

Hair Straightener Use in Relation to Prevalent and Incident Fibroids in the Sister Study with a Focus on Black Women

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BACKGROUND: Uterine fibroids disproportionately affect Black women, and exposure to chemicals from hair relaxers or straighteners (“straighteners”) may contribute to fibroid development.

OBJECTIVES: We examined the association between straightener use and prevalent young-onset uterine fibroids (diagnosed before age 36 y), as well as incident fibroids (diagnosed age 36–60 y), with a focus on Black women. We also examined differences in associations across birth cohorts as proxies for formulation changes.

METHODS: Data from 4,162 Black women in the Sister Study, a prospective cohort of women 35–74 y of age (enrolled 2003–2009), were analyzed. We used logistic regression to estimate odds ratios (ORs) for the association of straightener use at 10–13 y of age and self-reported young-onset fibroids. We used Cox regression to assess hazard ratios (HRs) for straightener use (age 10–13 y and in 12 months before enrollment) and incident fibroids among 779 premenopausal Black women. Similar analyses were conducted in 40,782 non-Hispanic White women.

RESULTS: Over 70% of Black women used straighteners. In comparison with no use, any [OR = 1.15; 95% confidence interval (CI): 0.96, 1.36] and frequent use (OR = 1.18; 95% CI: 0.99, 1.42) of straighteners at 10–13 y of age were associated with young-onset fibroids. This association was most apparent among those born between 1928 and 1945 (OR = 1.78; 95% CI: 1.15, 2.74) and 1965–1974 (OR = 1.64; 95% CI: 0.82, 3.29). Fibroid incidence from 36 to 60 y of age was modestly associated with use of straighteners at 10–13 y of age [hazard ratio (HR) = 1.14; 95% CI: 0.81, 1.63] and in the 12 months prior to enrollment (HR = 1.32; 95% CI: 0.88, 2.00). Among non-Hispanic White women, straightener use at 10–13 y of age was similarly associated with young-onset fibroids (OR = 1.23; 95% CI: 1.03, 1.47) despite lower use ($\leq 5\%$) of straighteners. Sensitivity analyses indicated a potential for bias due to fibroid misclassification, with an overestimation of the effect likely if nulliparous women or women from households with lower education reported their fibroid status less accurately.

DISCUSSION: Hair straightener use may be positively associated with fibroid risk. <https://doi.org/10.1289/EHP14493>

Introduction

Uterine fibroids (leiomyomas) are common hormone-dependent benign pelvic tumors¹ that develop during a woman's reproductive years² and are a significant cause of morbidity in the United States.³ Black women in the United States are more likely to develop fibroids at a younger age, have multiple and larger fibroids, and experience more severe symptoms in comparison with women from other race/ethnic groups.^{4,5} The cause of higher prevalence among Black women remains unclear. Studies suggest estrogen and progesterone hormonal activity as contributors to fibroid growth.⁶ Endocrine disrupting chemicals (EDCs) can act as agonists or antagonists for estrogen and progesterone receptors, which can induce growth or increase the survival of fibroid cells.⁷ Data from the National Health and Nutrition Examination Survey (NHANES) have shown that Black women have higher concentrations of some endocrine-disrupting phthalates in comparison with non-Hispanic White (NHW) or Hispanic women.^{8,9}

A possible source of exposure to EDCs is hair straightening,^{10–14} a process of loosening the curl pattern of Afro-textured or curly hair.^{15,16} Over 70% of Black women engage in hair straightening,^{13,17–20} often because of societal pressures to conform to Eurocentric ideologies related to professionalism and beauty standards.²¹ Further, hair straightening is often initiated during adolescence,¹⁸ coinciding with a critical period of uterine growth and maturation.²²

Hair straightening has evolved over time. It involves the use of either hair pressing products such as hot combs, curling irons, or flat irons, together with an ointment-based lubricant that often contains petrolatum or mineral oil,^{16,23} or the use of chemical relaxers.^{15,24} Relaxers typically contain corrosive alkaline chemicals such as sodium hydroxide, potassium hydroxide, lithium hydroxide, ammonium thioglycolate, guanidine, magnesium and calcium hydroxide,^{10,16,25,26} cyclosiloxanes,¹⁰ and EDCs such as phthalates,²⁷ parabens,²⁸ benzophenone-3, and triclosan.¹⁰ More recently developed treatments (including keratin and Brazilian keratin treatment) contain formaldehyde or formaldehyde-releasing chemicals.^{29,30} Henceforth, we refer to any pressing products or chemical straighteners/relaxers jointly as hair straighteners.

Hair straighteners can release chemical fumes that are easily inhaled, especially when used with hot irons.^{10,30} In addition, the process may result in contact irritation and chemical or hot comb burns to the scalp and hairline,^{16,31,32} which may increase dermal absorption,³³ potentially increasing systemic absorption of EDCs^{34,35} or carcinogens such as mineral oil/petrolatum^{36,37} and formaldehyde.³⁷

Studies have shown that hair products marketed to Black women often contain higher levels of potentially toxic chemicals than those more generally available.²¹ Further, use of these products by Black females often begins in childhood.^{10,38,39} Wise et al. previously observed positive associations between hair relaxer use and the risk of fibroids among African-American women,⁴⁰ but no study has evaluated risk from adolescent use or examined associations across birth cohorts. Here, we investigated the associations of

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Supplemental Material is available online (<https://doi.org/10.1289/EHP14493>).

The authors report no conflicts of interest.

Conclusions and opinions are those of the individual authors and do not necessarily reflect the policies or views of EHP Publishing or the National Institute of Environmental Health Sciences.

Received 18 December 2023; Revised 8 October 2024; Accepted 16 December 2024; Published 14 January 2025.

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reported hair straightener use during early adolescence and adulthood with prevalent and incident fibroids among Black women within a US-based prospective cohort. In addition, we considered the role of birth cohort as a proxy for changes in chemical formulations and hair straightening trends over time. For completeness and comparison, we carried out secondary analyses among NHW women. We hypothesized that straightener use is associated with a higher likelihood of fibroids and that this association could vary by birth cohort.

Methods

Study Population

Data were from the Sister Study, a prospective cohort of 50,884 US women 35–74 y of age with a sister diagnosed with breast cancer but no previous breast cancer diagnosis prior to enrollment (2003–2009).⁴¹ Extensive environmental and lifestyle data, including personal care product use, were collected at enrollment. Informed consent was obtained, and the study was approved by the institutional review board of the National Institutes of Health (NIH; No. 02-E-N271).

Among all women, we excluded Sister Study participants who withdrew from the study ($n = 5$), did not complete the personal care product use questionnaire ($n = 979$), reported fibroids diagnosed at <10 y of age ($n = 10$), or did not report age at prevalent fibroid diagnosis ($n = 1,507$).

