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Hair product use and breast cancer risk among African American and White women

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Abstract

Exposures to carcinogens in hair products have been explored as breast cancer risk factors, yielding equivocal findings. We examined hair product use (hair dyes, chemical relaxers and cholesterol or placenta-containing conditioners) among African American (AA) and White women, and explored associations with breast cancer. Multivariable-adjusted models were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) to describe the associations of interest among 2280 cases (1508 AA and 772 White) and 2005 controls (1290 AA and 715 White). Among controls, hair dye use was more common among Whites than AAs (58 versus 30%), while relaxer (88 versus 5%) and deep conditioner use (59 versus 6%) was more common among AAs. Among AAs, use of dark hair dye shades was associated with increased breast cancer risk (OR = 1.51, 95% CI: 1.20–1.90) and use of dark shades (OR = 1.72, 95% CI: 1.30–2.26) and higher frequency of use (OR = 1.36, 95% CI: 1.01–1.84) were associated with ER+ disease. Among Whites, relaxer use (OR = 1.74, 95% CI: 1.11–2.74) and dual use of relaxers and hair dyes (OR = 2.40, 95% CI: 1.35–4.27) was associated with breast cancer; use of dark hair dyes was associated with increased ER+ disease (OR = 1.54, 95% CI: 1.01–2.33), and relaxer use was associated with increased ER– disease (OR = 2.56, 95% CI: 1.06–6.16). These novel findings provide support a relationship between the use of some hair products and breast cancer. Further examinations of hair products as important exposures contributing to breast cancer carcinogenesis are necessary.

Introduction

Breast cancer is the most frequently diagnosed cancer and the second leading cause of cancer death among women in the United States (1). Historically, African American (AA) women were shown to have lower breast cancer incidence rates compared to White women, but recent data show a convergence of these rates, although AA women continue to have higher breast cancer incidence at younger ages and higher rates of breast cancer mortality (1,2). While there has been much inquiry

into risk factors for breast cancer and how differences among women may contribute to observed disparities, few studies have explored the contribution of hair product use among AA women.

Data from some animal models (3–5) suggest that exposures to compounds found in some hair products, particularly those exhibiting endocrine disrupting behaviors and potential mutagens, may be etiologic risk factors for several human cancers. However, much of the epidemiologic data have been equivocal

Abbreviations

AA	African American
CI	confidence interval
ER	estrogen receptor
OR	odds ratio
WCHS	Women's Circle of Health Study

(6–22) and came from studies conducted predominantly in White women (6,7,9,11–14,18–21). Only one study to date (23) has examined the association between chemical relaxer/straightener use and breast cancer among AA women, finding no association between relaxer use and breast cancer risk. Although relaxer use is not as common among Whites as AAs (24–26), examination of associations between relaxer use and breast cancer in this group is needed. A recent review paper (25) concluded that there is evidence to support a role of hair product use in risk of early onset breast cancer particularly in AA women. This review also highlighted critical periods of exposure including in utero, during puberty and during pregnancy, which have a potential to result in alterations of mammary gland development that may be associated with increased risk of breast cancer.

The objective of this study was to examine the prevalence and patterns of use of hair products, specifically hair dye, chemical relaxers and deep conditioning creams containing cholesterol or placenta and their associations with breast cancer risk and whether the risks vary by estrogen receptor (ER) status among AA and White women in the Women's Circle of Health Study (WCHS).

Materials and methods

Study participants

As previously described (27–31), the WCHS is a case-control study conducted in metropolitan New York City (NYC) and ten counties in New Jersey (NJ). Breast cancer cases with histologically confirmed ductal carcinoma in situ or invasive breast cancer (stages I–IV), who self-identified as either Black/African American or White/European American, were age 20–75 years, able to complete an interview in English, and had no history of cancer except non-melanoma skin cancer, were eligible to participate. Eligibility for controls included no history of cancer except non-melanoma skin cancer and the same age and English language criteria as breast cancer cases. Recruitment in NYC was conducted between January 2002 and December 2008. Case identification was done through the hospitals within the five boroughs with the largest referrals for AA women. Frequency-matched controls (matched on age and race) were recruited through random digit dialing, with sampling based on the same telephone exchanges as cases receiving breast cancer care at participating hospitals. Recruitment in NJ began in March 2006 and is ongoing. Breast cancer cases residing in ten NJ counties were identified through rapid case ascertainment by the NJ State Cancer Registry. In NJ, a combination of random digit dialing and community-based recruitment (facilitated by AA breast cancer advocacy groups and cancer support organizations, AA churches and community centers) was used to identify frequency-matched controls (matched to cases by age and county of residence). A more detailed description of the community-based control recruitment process is available elsewhere (32). For the present analysis, we included cases and controls recruited through 2014. A total of 2280 cases (1508 AA and 772 White) and 2005 controls (1290 AA and 715 White) completed the baseline interview and were included in the present analysis.

Data collection

Data collection for the WCHS was conducted through in-person interviews and anthropometric and body composition measurements. The baseline study questionnaire ascertained information on sociodemographics and established and probable breast cancer risk factors, including: family and personal health history, prenatal exposures, reproductive

history and hormone use and lifestyle exposures (e.g. hair product use, tobacco smoke exposure, alcohol consumption, physical activity, vitamin use). Anthropometric measurements (height, weight, waist and hip circumference measures) and body composition measures (lean and fat mass, percent body fat) were also taken at the in-person, baseline interview using standardized protocols and instruments (33). For breast cancer cases, tumor pathology and hormone receptor data were collected through medical and pathology records obtained from hospitals where breast cancer care was received.

