and invasive ($n = 1,091$) (see Table S3), and compared with infrequent use, moderate and frequent use of beauty products were associated with higher risk of *in situ* breast cancer [adjHR = 1.41 (95% CI: 1.06, 1.89) and adjHR = 1.38 (95% CI: 1.03, 1.85), respectively] but not with invasive breast cancer [adjHR = 1.09 (95% CI: 0.94, 1.27) and adjHR = 1.13 (95% CI: 0.97, 1.32), respectively].

Discussion

Our findings from this large, prospective study with detailed self-report of personal care product use suggest that for non-Hispanic white women (the majority of the cohort), the risk of breast cancer was 10–15% higher among those classified as moderate and frequent users of beauty products than among women classified as infrequent users of beauty products. When stratified by menopausal status, associations with beauty product use appeared to be limited to postmenopausal white women because all HRs for premenopausal women were close to the null. Frequent users of beauty products can be broadly categorized as women who report using a combination of beauty products on a weekly basis (e.g., mascara, foundation, and lipstick). Moderate users were more likely to report using these same products at least monthly or up to several times a month. The relative risk of breast cancer among non-Hispanic white women classified as frequent users of skincare products (likely to use cleansing cream, antiaging cream, body lotion, hand lotion, face cream, and foot cream at least weekly, but unlikely to use talcum powder) was approximately 13% higher (95% CI: 0, 29%) than among women classified as infrequent users of skincare products.

The hypothesis that personal care products are associated with increased breast cancer risk is primarily based on animal and laboratory studies. In these settings, chemicals found in a wide variety of personal care products (e.g., parabens and phthalates) mimic estrogens (Davis et al. 1993), alter hormonal signaling, affect developing reproductive systems (Colborn et al. 1993), disrupt normal mammary development (Macon 2013), or provide a combination of any or all of these effects. The association between beauty latent classes and breast cancer risk appeared stronger among postmenopausal women than among premenopausal women. This finding is consistent with the hypothesis that weak estrogenic effects might have a greater impact during the postmenopausal period because women with lower endogenous estrogen levels are more susceptible to exogenous estrogenic exposures.

It is important to acknowledge that the frequency of use of different beauty products may not be a true risk factor for breast cancer but may instead be a proxy marker for other breast cancer risk factors. Similarly, the frequency of use of different personal care products might be associated with the likelihood of screenings and mammograms, and thus the likelihood that a woman would be diagnosed with a carcinoma *in situ*.

Personal care product exposure is difficult to characterize because each product is a complex mixture, and multiple products are often used in combination by one person. Co-occurring

exposures may have additive or interacting effects or may result in confounding. For example, a chemical that does not show estrogenic activity could be a marker for other chemicals that are estrogenic. Products that include chemicals that can be estrogenic may show either estrogenic or antiestrogenic effects in specific tissues (Myers et al. 2015). We used LCA as an innovative method for characterizing exposure to mixtures. As mentioned in previous work (Taylor et al. 2017), relative to individual product use questions, latent class variables capture complex patterns of personal care product usage and have been used to capture complex exposures in a variety of research settings (Lanza et al. 2010; Lanza and Rhoades 2013). LCA also addresses many limitations related to mixtures. For example, latent classes can be used to describe the variability among multiple correlated and observed exposures. However, although this approach provides insights about patterns of use, it does not allow us to address the individual and combined effects of separate agents. Previous studies have examined correlation structure between specific personal care products (Biesterbos et al. 2013; Manová et al. 2013; Wu et al. 2010), but these studies did not evaluate associations between personal care product use and health outcomes.

Our study was not able to assess breast cancer risk associated with specific chemicals. The questionnaire did not capture information on specific brands of personal care products or on the individual components of these products, nor did it capture potential changes in brand preference over time. In a previous study, brand loyalty varied greatly by product type; there was less loyalty for antiaging products, antibacterial liquid soap, and hair mousse, and more loyalty for contact lens solution and lip balm (Wu et al. 2010). However, that study population was limited to 604 households in northern California and may not be generalizable to the U.S. population. Additionally, even if product brand information were available from our study population, manufacturers are not required to disclose all chemical ingredients in consumer products (EWG 2012). Chemical compositions of products change over time and across batches, and chemicals [e.g., bisphenol A (BPA)] can leach from containers into the product (Yang et al. 2011). In addition to the challenges involved in collecting brand information, exposure may vary depending on how products are used or applied. Thus, it was not feasible for us to ascertain exposures to individual chemicals from the questionnaire data.

Our study addresses the idea that combinations and patterns of exposure may be particularly important in relation to risk. The large sample size of white women, detailed self-report of personal care product use, prospective identification of breast cancer, multivariable analysis, and inclusion of both the aggregated and individual exposure data strengthen our study. Women provided information on personal care products used during the twelve months before enrollment. We do not know how constant women's exposures are over time, or if product use at baseline would capture use during etiologically relevant time windows of exposure, which may have occurred years in the past. Latency periods of 8 to 15 y have been reported for breast cancer (Aschengrau et al. 1998; Brody et al. 2007; Lewis-Michl et al. 1996; Petralia et al. 1999), and empirical induction periods could be at least one to two decades (Brody et al. 2007). However, if the exposure acts primarily on tumor survival and growth, more recent exposures may be relevant. Additional research is needed to investigate the stability of personal care product use within different populations of women and to identify relevant windows of exposure.

Our study has other limitations. First, we had limited power to examine associations among black women. As previously reported (Taylor et al. 2017), we observed that latent class distribution differed by race. We observed race-related patterns of hair product use: The class that was characterized by moderate use of pomade, hair straightener, hair spray, and conditioner contained the majority of black women, but only 3% of white women (Aschengrau et al. 1998; Brody et al. 2007; Lewis-Michl et al. 1996; Petralia et al. 1999). The associations we report between breast cancer and personal care product use are modest in magnitude and do not show a dose–response relationship. Finally, although our study was motivated by the literature on endocrine disruptors, the results may have other interpretations. The finding that the associations tended to be stronger for *in situ* than for invasive breast cancer raises the concern that the latent classes might be confounded to some extent by cancer-screening behavior. Some *in situ* lesions never progress to invasive cancer (Kerlikowske et al. 2010), and if frequent beauty and skincare product users are screened more often, such lesions may be over-represented. If so, the observed associations may have little causal relationship. Even if screening frequency is not an issue, given the relatively modest hazard ratios and the opportunity for exposure misclassification, further epidemiologic and mechanistic studies would be needed to infer causality.

Conclusion

The results from this study generate novel hypotheses concerning the relationship between the use of personal care products and risk of breast cancer. Evidence that breast cancer may be associated with moderate or frequent beauty product use or with frequent skincare product use may indicate effects of chemicals used in the products, although noncausal associations resulting from confounding by correlated behaviors and conditions are also possible. Future work should also address duration of exposure and how product use patterns vary over time.

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