During data collection, participants were asked to self-identify their race by choosing one or more of the following: American Indian or Alaskan Native, Asian, Black or African American, Native Hawaiian or other Pacific Islander, and/or White. Women were also asked if they considered themselves to be Hispanic or Latina. Based on their responses, women were categorized into Non-Hispanic White, Black (includes Hispanic Black), Hispanic, and other races (Asian, American Indian or Alaskan Native, and Native Hawaiian or other Pacific Islander). Participants who identified as Black and one or more other races were classified as Black under the assumption that multiracial or multiethnic Black women may share similar sociocultural experiences. We narrowed this analysis down to the two groups (Black and NHW) that are the largest. Our primary analyses focused on Black/African-American women because of the high prevalence of hair straightener use and fibroids among this group,⁴⁰ but we also carried out parallel analyses among NHW women, whose frequency of use is lower and whose product choice may differ.²⁸ Because of these differences in patterns of use and potential differences in the chemical makeup of products marketed to Black vs. White women, all analyses were stratified by race. Data were from Sister Study data release 10.1, with participant follow-up until October 2020.

Exposure Assessment

At enrollment, participants reported hair straightener use at 10–13 y of age and the year before enrollment. Exact wording of the questions is included as Table S1. Age 10–13 y represents exposure to hair straightening chemicals during adolescence, a potentially critical period of development.⁴² For this time frame, participants indicated whether they did not, sometimes, or frequently straightened their hair using chemical relaxers or hair pressing products. We also dichotomized this to “Yes” (sometimes or frequently use) vs. “no” use.

For use in the prior 12 months, a proxy for use in adulthood, participants reported frequency of straightener use as none, 1–2 times a year, every 3–4 months, every 5–8 wk, once a month, or more than once a month. We consolidated these into three

categories: no use, sometime use (1–2 times/y or every 3–4 months) and frequent use (at least every 5–8 wk).

In addition, we approximated long-term hair straightener use by considering use at both time points.

Outcome Assessment

Participants reported ever having been diagnosed by a doctor or other health professional with fibroids and the age of diagnosis (Table S1). We conducted separate analyses for prevalent young-onset fibroids (diagnosed before baseline and before age 36 y) and incident fibroids (diagnosed after baseline but before age 61 y).

To ensure that all included participants experienced the same risk period, the prevalence analysis was limited to fibroids diagnosed before age 36 y because the minimum age of enrollment in the Sister Study was 35 y of age. Participants diagnosed after age 35 y were considered noncases, because they did not have prebaseline young-onset fibroids. The prevalence analyses included 4,162 Black participants, 1,145 of whom reported a young-onset fibroid diagnosis (Figure 1). For the parallel analysis among NHW women, there were 3,417 prebaseline young-onset cases among 40,782 eligible women. Only straightener use during age 10–13 y was considered when evaluating prevalent disease to allow temporality between exposure and outcome.

Women were followed for incident fibroids diagnoses upon enrollment in the study. They were considered ineligible for the incidence analysis if they had a prior fibroids diagnosis ($n = 2,289$), were older than 60 y at enrollment ($n = 377$), or had experienced menopause ($n = 473$) (because fibroids size and symptoms are thought to regress with menopause)⁴³ or hysterectomy ($n = 244$) before enrollment. Fibroids diagnosed after enrollment but before 61 y of age were considered incident events. The analytic sample included 779 premenopausal Black women (including 215 who self-reported a fibroid diagnosis after enrollment). For NHW women, there were 1,757 women with incident fibroids among 9,822 eligible women. When assessing risk of incident fibroids, we considered straightener use during age 10–13 y and in the 12 months prior to enrollment.

Covariates

Participants who did not respond or responded “do not know” to questions were treated as missing, and we conducted a complete case analysis, limiting to those participants without missing data. Selection of model covariates was guided by the literature and our understanding of factors plausibly affecting both hair straightener use and fibroid incidence. We provided a simplified directed acyclic graph depicting the proposed relationships⁴⁴ between hair straightener exposure during both childhood and adulthood (Figure S1). The covariates for each analysis are described in detail within their respective analytic (prevalence and incidence) section.

Statistical Analyses

Prevalence analysis. We first assessed baseline sociodemographic factors, as well as hair straightener use, stratified by young-onset fibroids. We summarized findings as means and standard deviations (SDs) or frequencies and percentages. Women who were without fibroid diagnosis or diagnosed with fibroids after age 35 y were categorized as no fibroids. Using multivariable logistic regression models, we estimated odds ratios (OR) and 95% confidence intervals (CIs) for associations between use of hair straighteners and prevalent fibroids. Based on literature reviews, we adjusted for age at enrollment (continuous), and then in a fully adjusted model we adjusted for participant’s childhood family income (well-off, middle income, low

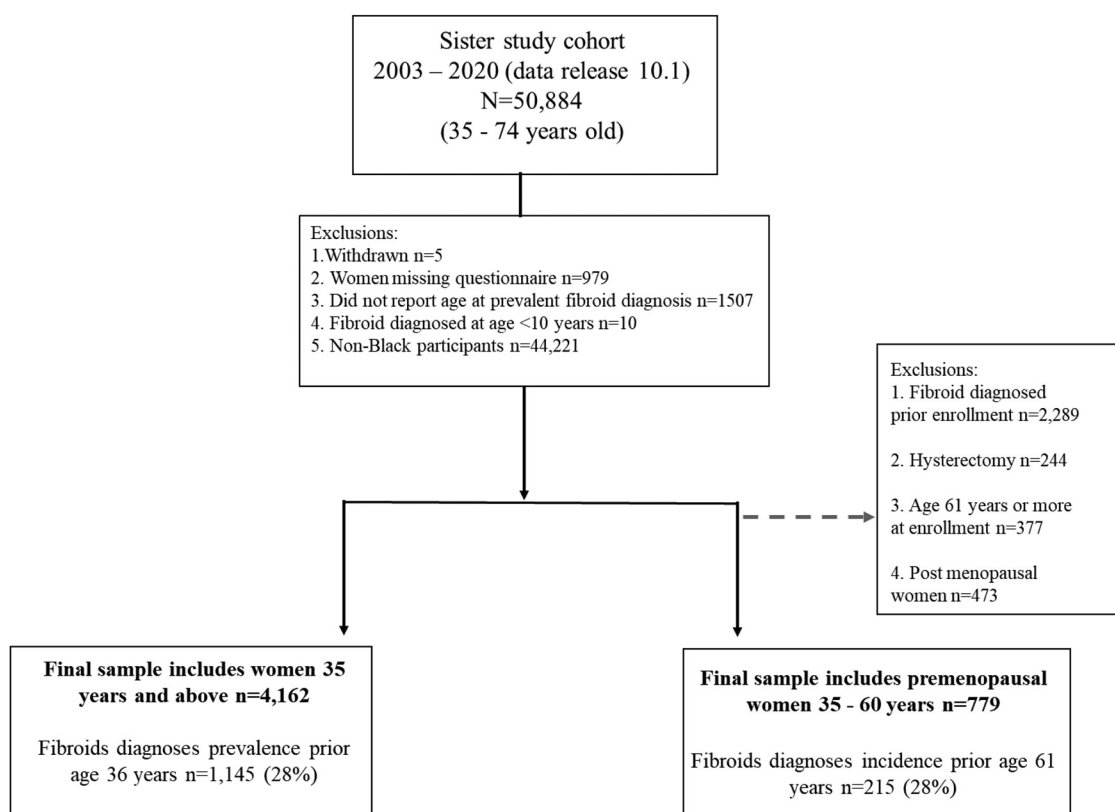


Figure 1. Flow chart showing Black participants in the Sister Study included in the prevalence and incidence analysis of the association of hair straightener use and fibroids.