In terms of hair product use, the baseline interview queried on participants' use of hair dyes, chemical relaxers/straighteners and cholesterol- or placenta-containing deep conditioning creams. Regular hair dye use was defined as 'having ever used permanent hair dye for at least 1 year at a rate of ≥ 2 times per year'. Data collected on patterns of hair dye use included the age women started regularly using hair dye, the typical annual frequency of use, the typical shade used, typical application used (home-kit or salon), total duration (years) of use and frequency of use. Regular use of chemical relaxers/straighteners (referred to as 'relaxers' hereafter) was defined as 'having ever chemically relaxed or straightened hair for at least 1 year'. Data collected on patterns of use of relaxers included use of lye or no-lye relaxers, typical application used, total duration (years) of use and frequency of use. We also collected patterns of use of relaxers at various ages (≤ 12 , 13–19 and ≥ 20 years). Regular use of cholesterol- or placenta-containing conditioning creams (referred to as 'deep conditioners' hereafter) was defined as 'having ever used deep conditioning hair creams that contain cholesterol or placenta for at least 1 year'. Data collected on patterns of use of deep conditioners included patterns of use at different ages and frequency of use.

This study was approved by the Institutional Review Boards of all participating institutions and all study participants provided written informed consent prior to the interview.

Statistical analysis

Hair product use and patterns of use (stratified by race) were described using frequencies and proportions. Chi-square tests were used to compare differences in hair product variables by case-control status among AA and White women. To address concerns of multiple comparisons, Bonferroni correction was used. Race-stratified, age-adjusted and multivariable-adjusted unconditional logistic regression models were used to estimate odds ratios (OR) and 95% confidence intervals (CI) to describe the associations between hair product use including patterns of use and breast cancer risk among AA and White women. We used a backward selection process to identify a parsimonious multivariable model, whereby potential confounders were selected *a priori* and omitted based on the *P* value ($P > 0.10$ criterion). We started with established and suspected breast cancer risk factors [age, education, body mass index (BMI), family history of breast cancer, age at menarche, parity, oral contraceptive use and hormone replacement therapy use]; the final multivariable model included the following covariates: age, education, BMI, family history of breast cancer and oral contraceptive use. We also explored the multivariable adjusted associations between hair product use including patterns of use and risk of breast cancer by ER (ER–, ER+) and triple-negative (TN) status. All reported *P* values are two-sided and $P < 0.05$ was considered statistically significant. Analyses were performed using SAS (v9.3 SAS Institute, Cary, NC).

Results

Race-stratified distributions of sociodemographic, clinical and reproductive characteristics, as well as hair product use and patterns of use among WCHS participants are shown in Table 1. As previously reported (28–31), Whites reported higher levels of education, fewer children and lower BMI. Additionally, White women were more likely than AA women to have ever used postmenopausal hormone replacement therapy. Cases were more likely than controls to be older, have a family history and be less educated. In terms of hair product use, among controls, ~30% of AAs and 58% of Whites reported regular use of hair dyes; 88% of AAs and 5% of Whites reported regular use of relaxers; and 59% of AAs and 6% of Whites reported regular use of deep

Table 1. Selected characteristics and hair product use and patterns of use in the Women's Circle of Health Study, by race

	African American women, n = 2798		P	European American women, n = 1487		P
	Cases (n = 1508)	Controls (n = 1290)		Cases (n = 772)	Controls (n = 715)	
	n (%)	n (%)		n (%)	n (%)	
Sociodemographic and clinical/reproductive characteristics						
Age (years), mean ± SD	52.7 ± 10.7	50.9 ± 10.3	<0.0001	52.0 ± 10.0	49.8 ± 8.7	<0.0001
Education			0.001			<0.0001
Less than 12th grade	186 (12.3)	154 (11.9)		22 (2.9)	10 (1.4)	
High school graduate or equivalent	478 (31.7)	321 (24.9)		130 (16.8)	70 (9.8)	
Some college	420 (27.9)	386 (29.9)		169 (21.9)	134 (18.7)	
College graduate	264 (17.5)	268 (20.8)		235 (30.4)	231 (32.3)	
Post-graduate	160 (10.6)	161 (12.5)		216 (28.0)	270 (37.8)	
Body mass index (kg/m ²), mean ± SD	31.6 ± 7.1	32.2 ± 7.8	0.03	27.1 ± 6.4	27.3 ± 7.1	0.45
Family history of breast cancer			0.0005			0.002
No	1266 (84.0)	1142 (88.5)		593 (76.8)	596 (83.4)	
Yes	242 (16.0)	148 (11.5)		179 (23.2)	119 (16.6)	
Age at menarche (years), mean±SD	12.5 ± 1.9	12.5 ± 1.9	0.62	12.5 ± 1.5	12.6 ± 1.5	0.28
Parity			0.93			0.21
Nulliparous	241 (16.0)	211 (16.4)		243 (31.5)	206 (28.8)	
1–2	762 (50.5)	643 (49.8)		361 (46.8)	367 (51.3)	
≥3	505 (33.5)	436 (33.8)		168 (21.8)	142 (19.9)	
History of oral contraceptive use			0.04			0.02
No	551 (36.6)	519 (40.3)		270 (35.1)	210 (29.4)	
Yes	956 (63.4)	768 (59.7)		500 (64.9)	505 (70.6)	
History of hormone replacement therapy use			0.01			0.23
No	1277 (82.3)	1138 (88.4)		575 (74.5)	551 (77.2)	
Yes	221 (14.7)	149 (11.6)		197 (25.5)	163 (22.8)	
Hair product use and patterns of use						
<i>Hair dye</i>						
History of regular hair dye use			0.06			0.09
No	1000 (66.5)	899 (69.7)		292 (37.9)	302 (42.2)	
Yes	505 (33.5)	390 (30.3)		479 (62.1)	413 (57.8)	
Total duration of hair dye use (years)			0.17			0.19
Non-user	1000 (66.9)	899 (70.1)		292 (38.8)	302 (43.5)	
≤10 years	305 (20.4)	230 (17.9)		215 (28.6)	186 (26.8)	
>10 years	190 (12.7)	154 (12.0)		245 (32.6)	206 (29.7)	
Frequency of use of typical hair dye			0.12			0.21
Non-user	1000 (67.1)	899 (70.3)		292 (38.0)	302 (42.4)	
Twice per year or less	313 (21.0)	254 (19.9)		223 (29.0)	187 (26.2)	
More than twice per year	178 (11.9)	126 (9.8)		254 (33.0)	224 (31.4)	
Typical shade of hair dye used			0.0006			0.30
Non-user	1000 (66.4)	899 (69.7)		292 (37.9)	302 (42.3)	
Light (blonde, light brown)	140 (9.3)	133 (10.3)		180 (23.4)	165 (23.1)	
Medium (medium brown, red)	123 (8.2)	119 (9.2)		198 (25.7)	168 (23.5)	
Dark (dark brown, black)	242 (16.1)	138 (10.7)		100 (13.0)	79 (11.1)	
Typical application of hair dye			0.09			0.29
Non-user	1000 (66.5)	899 (69.9)		292 (38.9)	302 (43.2)	
Salon	214 (14.2)	145 (11.3)		152 (20.2)	142 (20.3)	
Home kit	118 (7.9)	107 (8.3)		193 (25.7)	155 (22.2)	
Both	171 (11.4)	135 (10.5)		114 (15.2)	100 (14.3)	
<i>Chemical relaxer/straightener</i>						
History of regular chemical relaxer use			0.50			0.02
No	188 (12.5)	149 (11.7)		681 (92.3)	652 (95.2)	
Yes	1311 (87.5)	1124 (88.3)		57 (7.7)	33 (4.8)	
Total duration of relaxer use (years)			0.70			0.005
Non-user	188 (12.6)	149 (11.8)		681 (92.4)	652 (95.3)	
≤10 years	203 (13.6)	158 (12.5)		45 (6.1)	30 (4.4)	
11–20 years	262 (17.6)	226 (17.9)		2 (0.3)	2 (0.3)	
>20 years	838 (56.2)	732 (57.9)		9 (1.2)	0 (0.0)	

