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Use of Hair Straighteners/Chemical Relaxers and Incidence of Non-Reproductive Cancers

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Abstract

Background: Use of hair straighteners and chemical relaxers has been associated with increased incidence of breast, uterine, and ovarian cancers. However, their potential association with non-reproductive cancers remains unknown, despite evidence that some ingredients in these products may be genotoxic. We therefore examined use of hair straighteners/chemical relaxers in relation to the incidence of non-reproductive cancers.

Material and Methods. We analyzed data from 46,287 cancer-free women from the Sister Study, a U.S.-wide cohort enrolled between 2003–2009 (ages 35–74). Participants reported frequency of hair straightener/chemical relaxer use in the 12 months prior to enrollment. Incident cancers (melanoma, thyroid, lung, non-Hodgkin's lymphoma, leukemia, pancreatic, colorectal, and kidney cancers) were self-reported and confirmed with pathology reports when possible. We used multivariable Cox proportional hazards models to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for hair straighteners/chemical relaxer use and incident cancers, adjusting age, race and ethnicity, educational attainment, and smoking status.

Results. During a median follow-up of 13.1 years, use of hair straighteners/chemical relaxers was associated with a higher incidence of thyroid cancer (n=225 cases; HR:1.71, 95% CI:1.01–2.89), non-Hodgkin's lymphoma (n=313 cases; HR:1.62, 95% CI:0.94–2.80), and pancreatic cancer (n=138 cases; HR:2.66, 95% CI: 1.25–5.66). There was little evidence of dose-response with increasing frequency of use. We observed negligible or imprecise associations for the remaining cancer types.

Conclusions and Relevance: Use of hair straighteners/chemical relaxers may be associated with a higher incidence of thyroid cancer, non-Hodgkin's lymphoma, and pancreatic cancer. Further research is needed to confirm these findings.

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Introduction

Approximately two million incident cancer cases are estimated to occur in the United States in 2025.^{1,2} Moreover, it's estimated that 70–90% of lifetime cancer risk can be attributed to exogenous drivers such as environmental exposures.³ Personal care products, including chemical hair products, are a potentially important source of exposure to environmental chemicals.⁴ Chemical hair products are widespread and regularly used throughout the life course, and certain application-based products such as hair straighteners/chemical relaxers (hereafter referred to as "straighteners") require repeated usage to maintain desired results.^{5–7} Straighteners are defined as products to permanently or temporarily straighten or wave curly hair.^{7,8}

Use of hair straighteners is relatively common, with several studies reporting a range of 10% to 95% of participants using these products in their lifetime.^{9,10} These products tend to be used predominately by Black or African American women, and use of hair straighteners tends to start early including during childhood and adolescence.⁷ Previous studies have suggested that commercially available products can contain carcinogens and endocrine disrupting chemicals. Constituents such as formaldehyde/formaldehyde releasers, and derivatives, cyclosiloxanes, and various plasticizers such as phthalates^{11–14}, have been proposed to be banned or regulated under California's Proposition 65 and the European Union Cosmetics Directive.¹⁵ Frequent use of hair straighteners has been previously associated with a higher incidence of breast, ovarian, and uterine cancers.^{10,16,17} Specifically, in the Sister Study cohort, we have previously reported that frequent use of hair straighteners is related to a 30% higher incidence of breast cancer and over two times the incidence of ovarian and uterine cancer.^{18–20}

Although the biological plausibility of the relationship between hair straighteners and cancer is still under investigation, several chemical compounds that are present within these products have been shown to impact key mechanisms that can potentially drive carcinogenesis and genotoxicity.^{21,22} Formaldehyde, which has been found to be emitted during the application of hair straighteners,¹² exhibited covalent binding properties to DNA and proteins leading to DNA adduct formations.^{23,24} These genetic alterations or mutations from DNA lesions that are not properly repaired before replication may lead to genomic instability, a hallmark of cancer.^{25,26} Formaldehyde's chemical composition also has the ability to generate reactive oxygen species, a known cause of oxidative stress which weakens system-based antioxidants needed for free radical neutralization and promotes damage to DNA, lipids, and proteins.^{27,28} Furthermore, other chemicals present such as phthalates are associated with inflammation and oxidative stress, known mechanism that promote a tumor growth environment.^{29–31}

To our knowledge, no study has examined the relationship between hair straighteners and the incidence of cancer outcomes other than breast, ovarian, and uterine cancers. However, these chemicals may also contribute to higher risk of other cancers by, for instance, inducing oxidative stress, inflammation, and kidney injury.^{29,32,33} Therefore, the aim of this study is to assess the associations between self-reported hair straightener use and multiple cancers,

including melanoma, thyroid, lung, non-Hodgkin's lymphoma, leukemia, pancreatic cancer, colorectal, and kidney cancer.