income, and poor), geographic region longest lived during childhood (Northeast, Midwest, South, and West) because hair texture and access to health care may vary by region, and highest attained educational level in household during childhood (high school or less, some college, college graduate, and postgraduate degree), which are sociodemographic and lifestyle factors that impact product use and fibroids.^{18,45} We also adjusted for height and weight relative to peers at age 10–13 y (shorter/smaller, same, taller/heavier) because height and weight can be linked to lifestyle behaviors, health care access, and socioeconomic status, which may correlate with hair product use and have been linked to fibroids.^{46,47} We did not adjust for age at menarche or birth control use because some of the participants had not attained menarche at the time of exposure, and birth control use is not common at age 10–13 y.

To examine the potential influence of trends in straightening practices and formulations, we categorized participants into preestablished birth cohorts as a proxy: 1928–1945, 1946–1954, 1955–1964, and 1965–1974.⁴⁸ We assumed that women within the same generation are likely to follow similar trends in hair styles, fashion, and beauty products. We estimated birth cohort–stratified ORs, adjusting for the same covariates as in our fully adjusted model. We assessed heterogeneity across strata of birth cohorts via a joint Wald test of birth cohort by straightener use interaction term.

Incidence analysis. We used multivariable Cox proportional hazards models to estimate adjusted hazard ratios (aHR) with 95% CI for the association between hair straightener use and incident fibroids. Using age as the timescale, participants accrued person-time from enrollment to age at fibroids diagnosis, with censoring at age of hysterectomy, menopause, loss to follow-up, end of follow-up, death, or age 61 y, whichever came first. When assessing the relationship with straightener use at age 10–13 y, we first ran a model that was age-adjusted only (as timescale) and

then a model adjusting for early adolescence factors, as described above for the prevalence models.

When assessing the relationship between incident fibroids and straightener use during the 12 months prior enrollment, we adjusted for several additional potential confounders related to sociodemographic, lifestyle, and reproductive factors^{40,46} that were measured at enrollment, including annual household income categorized as poor (<USD \$20,000), low (USD \$20,001–\$49,999), middle (USD \$50,000–\$99,999), and well-off (≥USD \$100,000); highest educational level attained, categorized as no high school or less, some college/associate’s degree, college graduate, and postgraduate degree⁴⁰; duration of hormonal birth control use (<2 y, 2–10 y, >10 y); age at menarche; parity (0, 1, 2, ≥3); age at last childbirth (<25 y, 25–34 y, ≥35 y); body mass index; alcohol use (never, former, current nonregular, current regular); smoking history (never, past, and current smoker); primary current job [the one with the most hours worked per week as a hairdresser or cosmetologist (yes or no)]; census region (Northeast, Midwest, South, West); and health insurance (yes or no). Proportional hazards assumptions were assessed using graphical evaluation of Kaplan–Meier curves and the log (–log) curve, with no violations observed.

For all analysis, we calculated *p* for trend using a Wald test of parameters for ordinal frequency of use variables. Analyses were conducted using SAS software (version 9.4; SAS Institute Inc.).

Sensitivity analyses. Fibroids may go undetected, especially because not all are symptomatic, leading to misclassification when using self-reported data. Given evidence that fibroid detection varies with parity,⁴⁹ we conducted analyses stratified by parity. We further explored the impact of misclassification of fibroid status on estimated associations between straightener use and prevalent fibroids by estimating ORs and 95% CIs assuming different negative predictive values (NPVs) informed by the sensitivity and specificity of ultrasound in comparison with self-report diagnosis of fibroids in

Table 1. Baseline characteristics of Black participants in the Sister Study stratified by self-reported young-onset fibroids (diagnosed before age 36 y).

Characteristics	All <i>n</i> = 4,162 (100%)	No fibroids <i>n</i> = 3,017 (72%)	Fibroids <i>n</i> = 1,145 (28%)
Age at baseline [y (SD)]	53.6 (8.3)	53.5 ± 8.4	53.8 ± 8.2
Body mass index at baseline [kg/m ² (SD)]	31.3 ± 7.0	31.3 ± 7.3	31.2 ± 6.4
Age at menarche [y (SD)]	12.5 ± 1.7	12.6 ± 1.7	12.3 ± 1.7
Relative height ^a			
Shorter	1,215 (29)	885 (29)	330 (29)
Same	1,894 (46)	1,397 (46)	497 (44)
Taller	1,038 (25)	724 (24)	314 (28)
Relative weight ^b			
Lighter	1,735 (42)	1,218 (41)	517 (45)
Heavier	643 (15)	479 (16)	164 (14)
Same	1,758 (43)	1,301 (43)	457 (40)
Childhood household highest educational level			
High school or less	2,930 (73)	2,136 (73)	794 (72)
Some college	649 (16)	469 (16)	180 (16)
College graduate	306 (8)	215 (7)	91 (8)
Postgraduate degree	154 (4)	111 (4)	43 (4)
Childhood family income			
Poor	773 (19)	552 (18)	221 (19)
Low income	1,521 (37)	1,096 (37)	425 (37)
Middle income	1,730 (42)	1,271 (42)	459 (40)
Well-off	118 (3)	84 (3)	34 (3)
Childhood geographic region			
Northeast	581 (15)	399 (14)	182 (17)
Midwest	967 (24)	707 (25)	260 (24)
South	2,228 (56)	1,613 (57)	615 (56)
West	180 (5)	134 (5)	46 (4)
Education attainment at enrollment			
High school or less	436 (11)	356 (12)	80 (7)
Some college/Associate's degree	1,492 (36)	1,096 (36)	396 (35)
College graduate	1,125 (27)	799 (26)	326 (28)
Postgraduate degree	1,108 (27)	765 (25)	343 (30)
Household income at enrollment			
Poor	275 (7)	218 (7)	57 (5)
Low	1,091 (26)	803 (27)	288 (25)
Middle	1,751 (42)	1,252 (42)	499 (44)
Well-off	1,045 (25)	744 (25)	301 (26)
Smoking status at enrollment			
Never	2,637 (63)	1,924 (64)	713 (62)
Past smoker	1,110 (27)	801 (27)	309 (27)
Current smoker	414 (10)	292 (10)	122 (11)
Alcohol consumption status at enrollment			
Never	229 (6)	170 (6)	59 (5)
Past	1,026 (25)	754 (25)	272 (24)
Current nonregular	657 (16)	483 (16)	174 (15)
Current regular	2,249 (54)	1,610 (53)	639 (56)
Health insurance at enrollment			
No	259 (7)	202 (8)	57 (6)
Yes	3,371 (93)	2,412 (92)	959 (94)
Hormonal birth control use			
None	510 (12)	380 (13)	130 (11)
<2 y	548 (13)	407 (14)	141 (12)
2–10 y	1,863 (45)	1,326 (44)	537 (47)
>10 y	1,214 (29)	883 (29)	331 (29)
Parity			
Nullipara	768 (18)	504 (17)	264 (23)
One	945 (23)	640 (21)	305 (27)
Two	1,379 (33)	1,029 (34)	350 (31)
Three or more	1,061 (26)	837 (28)	224 (20)
Age at last birth			
No birth	768 (19)	504 (17)	264 (23)
<25 y	1,013 (24)	718 (24)	295 (26)
25–34 y	1,861 (45)	1,393 (46)	468 (41)
≥35 y	507 (12)	391 (13)	116 (10)
Birth year cohort			
1928–1945	704 (17)	509 (17)	195 (17)
1946–1954	1,500 (36)	1,082 (36)	418 (37)
1955–1964	1,512 (36)	1,087 (36)	425 (37)
1965–1974	446 (11)	339 (11)	107 (9)