Table 1. Continued

	African American women, n = 2798		P	European American women, n = 1487		P
	Cases (n = 1508)	Controls (n = 1290)		Cases (n = 772)	Controls (n = 715)	
	n (%)	n (%)		n (%)	n (%)	
Frequency of relaxer use at age ≤12 years			0.67			0.11
Non-use	188 (59.5)	149 (57.5)		681 (98.8)	652 (99.7)	
Twice per year or less	73 (23.1)	68 (26.3)		8 (1.2)	2 (0.3)	
More than twice per year	55 (17.4)	42 (16.2)		0 (0.0)	0 (0.0)	
Frequency of relaxer use at age 13–19 years			0.26			0.54
Non-use	188 (21.4)	149 (18.9)		681 (97.0)	652 (96.4)	
Twice per year or less	405 (46.1)	393 (49.9)		21 (3.0)	23 (3.4)	
More than twice per year	285 (32.5)	246 (31.2)		0 (0.0)	1 (0.2)	
Frequency of relaxer use at age ≥20 years			0.17			0.001
Non-use	188 (12.9)	149 (12.0)		681 (94.7)	652 (98.3)	
Twice per year or less	778 (53.4)	708 (57.0)		35 (4.9)	11 (1.7)	
More than twice per year	491 (33.7)	385 (31.0)		3 (0.4)	0 (0.0)	
Type of chemical relaxer typically used			0.0008			0.04
Non-user	188 (19.5)	149 (12.3)		681 (96.6)	652 (98.6)	
No-lye	627 (44.2)	624 (51.4)		16 (2.3)	7 (1.1)	
Lye ^a	604 (42.6)	440 (36.3)		8 (1.1)	2 (0.3)	
Typical application of chemical relaxer			0.07			0.01
Non-user	188 (12.5)	149 (11.7)		681 (92.3)	652 (95.2)	
Salon	233 (15.6)	232 (18.3)		14 (1.9)	16 (2.3)	
Home-kit	441 (29.5)	401 (31.6)		40 (5.4)	15 (2.2)	
Both	634 (42.4)	488 (38.4)		3 (0.4)	2 (0.3)	
History of use of both chemical relaxer and hair dye			0.08			0.003
No	992 (68.8)	884 (71.9)		271 (86.3)	288 (93.5)	
Yes	450 (31.2)	346 (28.1)		43 (13.7)	20 (6.5)	
Deep conditioning cream (containing cholesterol or placenta)						
History of deep conditioning cream use			0.07			0.26
No	638 (44.2)	498 (40.8)		657 (92.0)	628 (93.6)	
Yes	804 (55.8)	724 (59.2)		57 (8.0)	43 (6.4)	
Total duration of deep conditioning cream use (years)			0.14			0.46
Non-user	638 (44.7)	498 (41.0)		657 (92.0)	628 (93.7)	
≤10 years	255 (17.9)	225 (18.5)		43 (6.0)	32 (4.8)	
>10 years	534 (37.4)	492 (40.5)		14 (2.0)	10 (1.5)	

Percentages may not sum to 100 due to rounding. P values generated using chi-square or Fisher's exact test (where cells have counts <5) for categorical variables and t-tests for continuous variables. Bold values indicate statistical significance ($P < 0.05$).

^aIncludes ever exposure to lye (i.e. history of use of both lye and no-lye chemical relaxers/straighteners).

conditioners. Among controls who reported regular hair dye use, ~27% of AAs and 3% of Whites reported regular use of relaxers as well. Among AAs, a higher proportion of cases reported use of dark hair dye shades ($P = 0.0006$) than controls. Among Whites, there were no differences in the prevalence of hair dye use or patterns of use. In terms of relaxer use, among AAs, a higher proportion of cases than controls reported use of lye-containing relaxers ($P = 0.0008$). After Bonferroni correction, the observed differences in use of dark hair dye shades and type of chemical relaxer used among AA cases and controls remained statistically significant. Among Whites, cases were more likely than controls to report relaxer use ($P = 0.02$), longer duration of use ($P = 0.005$), use of lye relaxers ($P = 0.04$), higher frequency of relaxer use at age ≥20 years ($P = 0.001$), use of home-kits for relaxer application ($P = 0.01$) and dual use of relaxers and hair dyes ($P = 0.003$). No differences were observed for use of deep conditioners among AAs or Whites. After Bonferroni correction, the observed differences in frequency of relaxer use at age ≥20 years and dual

use of relaxers and hair dyes among White cases and controls remained statistically significant.