Methods

Study Population

The Sister Study is a US-wide prospective cohort that enrolled 50,884 women between the ages of 35 and 74 years from 2003 to 2009.³⁴ The study included women who had no history of breast cancer themselves but had a sister previously diagnosed with breast cancer. At baseline, detailed information on individual's demographics and lifestyle factors, medical and family history, and occupational and environmental exposures was collected. All participants completed a home visit with a trained examiner to collect anthropometric measures and biospecimen samples. Sister Study participants complete annual health updates and more detailed follow-up surveys every 2–3 years. The cohort response rates averaged approximately 80% during the follow-up period.³⁵ This analysis includes data from cohort follow-up until September 30, 2021 (Data Release 11.1). All Sister Study participants provided informed consent, and the study is approved by the Institutional Review Board of the National Institutes of Health.³⁴

We excluded women who withdrew from the study (n=9), who had self-reported a diagnosis of invasive cancer before enrollment (n=2,847), had an unclear timing of cancer diagnosis relative to enrollment (n=261), had a confirmed or uncertain in situ cancer diagnosis before enrollment (n=110), who did not contribute any follow-up time (n=269), who did not answer any hair straightener use questions (n=1,077), or were missing data for any of the covariates in the main analysis (n=24). After these exclusions, the final analytical samples consisted of 46,287 participants.

Exposure and Covariate Assessment

At baseline, participants completed self-administered questionnaires that assessed use of hair straighteners/chemical relaxers in the past 12 months. Specifically, participants were asked, "In the past 12 months, how frequently have you or someone else straightened or relaxed your hair, or used hair pressing products?" We collapsed the frequency variables (never ['did not use']), 4 times/year ['1–2 times a year' to 'every 3–4 months'], or > 4 times/year ['every 5–8 weeks' to 'more than once a month']). We also used a binary variable for ever- or never use in the past 12 months. Our justification for using specified cut-points (< 4 times/year or > 4 times/year) when measuring the frequency of hair product use ensures that the sample sizes across exposure groups are proportionally balanced and well distributed for improved statistical power; however, this also aligns with adherence to the recommended and historical patterns of applying these products yearly.³⁶ For covariates, we considered sociodemographic factors that were assessed on the baseline questionnaires including self-identified race and ethnicity as well as self-reported smoking history, and educational attainment, as a proxy for socioeconomic status. Body mass index (BMI, kg/m²) was calculated from the height and weight measured at the home visit. We adjusted models for factors that are known risk factors for cancer and are associated with our exposure of interest, as potential confounders.^{37,38}

Outcome Assessment

We included cancers for which there were at least 100 incident cases during the follow-up period, with the exception of cancer sites that had been previously evaluated, specifically breast, ovarian, and uterine cancers.^{18–20} Study participants who self-reported a diagnosis of incident cancers during follow-up were asked to provide a copy of their pathology reports with additional medical confirmation possible via linkage to the National Death Index and death certificates, indicating a cancer specific cause of death. Among participants who provided pathology reports, positive predictive values range from 74% for cancer of the colon/rectum to 95% for pancreatic cancer.³⁹ We included first cancer diagnoses only, including 578 melanoma, 225 thyroid cancer, 376 lung cancer, 313 non-Hodgkin's lymphoma, 161 leukemia, 138 pancreatic cancer, 249 colorectal cancer, and 129 kidney cancers. To improve statistical power and allow for the inclusion of some less common cancer types, we also evaluated associations of hair straighteners and groups of cancers defined by organ system. This approach allowed for the consideration of 488 lymphoid and hematopoietic cancers (non-Hodgkin's lymphoma, Hodgkin's lymphoma, multiple myeloma, leukemia, myelodysplastic syndrome, polycythemia vera), 482 digestive system cancers (colon, rectal, appendiceal, small intestinal, anal, pancreatic, liver, intrahepatic bile duct, other biliary tract, stomach, and esophageal), and 207 urinary tract cancers (kidney, bladder, renal pelvis, ureter and urethra).