Table 1. (Continued.)

Characteristics	All <i>n</i> = 4,162 (100%)	No fibroids <i>n</i> = 3,017 (72%)	Fibroids <i>n</i> = 1,145 (28%)
Geographic region at enrollment			
Northeast	402 (10)	290 (10)	112 (10)
Midwest	895 (22)	642 (22)	253 (22)
South	2,471 (60)	1,792 (61)	679 (60)
West	324 (8)	230 (8)	94 (8)
Currently works as hairdresser or cosmetologist ^c			
No	3,040 (99)	2,204 (99)	836 (100)
Yes	12 (1)	12 (1)	0 (0)

Note: Women who were diagnosed with fibroids after age 35 y were included in no-fibroids column (noncases). Percentages may not add up to 100 due to rounding. Missing: BMI *n* = 1, age at menarche *n* = 8, relative height *n* = 15, relative weight *n* = 26, childhood highest education level in household *n* = 123, childhood family income *n* = 20, childhood geographic region *n* = 206, highest level of education at enrollment *n* = 1, smoke status at enrollment *n* = 1, alcohol status at enrollment *n* = 1, hormonal birth control use *n* = 27, parity *n* = 9, age at last birth *n* = 13, birth year cohort *n* = 0, health insurance *n* = 532, geographic region at enrollment *n* = 70, works as hairdresser or cosmetologist *n* = 1,110.

^aSelf-reported height relative to peers at age 10–13 y.

^bSelf-reported weight relative to peers at age 10–13 y.

^cCurrent job with the most hours worked.

the Uterine Fibroid Study (UFS).⁴⁹ Because the likelihood of fibroid diagnosis may vary by other factors, such as education level, we also evaluated the potential for bias by examining various scenarios of differential misclassification of fibroids diagnosis, including consideration of how this misclassification may vary by highest educational level in household during childhood and parity. Fibroids may be slow-growing and undiagnosed; thus, we conducted additional sensitivity analyses for the association of straightener use and young-onset fibroids excluding participants diagnosed with incident fibroids from the noncases.

Results

Black Participants

Prevalence analysis. Among the 4,162 Black participants (mean age: 54 y), 28% (*n* = 1,145) reported having young-onset fibroids (Table 1). Participants with fibroids were more likely to be taller (28%) and weigh less (45%) relative to their peers at age 10–13 y in comparison with participants without fibroids (24% and 41%). They were also more likely to have a postgraduate degree (30% vs. 25%) and more likely to be nulliparous than participants without fibroids (23% vs. 17%). At age 10–13 y, 77% of participants who later developed young-onset fibroids and 74% of participants who did not develop young-onset fibroids reported hair straightener use. Participants with young-onset fibroids were also more likely to report frequent use of straightening products at 10–13 y of age (52% vs. 48% among noncases) (Table 2).

In multivariable-adjusted models, hair straightener use at age 10–13 y was associated with higher odds of young-onset fibroids (OR = 1.15; 95% CI: 0.96, 1.36), for frequent vs. never use (aOR = 1.18; 95% CI: 0.99, 1.42, *p* for trend: 0.06) (Table 2).

The association with ever vs. never use differed by birth cohort (*p* for heterogeneity = 0.05) (Figure 2) and was more apparent among participants born between 1928–1945 (aOR = 1.78; 95% CI: 1.15, 2.74), and between 1965–1974 (aOR = 1.64; 95% CI: 0.82, 3.29) than among those born between 1946–1954 (aOR = 1.14; 95% CI: 0.87, 1.51), or 1955–1964 (aOR = 0.89; 95% CI: 0.66, 1.18).

Incidence analysis. Among the 779 eligible premenopausal Black women, 215 (28%) self-reported a newly diagnosed fibroid during a median of 5 y follow-up (maximum 15 y). The mean age at enrollment was 44 y for participants with incident fibroids and 46 y for those without fibroids. In comparison with those without

Table 2. Association of hair straightener use and self-reported young-onset fibroids among Black participants in the Sister Study ($n = 4,162$).

Factors	No fibroids $n = 3,017$ (72%)	Fibroids $n = 1,145$ (28%)	Age adjusted OR (95% CI)	Fully adjusted OR (95% CI) ^a
Hair straightener use at 10–13 y of age				
No	757 (26)	257 (23)	Ref	Ref
Yes	2,187 (74)	869 (77)	1.18 (1.00, 1.39)	1.15 (0.96, 1.36)
Frequency of hair straightener use at 10–13 y of age				
None	757 (26)	257 (23)	Ref	Ref
Sometimes	767 (26)	285 (25)	1.10 (0.90, 1.34)	1.08 (0.87, 1.33)
Frequently	1,420 (48)	584 (52)	1.23 (1.03, 1.46)	1.18 (0.99, 1.42)
<i>p</i> for trend	—	—	0.02	0.06

Note: Missing hair straightener data for use at age 10–13 y of age, $n = 92$, missing frequency of hair straightener use at 10–13 y of age, $n = 92$. —, no data; CI, confidence interval; OR, odds ratio; Ref, reference; SD, standard deviation.