Associations between hair product use and breast cancer risk by race are shown in Table 2. Among AA women, there was no association between regular hair dye use and breast cancer risk (OR = 1.12, 95% CI: 0.95–1.32). Compared to non-users, breast cancer risk was higher among AA women who reported use of dark hair dyes (OR = 1.51, 95% CI: 1.20–1.90) and salon application of dyes (OR = 1.26, 95% CI: 1.00–1.58). Among White women, there were no associations between hair dye use and patterns of use and breast cancer risk. Among AA women, compared to non-use, regular use of relaxers was not significantly associated with breast cancer risk (OR = 0.99, 95% CI: 0.79–1.26). Among White women, although prevalence of relaxer use was very low (compared to AAs), those reporting use of relaxers (OR = 1.74, 95% CI: 1.11–2.74), use of home-kits for application of relaxers (OR = 2.68, 95% CI: 1.46–4.95) and dual use of relaxers and hair dyes (OR = 2.40, 95% CI: 1.35–4.27) had increased breast cancer risk compared to non-users.

Table 2. Associations between hair product use and breast cancer risk in the Women's Circle of Health Study, by race

	African American women, n = 2798			European American women, n = 1487		
	Ca/Co n/n	Age-adjusted OR (95% CI)	Multivariable- Adjusted ^a OR (95% CI)	Ca/Co n/n	Age-adjusted OR (95% CI)	Multivariable- Adjusted ^a OR (95% CI)
<i>Hair dye</i>						
History of regular hair dye use						
No	1000/899	1.00 (ref)	1.00 (ref)	292/302	1.00 (ref)	1.00 (ref)
Yes	505/390	1.12 (0.96, 1.32)	1.12 (0.95, 1.32)	479/413	1.13 (0.92, 1.40)	1.07 (0.86, 1.32)
Total duration of hair dye use (years)						
Non-user	1000/899	1.00 (ref)	1.00 (ref)	292/302	1.00 (ref)	1.00 (ref)
1–10 years	305/230	1.17 (0.97, 1.42)	1.17 (0.96, 1.42)	215/186	1.19 (0.92, 1.53)	1.14 (0.88, 1.48)
>10 years	190/154	1.04 (0.82, 1.31)	1.03 (0.81, 1.31)	245/206	1.12 (0.87, 1.43)	1.03 (0.80, 1.33)
Frequency of use of typical hair dye						
Non-user	1000/899	1.00 (ref)	1.00 (ref)	292/302	1.00 (ref)	1.00 (ref)
Twice per year or less	313/254	1.08 (0.89, 1.30)	1.06 (0.88, 1.29)	223/187	1.23 (0.95, 1.58)	1.16 (0.89, 1.50)
More than twice per year	178/126	1.20 (0.94, 1.54)	1.20 (0.93, 1.54)	254/224	1.05 (0.82, 1.35)	0.99 (0.77, 1.28)
Typical shade of hair dye used						
Non-user	1000/899	1.00 (ref)	1.00 (ref)	292/302	1.00 (ref)	1.00 (ref)
Light (blonde, light brown)	140/133	0.93 (0.72, 1.19)	0.92 (0.71, 1.19)	180/165	1.05 (0.81, 1.38)	0.97 (0.73, 1.27)
Medium (medium brown, red)	123/119	0.89 (0.68, 1.16)	0.89 (0.68, 1.16)	198/168	1.16 (0.89, 1.51)	1.09 (0.84, 1.43)
Dark (dark brown, black)	242/138	1.52 (1.21, 1.91)	1.51 (1.20, 1.90)	100/79	1.24 (0.88, 1.74)	1.22 (0.87, 1.73)
Typical application of hair dye						
Non-user	1000/899	1.00 (ref)	1.00 (ref)	292/302	1.00 (ref)	1.00 (ref)
Salon	214/145	1.30 (1.03, 1.63)	1.26 (1.00, 1.58)	152/142	1.04 (0.78, 1.37)	0.95 (0.71, 1.27)
Home-kit	118/107	0.94 (0.71, 1.24)	0.97 (0.73, 1.29)	193/155	1.21 (0.93, 1.59)	1.20 (0.92, 1.58)
Both	171/135	1.10 (0.86, 1.40)	1.10 (0.86, 1.41)	114/100	1.12 (0.82, 1.54)	1.01 (0.73, 1.40)
<i>Chemical relaxer/straightener</i>						
History of regular chemical relaxer use						
No	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
Yes	1311/1124	0.97 (0.77, 1.22)	0.99 (0.79, 1.26)	57/33	1.64 (1.05, 2.56)	1.74 (1.11, 2.74)
Total duration of relaxer use (years)						
Non-user	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
1–10 years	203/158	1.03 (0.76, 1.39)	1.07 (0.79, 1.46)	45/30	1.41 (0.88, 2.28)	1.51 (0.93, 2.45)
11–20 years	262/226	1.03 (0.77, 1.37)	1.07 (0.80, 1.43)	2/2	1.15 (0.16, 8.23)	1.18 (0.16, 8.82)
>20 years	838/732	0.94 (0.74, 1.19)	0.96 (0.45, 1.22)	9/0	—	—
Frequency of relaxer use at age ≤12 years						
Non-use	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
Twice per year or less	73/68	1.09 (0.70, 1.69)	1.14 (0.72, 1.82)	8/2	4.36 (0.91, 20.84)	4.55 (0.94, 21.96)
More than twice per year	55/42	1.26 (0.78, 2.04)	1.35 (0.82, 2.22)	0/0	—	—
Frequency of relaxer use at age 13–19 years						
Non-use	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
Twice per year or less	405/393	0.91 (0.70, 1.19)	0.92 (0.70, 1.21)	21/23	0.85 (0.47, 1.56)	0.94 (0.51, 1.73)
More than twice per year	285/246	1.02 (0.77, 1.35)	1.05 (0.78, 1.41)	0/1	—	—
Frequency of relaxer use at age ≥20 years						
Non-use	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
Twice per year or less	778/708	0.91 (0.72, 1.15)	0.93 (0.73, 1.19)	35/11	3.10 (1.55, 6.18)	3.15 (1.57, 6.31)
More than twice per year	491/385	1.06 (0.82, 1.36)	1.09 (0.84, 1.42)	3/0	—	—
Type of chemical relaxer typically used						
Non-user	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
No lye	627/624	0.83 (0.65, 1.06)	0.84 (0.66, 1.08)	16/7	2.24 (0.91, 5.52)	2.25 (0.90, 5.63)
Lye ^b	604/440	1.13 (0.88, 1.45)	1.19 (0.92, 1.54)	8/2	3.76 (0.79, 17.87)	4.10 (0.86, 19.58)
Typical application of chemical relaxer						
Non-user	188/149	1.00 (ref)	1.00 (ref)	681/652	1.00 (ref)	1.00 (ref)
Salon	233/232	0.85 (0.64, 1.13)	0.83 (0.63, 1.11)	14/16	0.77 (0.37, 1.60)	0.86 (0.41, 1.79)
Home-kit	441/401	0.88 (0.68, 1.14)	0.93 (0.72, 1.21)	40/15	2.61 (1.42, 4.79)	2.68 (1.46, 4.95)
Both	634/488	1.10 (0.86, 1.41)	1.14 (0.88, 1.47)	3/2	1.69 (0.28, 10.22)	1.88 (0.30, 11.67)
History of use of both hair dye and chemical relaxer						
No	992/884	1.00 (ref)	1.00 (ref)	271/288	1.00 (ref)	1.00 (ref)
Yes	450/346	1.12 (0.95, 1.33)	1.13 (0.95, 1.34)	43/20	2.21 (1.26, 3.86)	2.40 (1.35, 4.27)
Deep conditioning cream (containing cholesterol or placenta)						
History of deep conditioning cream use						
No	638/498	1.00 (ref)	1.00 (ref)	657/628	1.00 (ref)	1.00 (ref)
Yes	804/724	0.91 (0.78, 1.06)	0.92 (0.78, 1.08)	57/43	1.36 (0.90, 2.05)	1.30 (0.85, 1.99)