^aAdjusted for age at enrollment, childhood family income, highest educational level in household during childhood, height, and weight relative to peers at age 10–13 y, childhood geographic region.

incident fibroids, participants with incident fibroids were more likely to weigh more at 10–13 y of age (22% vs. 18%), more likely to come from a family where the highest educational attainment among household members was college graduate (16% vs. 8%), have middle-level childhood family income (56% vs. 48%), and to have a postgraduate degree themselves (29% vs. 22%). Participants with incident fibroids were less likely to have ever smoked (80% vs. 73%), more likely to use hormonal birth control for >10 y (40% vs. 35%) and be nulliparous (26% vs. 18%) (Table S2).

Participants with incident fibroids were also more likely to report frequent straightener use at enrollment (56% vs. 48%). In fully adjusted models, the HR for the association of hair straightener use at ages 10–13 y and incident fibroids was 1.14 (95% CI: 0.81, 1.63), and the HR for the association of hair straightener use during the 12 months prior to enrollment was 1.32 (95% CI: 0.88, 2.00). The HR for use at both time points, relative to never use, was 1.07 (95% CI: 0.54, 2.14) (Table 3).

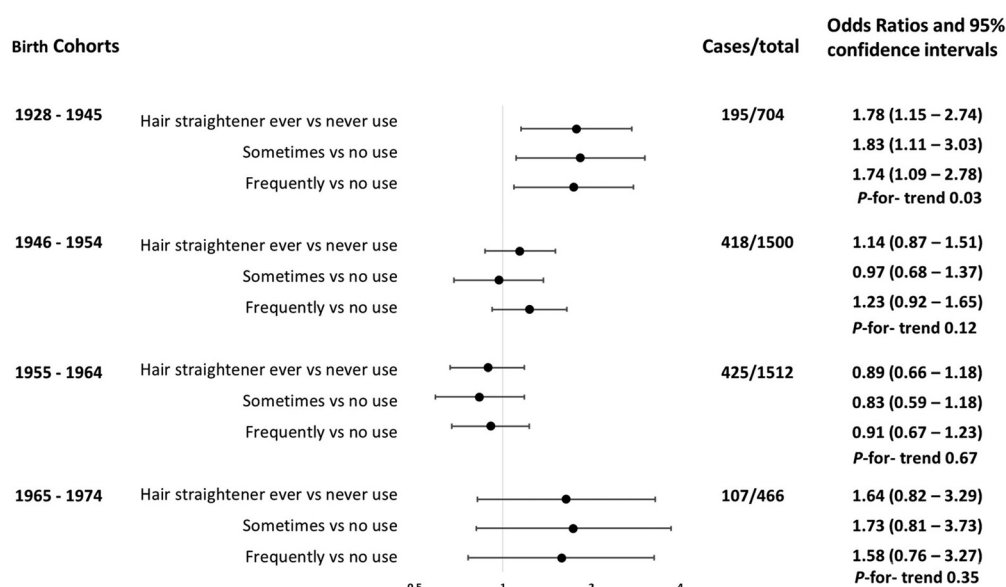
NHW Participants

Prevalence analysis. Within the larger sample of NHW participants, straightener use was much less common (4% between ages

10 and 13 y) than among Black participants (over 70%). As was observed among Black Sister Study participants, hair straightener use at 10–13 y of age was associated with higher odds of young-onset fibroids (OR = 1.23; 95% CI: 1.03, 1.47), for frequent vs. never use (OR = 1.04; 95% CI: 0.60, 1.80, *p* for trend: 0.05) (Table 4).

Incidence analysis. Among the 9,822 eligible premenopausal NHW women, 1,757 (18%) developed incident fibroids over a median of 5 y follow-up (maximum 16 y). Participants with incident fibroids were less likely to have used hormonal birth control for >10 y (30% vs. 35%) and were less likely to be ≥ 35 y of age at last birth (19% vs. 24%) (Table S3).

In the 12 months prior to enrollment, 5% of noncases and 6% of cases reported having used hair straighteners. In the fully adjusted models, hair straightener use at ages 10–13 y showed an association with higher rate of incident fibroids (HR = 1.30; 95% CI: 1.06, 1.58). Use during the 12 months prior to enrollment was also positively associated with incident fibroids, with a 25% higher rate observed before age 61 y (HR = 1.25; 95% CI: 0.99, 1.57), relative to nonusers. The HR for use at both time points, in comparison with nonusers, was 1.43 (95% CI: 0.84, 2.43) (Table 5).



p-for heterogeneity any straightener use = 0.05, and for frequency of hair straightener use = 0.12.

All models adjusted for age at enrollment, childhood family income, highest educational level in household during childhood, height, and weight relative to peers at age 10–13 years, and childhood geographic region.

Young onset fibroids (fibroids diagnosed before age 36 years)

Figure 2. The association of hair straightener use and young-onset fibroids (diagnosed before age 36 y) stratified by birth cohort among Black participants in the Sister Study ($n = 4,162$).

Table 3. Association of hair straightener use and self-reported fibroid incidence among premenopausal Black participants in the Sister Study [$n = 779$ (215 incident cases)].

Factors	No Fibroids $n = 564$ (72%)	Person-years	Events ($n = 215$)	Age-adjusted HR (95% CI)	Fully adjusted HR (95% CI)
Hair straightener use at 10–13 y of age					
No	135 (24)	877	41	Ref	Ref
Yes	417 (76)	3,178	171	1.16 (0.82, 1.64)	1.14 (0.81, 1.63) ^a
Frequency of hair straightener use at 10–13 y of age					
None	135 (24)	877	41	Ref	Ref
Sometimes	154 (28)	1,139	52	0.98 (0.65, 1.47)	1.01 (0.67, 1.54) ^a
Frequently	263 (48)	2,040	119	1.27 (0.89, 1.81)	1.22 (0.84, 1.75) ^a
p for trend	—	—	—	0.01	0.01
Hair straightener use within 12 months prior to enrollment					
No	137 (25)	869	35	Ref	Ref
Yes	419 (75)	3,214	178	1.36 (0.94, 1.96)	1.32 (0.88, 2.00) ^b
Frequency of hair straightener use within 12 months prior to enrollment					
None	137 (25)	869	35	Ref	Ref
Sometimes	153 (28)	1,075	58	1.31 (0.86, 2.00)	1.28 (0.79, 2.06) ^b
Frequently	263 (47)	2,139	120	1.38 (0.95, 2.02)	1.35 (0.88, 2.07) ^b
p for trend	—	—	—	0.22	0.13
Duration of hair straightener use ^c					
No use	52 (9)	321	11	Ref	Ref
One time point	178 (32)	1,170	56	1.38 (0.72, 2.64)	0.82 (0.39, 1.71) ^b
Both time points	334 (59)	2,640	148	1.63 (0.88, 3.01)	1.07 (0.54, 2.14) ^b

Note: Incident cases are women <61 y of age who reported a diagnosis of fibroids after enrolling in the study. Study participants who developed fibroids prior to study enrollment or who were 61 y of age or older were not included in this incidence analysis. Missing hair straightener data for use at age 10–13 y ($n = 15$); 12 months prior enrollment ($n = 10$). —, no data; CI, confidence interval; HR, hazard ratio; Ref, reference.