^aMultivariable-adjusted models were adjusted for age, education, body mass index, family history of breast cancer and oral contraceptive use. Bold values indicate statistical significance ($P < 0.05$).^bIncludes ever exposure to lye (i.e. history of use of both lye and no-lye chemical relaxers/straighteners).

Associations between hair product use and breast cancer risk by ER and TN status are shown in [Table 3](#) (AAs) and [Table 4](#) (Whites). Among AAs, there was a significant association between higher frequency of hair dye use (more than twice per year, OR = 1.36, 95% CI: 1.01–1.84), use of dark hair dye shades (OR = 1.72, 95% CI: 1.30–2.26) and salon application of hair dyes (OR = 1.37, 95% CI: 1.03–1.82) and risk of ER+ breast cancer. It is worth noting that while no significant association between relaxer use and overall breast cancer risk or risk of ER+ disease was observed, findings were suggestive of an association between use of lye relaxers and increased risk of ER– disease among both AAs (ER–, OR = 1.54, 95% CI: 0.93–2.53) and Whites (ER–, OR = 1.54, 95% CI: 0.93–2.53), and TN disease among AAs (OR = 1.48, 95% CI: 0.94–2.59), although these findings need to be further explored in larger samples. Unexpectedly, compared to non-use, the use of no-lye relaxers (OR = 0.68, 95% CI: 0.50–0.91), salon application of relaxers (OR = 0.69, 95% CI: 0.48–0.99) and longer duration of deep conditioners (>10 years versus non-use, OR=0.77, 95% CI: 0.62–0.96) was associated with decreased risk of ER+ breast cancer among AAs. We observed no significant associations between hair product use and risk of ER– or TN breast cancers among AAs. Among Whites, there was an increased risk of ER+ breast cancer among women reporting dual use of relaxers and hair dyes (OR = 2.57, 95% CI: 1.29–5.12) and increased risk of ER– breast cancer among women with a history of relaxer use (OR = 2.56, 95% CI: 1.06–6.16) compared to non-users. Additionally, compared to non-users, White women reporting use of no-lye relaxers (OR = 5.88, 95% CI: 1.16–29.96) were at increased risk of TN breast cancer compared to non-users. Given the small sample size of Whites reporting use of the hair products of interest, these findings should be interpreted with caution.

Discussion

In this large case-control study of breast cancer, we found that use of dark hair dye shades was associated with 51% increased overall risk and 72% increased risk of ER+ disease among AAs. We also found that salon application of hair dyes was associated with 26% increased breast cancer risk and 37% increased risk of ER+ disease among AA women. Among Whites, use of relaxers was associated with 74% increased risk of breast cancer and with more than 2-fold increased risk of ER– disease. Dual use of relaxers and hair dyes, as well as home-kit application of relaxers, was also associated with more than 2-fold increased risk among Whites. Although relaxer use was less frequent among Whites, we observed significant increases in risk associated with use of these hair products in this group, which has never been reported previously. While novel, these findings must be interpreted with caution given the small sample size of Whites with these exposures.

Over the last several decades, the concern of environmental exposures to carcinogens and mutagens found in hair dyes, particularly aromatic amines which were shown to be components of oxidative hair dyes (34), have been explored for evidence of an association with breast cancer risk (6,7,9,11–14,18–21). Furthermore, evidence of 4-aminobiphenyl (ABP) DNA adducts in breast epithelial cells (and an observed association between hair dye use and these adducts) (35,36) and the presence of ABP in commercial hair dye (37) support a link between exposure to aromatic amines, via hair dye use and increased breast cancer risk. However, to date there appears to be only fairly weak evidence (6,7,9,11–14,18–21) to support a significant association between hair dye use and breast cancer risk. One recent study

(7), reported an increase in the odds of breast cancer (23%) among women who ever used hair dyes. Findings from our study showed that while ever use of hair dyes was not significantly associated with increased breast cancer risk among AAs or Whites overall, higher annual frequency of hair dye use and use of dark hair dye shades were associated with increased risk among AA women, and with increased risk of ER+ breast cancer in both groups. It should be noted that our study included a larger sample size than nine of the eleven previous breast cancer studies (6,9,11–13,18–21) and with the largest number, to date, of AA women, an understudied population in the context of hair dye use and breast cancer risk. Our observation of differences in the association between dark hair dye use and breast cancer risk by race could relate to variable patterns of use of dark hair dyes (e.g. timing of use, duration of use and varying preferences for darker shades of dyes) between AA and White women. For instance, although AA women reported substantially lower frequency of hair dye use than white women, AA women reported more frequent use of dark shades of hair dye. This could reflect differences in preferences for darker hair dye shades possibly for the purposes of covering greying hair among White women (which may also relate to initiation of dark hair dye use at older ages than among AA women), whereas AA women may use darker shades of dye to merely darken their already darker hair color (or for myriad reasons other than dyeing grey hair). Furthermore, the level of darkness of dark hair dye shades may differ among commercial products depending on desired use (e.g. for dyeing grey hair versus further darkening naturally darker hair), thereby requiring a different chemical composition. A related hypothesis is that the chemical composition of hair dyes in general, and darker shades of dye in particular, marketed for and used among Whites may differ from those used by AAs, which could explain higher breast cancer risk observed among AAs than Whites although they reported lower annual frequency as well as shorter lifetime duration of hair dye use. Because this study collected no information on specific brands and ingredients of hair dyes, or differences in composition among retail products, future research is needed to describe associated risks more completely.

Although no other studies have found the use of dark hair dye shades to be associated with breast cancer, long-term use of dark hair dyes have been associated with 4-fold increased risks of fatal non-Hodgkin's lymphoma and multiple myeloma among women enrolled in the Cancer Prevention Study II (10) and marginally associated with a 29% increased risk of bladder cancer in a recent meta-analysis (38). One hypothesis to explain these associations is that dark shades of commercial oxidative hair dyes pose a higher risk of cancer due to increased contamination of these dyes with potentially genotoxic compounds (37,39–41). Furthermore, direct scalp contact of these dyes can lead to cutaneous absorption of these harmful compounds (39,42), particularly with long-term exposure. The finding of a significant association between dark hair dyes and ER+ breast cancer among both AAs and Whites and the lack of an association between these dyes and ER– and TN disease warrants further study to understand hormone related mechanisms. It is also possible that use of dark shades of dye may also be associated with ER– and TN disease, although given the smaller sample size for these subgroups we were underpowered to detect significant associations.

History of relaxer use overall was not associated with breast cancer risk among AAs in this study, similar to findings from the Black Women's Health Study (23). We are the first to report a significant association between relaxer use and breast cancer risk

Table 3. Associations between hair product use and breast cancer risk by estrogen receptor status and triple-negative among African American women in the Women's Circle of Health Study