^aAdjusted for age at enrollment, childhood family income, highest educational level in household during childhood, height, and weight relative to peers at age 10–13 y.

^bAdjusted for age at enrollment, family income at enrollment, highest educational level in household at enrollment, age at menarche, hormonal birth control use, parity, age at last birth, body mass index at enrollment, currently works as hairdresser or cosmetologist, census region, health insurance, alcohol, and smoking.

^c“No use” means participants who reported no use at both age 10–13 y and in the 12 months prior to enrollment. One time point is use at either age 10–13 or 12 months prior to enrollment. Both time points are use at both ages 10–13 and 12 months prior to enrollment.

Sensitivity analyses. Stratification by parity. In analyses stratified by parity, the association of hair straightener use at age 10–13 y and young-onset prevalent fibroids was OR = 1.07 (95% CI: 0.89, 1.30) among Black parous women and OR = 1.53 (95% CI: 1.01, 2.31) among Black nulliparous women. Among NHW women we found OR = 1.24 (95% CI: 1.02, 1.52) among parous women and OR = 1.17 (95% CI: 0.77, 1.77) among nulliparous women (Table S4).

Underreporting fibroids. In unadjusted models when we assumed a NPV of 80% for self-reported fibroids (i.e., that 20% of women with fibroids reported no fibroids), the OR for the association of straightener use at age 10–13 y and fibroids among Black participants was attenuated (OR = 1.11; 95% CI: 0.96, 1.28). The OR was further attenuated if we assume a NPV of 60% (OR = 1.08; 95% CI: 0.93, 1.24). Results also varied for different scenarios of differential reporting by household educational attainment, from higher OR estimates when NPV is greater among those with less than a high school education than among those from childhood households with greater educational attainment, to an OR <1.0 when reporting was assumed to be better among participants from households with higher than high school educations. A similar pattern was seen for parity, with results that remained positive when

reporting was better among nulliparous than parous women, to inverse when parous women were assumed to report more accurately (Table S5).

Excluding incident fibroids from noncases in young-onset prevalence analysis. Similar association was found after excluding women diagnosed with incident fibroids from noncases in the prevalence analysis of young-onset fibroids. Any hair straightener use at age 10–13 y was associated with higher odds of young-onset fibroids (OR = 1.13; 95% CI: 0.93, 1.36) among Black participants, and (OR = 1.30; 95% CI: 1.08, 1.57) among NHW participants (Table S6).

Discussion

In this study of Black women across the United States, we found that the use of hair straighteners was associated with a higher prevalence of young-onset fibroids. Associations were more pronounced among women born between 1928 and 1945, who were likely to have had exposure to the earliest formulations of hair straighteners, and those born between 1965 and 1974, who may have had increased access to home use and more “modern” products, potentially exposing them to formaldehyde. Hair straightener

Table 4. Association of hair straightener use and self-reported, young-onset fibroids among non-Hispanic White participants in the Sister Study [$n = 40,782$ (3,224 prevalent cases)].

Factors	No fibroids $n = 35,647$ (92%)	Fibroids $n = 3,224$ (8%)	Age-adjusted OR (95% CI)	Fully adjusted OR (95% CI) ^a
Hair straightener use at 10–13 y of age				
No	34,327 (96)	3,083 (96)	Ref	Ref
Yes	1,320 (4)	141 (4)	1.19 (1.00, 1.42)	1.23 (1.03, 1.47)
Frequency of hair straightener use at 10–13 y of age				
None	34,327 (96)	3,083 (96)	Ref	Ref
Sometimes	1,161 (3)	127 (4)	1.22 (1.01, 1.47)	1.25 (1.04, 1.51)
Frequently	159 (1)	14 (0)	0.98 (0.57, 1.70)	1.04 (0.60, 1.80)
p for trend	—	—	0.11	0.05

Note: —, no data; CI, confidence interval; OR, odds ratio; Ref, reference.

^aModel is adjusted for age at enrollment, childhood SES, highest educational level in household during childhood, height, and weight relative to peers at age 10–13 y; childhood geographic region; missing hair straightener use at 10–13 y of age ($n = 1,911$); missing frequency of hair straightener use at 10–13 y of age ($n = 1,911$).

Table 5. Association of hair straightener use and self-reported fibroid incidence among premenopausal non-Hispanic White participants in the Sister Study [$n = 9,822$ (1,757 incident cases)].

Factors	No fibroids $n = 8,065$ (82%)	Person-years	Events ($n = 1,757$)	Age-adjusted HR (95% CI)	Fully adjusted HR (95% CI)
Hair straightener use at age 10–13 y					
No	7,415 (96)	51,061	1,577	Ref	Ref
Yes	290 (4)	1,651	76	1.39 (1.10, 1.75)	1.30 (1.06, 1.58) ^a
Frequency of hair straightener use at age 10–13 y					
None	7,415 (96)	51,061	1,577	Ref	Ref
Sometimes	253 (3)	1,453	67	1.38 (1.08, 1.76)	1.39 (1.09, 1.77) ^a
Frequently	37 (1)	198	9	1.47 (0.76, 2.82)	1.51 (0.78, 2.91) ^a
p for trend	—	—	—	0.01	0.01
Hair straightener use 12 months prior enrollment					
No	7,317 (95)	49,692	1,550	Ref	Ref
Yes	396 (5)	3,067	105	1.17 (0.96, 1.43)	1.25 (0.99, 1.57) ^b
Frequency of hair straightener use at 12 months prior enrollment					
None	7,317 (95)	49,692	1,550	Ref	Ref
Sometimes	226 (3)	1,785	63	1.23 (0.96, 1.59)	1.33 (1.00, 1.78) ^b
Frequently	170 (2)	1,282	42	1.09 (0.80, 1.48)	1.14 (0.79, 1.63) ^b
p for trend	—	—	—	0.22	0.13
Duration of hair straightener use ^c					
No-use	7,068 (88)	48,430	1,491	Ref	Ref
One time point	939 (12)	6,643	246	1.21 (1.06, 1.38)	1.25 (1.07, 1.45) ^b
Both time points	58 (1)	492	20	1.40 (0.90, 2.18)	1.43 (0.84, 2.43) ^b

Note: Incident cases are women <61 years of age who reported a diagnosis of fibroids after enrolling in the study. Study participants who developed fibroids prior to study enrollment, were postmenopausal or 61 or older were not included in this incidence analysis. Missing hair straightener use at age 10–13 y: $n = 15$. At 12 months prior enrollment: $n = 10$. —, no data; CI, confidence interval; HR, hazard ratio; Ref, reference.

^aAdjusted for age at enrollment, childhood SES, highest educational level in household during childhood, height, and weight relative to peers at age 10–13.