	ER+, n = 648			ER-, n = 247		Triple-negative, n = 185	
	Co	Ca	OR (95% CI) ^a	Ca	OR (95% CI) ^a	Ca	OR (95% CI) ^a
	n	n		n		n	
<i>Hair dye</i>							
History of regular hair dye use							
No	899	418	1.00 (ref)	164	1.00 (ref)	123	1.00 (ref)
Yes	390	229	1.22 (0.99, 1.49)	83	1.17 (0.87, 1.57)	62	1.18 (0.85, 1.65)
Total duration of hair dye use (years)							
Non-user	899	418	1.00 (ref)	164	1.00 (ref)	123	1.00 (ref)
1–10 years	230	130	1.19 (0.93, 1.53)	56	1.36 (0.96, 1.91)	41	1.34 (0.91, 1.97)
>10 years	154	94	1.22 (0.92, 1.63)	27	0.94 (0.60, 1.47)	21	1.00 (0.60, 1.64)
Frequency of use of typical hair dye							
Non-user	899	418	1.00 (ref)	164	1.00 (ref)	123	1.00 (ref)
Twice per year or less	254	138	1.13 (0.89, 1.44)	52	1.11 (0.78, 1.57)	40	1.16 (0.78, 1.70)
More than twice per year	126	85	1.36 (1.01, 1.84)	30	1.33 (0.86, 2.07)	22	1.32 (0.80, 2.18)
Typical shade of hair dye used							
Non-user	899	418	1.00 (ref)	164	1.00 (ref)	123	1.00 (ref)
Light (blonde, light brown)	133	60	0.95 (0.68, 1.31)	25	1.04 (0.66, 1.66)	20	1.12 (0.67, 1.87)
Medium (medium brown, red)	119	54	0.94 (0.66, 1.32)	23	1.05 (0.64, 1.70)	15	0.94 (0.53, 1.68)
Dark (dark brown, black)	138	115	1.72 (1.30, 2.26)	35	1.39 (0.92, 2.10)	27	1.43 (0.91, 2.27)
Typical application of hair dye							
Non-user	899	418	1.00 (ref)	164	1.00 (ref)	123	1.00 (ref)
Salon	145	97	1.37 (1.03, 1.82)	39	1.41 (0.94, 2.09)	31	1.50 (0.97, 2.31)
Home-kit	107	48	0.94 (0.65, 1.35)	18	0.99 (0.58, 1.69)	14	1.04 (0.57, 1.89)
Both	135	84	1.29 (0.96, 1.35)	25	1.02 (0.64, 1.63)	17	0.95 (0.55, 1.64)
<i>Chemical relaxer/straightener</i>							
History of regular chemical relaxer use							
No	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
Yes	1124	552	0.80 (0.60, 1.06)	222	1.28 (0.81, 2.04)	166	1.29 (0.76, 2.18)
Total duration of relaxer use (years)							
Non-user	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
1–10 years	158	91	0.92 (0.63, 1.33)	30	1.22 (0.68, 2.21)	23	1.26 (0.65, 2.45)
11–20 years	226	113	0.91 (0.64, 1.29)	47	1.44 (0.83, 2.50)	37	1.47 (0.79, 2.72)
>20 years	732	346	0.75 (0.56, 1.01)	143	1.25 (0.78, 2.02)	105	1.24 (0.72, 2.12)
Frequency of relaxer use at age ≤12 years							
Non-use	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
Twice per year or less	68	27	0.73 (0.40, 1.33)	15	1.64 (0.71, 3.80)	13	1.55 (0.64, 3.79)
More than twice per year	42	25	1.10 (0.60, 2.02)	9	1.54 (0.62, 3.83)	8	1.55 (0.58, 4.14)
Frequency of relaxer use at age 13–19 years							
Non-use	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
Twice per year or less	393	160	0.67 (0.48, 0.94)	70	1.08 (0.64, 1.84)	51	1.02 (0.56, 1.84)
More than twice per year	246	127	0.87 (0.60, 1.24)	48	1.27 (0.72, 2.24)	34	1.13 (0.60, 2.14)
Frequency of relaxer use at age ≥20 years							
Non-use	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
Twice per year or less	708	307	0.71 (0.52, 0.95)	142	1.28 (0.80, 2.06)	108	1.31 (0.77, 2.24)
More than twice per year	385	231	0.99 (0.72, 1.35)	78	1.35 (0.81, 2.24)	56	1.29 (0.73, 2.29)
Type of chemical relaxer typically used							
Non-user	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
No lye	624	263	0.68 (0.50, 0.91)	112	1.14 (0.70, 1.85)	85	1.16 (0.67, 2.00)
Lye ^b	440	252	0.94 (0.69, 1.28)	98	1.54 (0.93, 2.53)	70	1.48 (0.84, 2.59)
Typical application of chemical relaxer							
Non-user	149	94	1.00 (ref)	24	1.00 (ref)	18	1.00 (ref)
Salon	232	100	0.69 (0.48, 0.99)	43	1.12 (0.65, 1.94)	33	1.12 (0.61, 2.08)
Home-kit	401	192	0.77 (0.56, 1.06)	66	1.11 (0.66, 1.87)	54	1.23 (0.69, 2.20)
Both	488	259	0.89 (0.65, 1.21)	113	1.54 (0.94, 2.51)	79	1.45 (0.83, 2.53)
History of use of both hair dye and chemical relaxer							
No	884	416	1.00 (ref)	163	1.00 (ref)	123	1.00 (ref)
Yes	346	204	1.22 (0.98, 1.50)	75	1.20 (0.88, 1.63)	59	1.21 (0.86, 1.71)
<i>Deep conditioning cream (containing cholesterol or placenta)</i>							
History of deep conditioning cream use							
No	498	288	1.00 (ref)	96	1.00 (ref)	73	1.00 (ref)
Yes	724	335	0.84 (0.68, 1.02)	138	0.99 (0.74, 1.33)	104	0.97 (0.70, 1.34)

^aMultivariable-adjusted models were adjusted for age, education, body mass index, family history of breast cancer and oral contraceptive use. Bold values indicate statistical significance ($P < 0.05$).^bIncludes ever exposure to lye (i.e. history of use of both lye and no-lye chemical relaxers/straighteners).

Table 4. Associations between hair product use and breast cancer risk by estrogen receptor status and triple-negative among European American women in the Women's Circle of Health Study

	ER+, n = 357			ER-, n = 68		Triple-negative, n = 41	
	Co	Ca	OR (95% CI) ^a	Ca	OR (95% CI) ^a	Ca	OR (95% CI) ^a
	n	n		n		n	
<i>Hair dye</i>							
History of regular hair dye use							
No	302	124	1.00 (ref)	27	1.00 (ref)	14	1.00 (ref)
Yes	413	232	1.19 (0.91, 1.57)	41	1.03 (0.61, 1.73)	27	1.28 (0.65, 2.53)
Total duration of hair dye use (years)							
Non-user	302	124	1.00 (ref)	27	1.00 (ref)	14	1.00 (ref)
1–10 years	186	102	1.27 (0.91, 1.76)	22	1.27 (0.69, 2.33)	14	1.45 (0.67, 3.15)
>10 years	206	124	1.19 (0.87, 1.64)	16	0.75 (0.39, 1.46)	12	1.10 (0.49, 2.48)
Frequency of use of typical hair dye							
Non-user	302	124	1.00 (ref)	27	1.00 (ref)	14	1.00 (ref)
Twice per year or less	187	105	1.27 (0.92, 1.77)	24	1.30 (0.72, 2.36)	17	1.71 (0.81, 3.61)
More than twice per year	224	126	1.13 (0.82, 1.55)	17	0.80 (0.42, 1.51)	10	0.90 (0.39, 2.12)
Typical shade of hair dye used							
Non-user	302	124	1.00 (ref)	27	1.00 (ref)	14	1.00 (ref)
Light (blonde, light brown)	165	89	1.11 (0.78, 1.56)	11	0.68 (0.32, 1.42)	7	0.83 (0.32, 2.14)
Medium (medium brown, red)	168	90	1.12 (0.80, 1.58)	22	1.35 (0.74, 2.47)	15	1.71 (0.79, 3.69)
Dark (dark brown, black)	79	53	1.54 (1.01, 2.33)	8	1.09 (0.47, 2.52)	5	1.31 (0.45, 3.79)
Typical application of hair dye							
Non-user	302	124	1.00 (ref)	27	1.00 (ref)	14	1.00 (ref)
Salon	142	76	1.13 (0.79, 1.61)	9	1.41 (0.94, 2.09)	6	0.79 (0.29, 2.13)
Home-kit	155	85	1.22 (0.86, 1.72)	17	0.99 (0.58, 1.69)	10	1.38 (0.59, 3.24)
Both	100	66	1.34 (0.90, 1.98)	12	1.02 (0.64, 1.63)	10	1.67 (0.70, 4.02)
<i>Chemical relaxer/straightener</i>							
History of regular chemical relaxer use							
No	652	322	1.00 (ref)	57	1.00 (ref)	35	1.00 (ref)
Yes	33	24	1.50 (0.86, 2.61)	7	2.56 (1.06, 6.16)	4	2.41 (0.79, 7.31)
Type of chemical relaxer typically used							
Non-user	652	322	1.00 (ref)	57	1.00 (ref)	35	1.00 (ref)
No lye	7	7	2.00 (0.67, 5.91)	2	1.14 (0.70, 1.85)	2	5.88 (1.16, 29.96)
Lye ^b	2	2	1.91 (0.26, 13.90)	1	1.54 (0.93, 2.53)	0	—
History of use of both hair dye and chemical relaxer							
No	288	116	1.00 (ref)	26	1.00 (ref)	13	1.00 (ref)
Yes	20	20	2.57 (1.29, 5.12)	3	1.89 (0.49, 7.30)	1	1.18 (0.14, 9.78)
<i>Deep conditioning cream (containing cholesterol or placenta)</i>							
History of deep conditioning cream use							
No	628	311	1.00 (ref)	58	1.00 (ref)	34	1.00 (ref)
Yes	43	26	1.25 (0.74, 2.11)	6	1.45 (0.58, 3.63)	5	2.07 (0.75, 5.68)

Due to relatively low frequencies of exposure to chemical relaxers among European Americans compared to African Americans, associations for only select hair product patterns of use variables are shown in this table.

^aMultivariable-adjusted models were adjusted for age, education, body mass index, family history of breast cancer and oral contraceptive use. Bold values indicate statistical significance ($P < 0.05$).

^bIncludes ever exposure to lye (i.e. history of use of both lye and no-lye chemical relaxers/straighteners).

among White women. Although the risk estimates by ER and TN status were not statistically significant, our findings were suggestive of increased risk of ER- and TN disease among AAs and increased risk of ER- disease among Whites in association with use of lye relaxers. AA women, especially younger women, commonly use relaxers for hair straightening, often for many years (23,26,43,44). In our analysis, we were particularly interested in the potential association between the use of lye-based relaxers and breast cancer, given that lye relaxers are thought to be more harmful than no-lye formulations, containing sodium hydroxide (45). Although newer chemical straightening products with varying active ingredients have become popular, such as low-lye relaxers which contain <2.5% sodium hydroxide, Brazilian-style keratin treatments which contain formaldehyde, and thio

relaxers which contain thioglycolic acid salts, lye-based and no-lye relaxers have historically been among the most commonly used products among AA women (43,44). The current findings provide novel data to support the hypothesis that exposure to lye (and exposure to other potentially harmful compounds found in relaxers and other hair products) could be important environmental risk exposures associated with carcinogenesis of the mammary gland. This is an important and understudied risk factor, particularly among AA women, as the prevalence of use of relaxers and other potentially harmful hair and cosmetic products is higher among AAs than Whites (24–26), which our findings and those of the BWHS (23) support. However, this may be an equally important exposure among White women as well, as our findings suggest harmful effects of these products

irrespective of race. One hypothesis to support this finding is that the chemical composition of chemical relaxers marketed for and used among Whites may differ from that of AA relaxers. Because this study collected no information on specific brands and ingredients of relaxers, or differences in composition among retail products marketed for and used by AA or White users, future research is needed to describe risks, in relation to these products, more completely.

Some studies (26,43,44,46) have provided empirical evidence to support the association between exposure to the carcinogenic and/or endocrine disrupting chemicals contained in hair products, and increased risk of precocious puberty which is known to be associated with increased breast cancer risk and potentially increased risk of breast cancers exhibiting aggressive phenotypes. Given the widespread use of these products, which are minimally regulated by the Food and Drug Administration (47), it is essential that more research is done to understand the ingredients found in hair products and other cosmetics and examine the effects of these exposures on breast cancer risk.

There were some limitations that should be considered in the interpretation of our findings. First, preferential recall bias is of particular concern given that this study relied on each participant to remember and accurately report on their use of hair products throughout their lifetime. As in any case-control study, there is always the potential for cases to recall and report habits and events differently than women who were not recently diagnosed with breast cancer. However, because hair product use is not a factor known to cause breast cancer, we do not expect a substantial impact on the reported risk estimates. Additionally, our questionnaire did not ascertain use of every type of hair product that is available on the market and may have yielded unreliable estimates on some of the exposures of interest. Furthermore, we cannot be certain of participants' ability to accurately distinguish their use of various hair product types (e.g. permanent versus temporary hair dyes, dark, medium or light hair dye shades, lye versus no-lye relaxers, conditioners that contain placenta or cholesterol versus those that do not). As a result, our findings possibly represent underestimates of the true associations between hair product use and breast cancer risk. Another potential concern is that we had limited statistical power to evaluate associations by ER and TN status due to small samples of these cases in this study. Further analysis of larger studies (with larger numbers of ER- and TN cases) are needed to clarify the observed relationships. Finally, multiple testing may also be a concern. Given the exploration of several exposures with stratified analysis, we could have increased our chances of finding significant associations. Despite these considerations, the major strength of this study was the large sample of AA women that allowed the first complete evaluation of associations between several hair products and breast cancer risk by ER status in this group. The population-based study design and extensive collection of detailed data on hair product use and patterns of use (more detailed than previously published studies), and potential confounding factors were also strengths.

In summary, findings from this large case-control study of AA and White women provide epidemiological data to support a relationship between the use of hair dye and some types of relaxers and breast cancer. As use of various hair products and other cosmetics continue among women in the US as well as in other countries, improved awareness of the potential effects of exposures to their chemical ingredients are needed.

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