^bAdjusted for age at enrollment, family income at enrollment, highest educational level in household at enrollment, age at menarche, hormonal birth control use, parity, age at last birth, body mass index at baseline, currently works as a hairdresser or cosmetologist, census region, health insurance, alcohol and smoking.

^c“No use” means participants who reported no use at both age 10–13 and 12 months prior enrollment. One time point means use at either age 10–13 y or 12 months prior enrollment; use at both time points is use at both age 10–13 and 12 months prior enrollment.

use within the 12 months prior to study enrollment was also associated with an increased rate of incident fibroids. Though hair straightener use among NHW women was less common, the magnitude of the association of hair straightener use with fibroids was similar to that of Black women in our study. As shown by several scenario-based sensitivity analyses, these findings should be interpreted with caution because of the potential for bias if certain subgroups, such as nulliparous women or women who grew up in households with lower educational attainment, were less likely to report a true fibroids diagnosis.

When studying the potential health effects of hair straightener use, it is important to focus on Black women because Black women are the most frequent users of straighteners and are often specifically targeted in the marketing of these hair products containing potentially toxic chemicals.²¹ Prior studies have indicated that Black women have higher body burden of some EDCs than women from other races and ethnicities.⁹

In our sample, hair straightener use was common among Black participants at both ages 10–13 y (75%) and just before enrollment (74%), which is consistent with reports from previous studies of Black women such as the Study of Environment, Lifestyle, and Fibroids (73%),¹⁸ the Black Women’s Health Study (95%),¹⁹ and the Women’s Circle of Health Study (88%).²⁰ Research on hair straighteners and fibroids is limited, but our findings align with previous research. For example, Wise et al.⁴⁰ reported an association between hair straightener use and fibroids in the Black Women’s Health Study, with stronger associations seen for increased frequency and longer duration of straightener use.⁴⁰

Although we did not have information on lifetime use of straighteners, we attempted to consider long-time use by evaluating the incidence of fibroids among women who reported use at both ages 10–13 y and in the year before diagnosis. In this analysis among Black women, use at both time periods was not associated with increased fibroid risk. However, it is likely that this construct underestimates the proportion of women who were true long-term users, because women who started using hair straighteners any time after age 13 y but prior to enrollment would not have been

included in this group, despite being long-term users. This underestimation is supported by Wise et al., who previously reported that 82.8% of Black women used straighteners for >10 y, vs. 57% of Black women approximated as long-term users in our sample. Overall, our findings align with studies linking hair straightener use to other hormone-related conditions, such as reduced fertility,⁵⁰ ovarian cancer, uterine cancer, and breast cancer,^{20,51–53} and are consistent with the positive association found between hair relaxer use and higher circulating levels of estrogen.¹³

The chemical composition of hair straighteners is complex. Of the chemicals sometimes included in hair straightener or relaxer products, the following have been noted to have potentially harmful effects: formaldehyde,³⁷ cyclosiloxanes,^{54,55} sodium hydroxide, mineral oil, petrolatum,³⁷ and EDCs such as parabens, phthalates, bisphenol A, diethanolamine, benzophenone-3, and triclosan.^{10,56} Hair care products are typically packaged in plastic, and endocrine-active compounds like phthalates²⁷ and bisphenol A can leach from plastic containers.⁵⁷ Hair relaxers, including those for children, are corrosive (pH >11.5).^{25,58} Thus, a common complication of hair relaxer use is burns and contact dermatitis, leading to increased dermal absorption of chemicals.^{15,25}

Hair pressing tools previously used with petrolatum-based oils⁵⁹ are now being used with formaldehyde or formaldehyde-releasing chemicals, which releases formaldehyde into the air (e.g., Brazilian Keratin Treatments).^{16,30} Chemicals are more readily absorbed through the scalp than any other areas of the skin.⁶⁰ Dermal absorption via compromised skin³³ combined with inhalation of chemical fumes from straightening products could lead to high systemic absorption of a combination of harmful chemicals.¹⁰

Developmental exposure to EDCs may also increase the risk of fibroids by epigenomic reprogramming.^{61–63} EDCs have been shown in rat models to convert myometrial stem cells into tumor initiating cells, eventually giving rise to fibroids.⁶⁴ Available *in vivo* studies indicate that EDCs, such as mono(2-ethyl-5-hydroxyhexyl) phthalate⁷ and bisphenol A, are associated with increased fibroid growth.⁶⁵ Black women are more likely to have higher urine levels of monoethyl phthalate;^{9,66} these higher levels

may explain why Black women are more likely to have larger and more complicated fibroids than NHW women.⁴ Studies among Black and Latina women comparing hairdressers to office workers found that hairdressers who provide natural services for Afro-textured hairstyles had lower monoethyl phthalate concentrations than those who did not.¹¹ These findings suggest that adoption of natural hairstyles may potentially reduce EDC exposure in Black women.

The cyclosiloxane octamethylcyclotetrasiloxane (D4) has been found to induce uterine tumors in animal studies; however, little is known about their mechanism of action alone or in combination with other chemicals.^{56,57} Other chemicals in straighteners, such as formaldehyde, untreated or mildly treated mineral oil,³⁷ and petrolatum,^{37,67} have carcinogenic effects. Although exact mechanisms of action in relation to fibroids have not yet been established, fibroids share some features and risk factors with malignant tumors of the reproductive tract.^{47,68,69}

In our study, the odds of fibroids were more pronounced among women born between 1928–1945 and between 1965–1974. Historical factors and changes in methods and formulations of chemical hair straightening products likely contributed to these variations. For instance, the earliest (prior to 1940s) form of hair pressing was with hot iron tools and petrolatum/mineral oil and was reported to cause burns resulting in alopecia.⁶¹ This process for hair straightening was followed by the introduction of chemical straighteners/relaxers containing sodium and potassium hydroxide, developed around 1940.²⁴ These products resulted in severe chemical burns and hair damage.^{24,26} The 1950s saw the addition of a cream base of mineral oil/petrolatum (later found to be carcinogenic)^{36,37} emulsifiers and fatty alcohol to relaxers,^{25,67} but this did not stop the risk of skin irritation and scalp burns caused by the corrosive nature of the chemicals.

The Black Power movement in the late 1960s and 1970s brought positive messaging toward Afrocentric hair and the resurgence of natural hairstyles.⁷⁰ This period also saw the use of blow out relaxers and texturizers containing the same chemicals but designed to be kept in the hair for a shorter time (5 min vs. 20 min for relaxers). This period may have seen a reduction in exposure to hazardous compounds, which in turn may explain the less-pronounced odds of fibroids observed among women born between 1946–1964, especially for those born in 1955–1964 who were adolescents and young adults in the late 1960s and early 1970s.

The introduction of relaxers for home use in the 1970s may have led to increased accessibility and frequency of use. Products containing mineral oil/petrolatum and EDCs and reports of scalp burns and other complications continue with modern-day relaxers.^{25,71} Although hair pressing products evolved to rely more on flat irons or curling irons and less grease,¹⁶ formaldehyde-containing products for keratin hair treatments are increasingly used.³⁰

It is important to acknowledge that some women with Afro-textured hair may continue to relax their hair because of the cost associated with managing natural hair⁷² or the perception that relaxed hair is easier to manage⁷⁰ or because of pressure to conform to dominant esthetic norms.^{26,70} Furthermore, scarcity of hair salons specializing in styling natural Afro-textured hair exacerbates this issue in the United States. The CROWN (Creating a Respectful and Open World for Natural hair) Act currently passed in 23 US states brings awareness to the systemic, social, and economic impact of hair bias and discrimination.⁷³

To reduce the burden of fibroids and health disparities that may be associated with chemical exposure from hair straighteners, guidance on best practices, including reducing the frequency of use of hair straightening products may be provided to individuals and hair salons. The lower odds of fibroids associated with straightener use among women born between 1946–1964 and

among natural hair stylists support the need for community interventions to encourage natural Afro hairstyle alternatives and grassroots education on the risks of hair straightener use.

We found only one other published study on hair relaxers and fibroids. Further studies are needed to evaluate the types of hair straighteners used and their chemical components in relation to serum/urine concentration of metabolites. In addition, studies should examine the characteristics of fibroids, including size, number, and severity, among women who use hair straighteners in comparison with those who do not. More studies are also needed to understand the specific mechanisms by which straighteners contribute to the development of fibroids.

The Sister Study comprises women who had a sister diagnosed with breast cancer; therefore, the findings may not be generalizable to the general US population. However, there is little evidence to suggest that women with a family history of breast cancer are at increased risk for fibroids. However, women with a family history of breast cancer may experience greater risk with a chemical environmental exposure, as they do with alcohol.⁷⁴ If those with a family history of breast cancer experience greater risk with hair straightener exposure, the exposure effect estimates observed in this study would be greater than those for the general population, which would include women both with and without a family history.

We did not capture the specific names and types of chemical hair straightener/hair pressing products used, which likely have different chemical profiles. However, chemical relaxers have been previously reported as the most commonly used form of straighteners among Black women.⁷⁵ We did not adjust for unmeasured and potentially correlated sources of EDC exposure, such as environmental exposure via food packaging and other items, all of which could vary by birth cohort. We do not have the data to stratify by hair curl pattern. It is not known whether hair curl pattern itself is associated with fibroids, but hair curl pattern is associated with increased exposure to hair straighteners, as suggested by findings of increased use of hair straighteners associated with decreasing percentage of European ancestry in African-American women.⁴⁰ If hair curl pattern were independently related to uterine fibroids, the effect estimate for the straightener–fibroid relationship would be upwardly biased.

The mean enrollment age was 45 y of age, and most fibroids are diagnosed between ages 40–50 y,^{4,46} meaning that a large number of fibroid cases may not have counted as cases in either the prevalence or incidence analyses. However, because fibroids tend to occur at an earlier age in Black women,⁴ we likely captured a large proportion of the Black young-onset cases in the prevalence analysis, where we used an age cutoff of 36 y to ensure all participants had experienced the full risk period. If the straightener–fibroid association is stronger for earlier-onset tumors, the results of our incidence analysis may be attenuated in comparison with a more comprehensive study where women are followed prospectively from their teens or 20s until early menopause.⁴⁰

We relied on self-reported data. Reliance on self-reports is a problem because not all fibroids come to clinical attention. We conducted several sensitivity analyses to demonstrate the potential impact of underdiagnosis. We showed that if fibroid misclassification is nondifferential with respect to hair straightener use, our ORs would overestimate the true association. If fibroid misclassification were more common among women from households with low educational attainment during childhood or among nulliparous women, the ORs observed in our study would also overestimate the true association between hair straightener use and prevalent fibroids. Although we cannot directly assess how much fibroid status misclassification is occurring in the Sister Study, the sample largely consists of well-educated women with access to health

insurance, which should correspond to higher levels of accuracy than would be seen in the general population. However, other studies have shown that Black women are more likely to underreport fibroid diagnoses than White women and that parous women will generally report fibroid diagnoses more accurately than nulliparous women.⁴⁹ However, when we stratified by parity, the OR for the association of straighteners with young-onset fibroids was actually greater among nulliparous than that among parous women, despite the concern that fibroids are likely to be detected during encounters for reproductive care. Even so, the possibility of misclassification remains, including possible differential misclassification by education, parity, or other relevant factors. These sensitivity analyses demonstrate that bias may be present and that our findings should be interpreted with some caution.

Then again, fibroids are more likely to be diagnosed if they are causing more severe symptoms, such as heavy bleeding or pain, and larger symptomatic fibroids are more likely to be diagnosed than smaller ones.⁷⁶ Therefore, even if fibroids are being underreported, the results of our analysis may accurately reflect the existence of a positive association between straightener use and symptomatic or severe fibroids, which are the most clinically relevant types of fibroids. Further, when we excluded women with fibroids diagnosed after age 36 y who may have had prevalent but asymptomatic fibroids prior to age 36 y from the no-fibroid group in the prevalence analysis, results were unchanged.

The Sister Study's main strengths are its large sample size and extensive covariate data. The concordance of results for NHW women, despite their lower frequency of straightener use, supports the observed associations seen among Black women. We were able to consider hair straightener use at two time periods, including a window of susceptibility in early adolescence. Although our primary interest was in risks associated with hair straightener use in Black women because of higher frequency of use and higher frequency of fibroid diagnosis, it is important to note that these products may be hazardous for all users.

In conclusion, our findings suggest an association between the use of hair straighteners and fibroids among Black women, more apparent with frequent use and among women born between 1928 and 1945 and between 1965 and 1974. Although this association was also observed among NHW women, the greater use of hair straighteners among Black women may help explain the disparate burden of fibroids and complications arising from fibroids among Black women in the United States.

Acknowledgments

This research was supported in part by the Intramural Research Program at the NIH, National Institute of Environmental Health Sciences (project Z1A ES103325 to D.P.S. and ES103332 to A.J.W.) and by the Intramural Research Program of the NIH, National Institute on Minority Health and Health Disparities (project Z1AES103325 to C.L.J.).

Conception or design: K.O., K.M.O., D.P.S. Analysis and interpretation of data: K.O., K.M.O., A.J.W., C.C., S.G., C.L.J., D.P.S. Writing (original draft preparation): K.O., K.M.O., D.P.S. Writing (reviewing and editing): K.O., K.M.O., A.J.W., C.C., S.G., C.L.J., D.P.S. Final approval of the version to be published: K.O., K.M.O., A.J.W., C.C., S.G., C.L.J., D.P.S.

Data availability statement: De-identified data are available on request through the Sister Study website (<https://sisterstudy.niehs.nih.gov/English/data-requests.htm>).

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