Statistical Analysis

We used Cox proportional hazard models to estimate the hazard ratio (HR) and 95% confidence interval (CI) for the association between self-reported use of hair straighteners in the 12 months before baseline and first-incident cancers. In each cancer-specific analysis, age was used as the underlying timescale, with follow-up beginning at the participant's age at baseline. Participants were followed until the diagnosis of the specific invasive cancer or were censored at the earliest occurrence of one of the following events: diagnosis of a different invasive cancer, diagnosis of an *in-situ* form of the cancer under analysis, loss to follow-up, death, or the end of study follow-up. These models were adjusted for an *a priori* list of confounders (Figure S1)⁴⁰, including race/ethnicity (non-Hispanic White, Black, Hispanic or other including American Indian/Alaska Native, and Hawaiian/Pacific Islander), educational attainment (high school or less, some college, college or above), and smoking status (never, past or current).

Our primary analyses compared individuals who used any hair straighteners/chemical relaxers with individuals who did not use them in the year preceding study enrollment. As exploratory analyses, we further investigated the frequency of relaxer use as well as race-stratified associations. To assess a monotonic relationship in frequency of use, we estimated a p-for-trend using a Wald test, with exposure variables characterized ordinally. Race-specific measures were evaluated by incorporating straightener-by-race interaction terms into our primary model, and heterogeneity was assessed using Wald tests. Only the associations among Black and non-Hispanic White participants were reported due to sample size constraints for Hispanic and the remaining racial and ethnic groups. In the sensitivity analyses, we additionally adjusted for body mass index (BMI; continuous kg/m²).

Results

Study participants were followed for an average of 13.1 years. The median age at baseline was 55.5 years and over half attained a college education or higher. Our study included Black (8.7%), Hispanic/Latina (4.5%), non-Hispanic White (84%) and other race/ethnic group (2.7%) participants. Any use of hair straighteners/chemical relaxers in the year prior to enrollment was more common among Black participants (66%) and Hispanic/Latina participants (25%) than among non-Hispanic White participants (1.3%) (Table 1).

Compared to not using hair straighteners in the past 12 months, use of hair straighteners in the year before enrollment was associated with an elevated hazard ratio for pancreatic cancer ($n=138$; HR: 2.66, 95% CI: 1.25, 5.66), thyroid cancer ($n=225$; HR: 1.71, 95% CI: 1.01, 2.89), and non-Hodgkin's lymphoma ($n=313$; HR: 1.62, 95% CI: 0.94, 2.80). Additionally, we observed a positive but imprecise association between the use of hair straighteners and incident kidney cancer ($n=129$; HR: 1.60, 95% CI: 0.76, 3.36). HR for other cancer types, including cancers grouped by organ system, were near 1.00 and had wide confidence intervals (Table 2).

Frequent use (>4 times/year) compared to no use of hair straighteners/chemical relaxers was also associated with elevated incidence of pancreatic cancer (HR: 2.36, 95% CI: 0.82, 6.84, p-trend: 0.04), thyroid cancer (HR: 1.66, CI: 0.80, 3.46, p-trend: 0.07), and non-Hodgkin's lymphoma (HR: 1.83, 95% CI: 0.89, 3.75, p-trend: 0.07), although confidence intervals were wide and the associations for all but pancreatic cancer were not supported by a monotonic dose-response trend (Table 3). There was little to no association between frequent use of these products and the remaining incident cancers considered in our analysis.

Associations among non-Hispanic White women were similar to those seen in the analysis of all participants. Among non-Hispanic White women, use of hair straighteners/chemical relaxers was associated with elevated risks of pancreatic cancer (HR: 2.92, 95% CI: 1.18, 7.25), thyroid cancer (HR: 1.58, 95% CI: 0.80, 3.10), non-Hodgkin's lymphoma (HR: 2.01, 95% CI: 1.09, 3.70), and kidney cancer (HR: 2.59, 95% CI: 1.13, 5.98) (Table S1). However, among Black women, we had limited power to detect associations, and most HRs were statistically indistinguishable from 1.00. In the sensitivity analyses, adjusting for body mass index in addition to the main adjustment set resulted in no to minimal changes to the primary findings (Table S2).

Discussion

In this large prospective cohort of women in the United States, we investigated the relationship between use of hair straighteners/chemical relaxers and the incidence of several cancers that have not been previously evaluated, including melanoma, thyroid, lung, non-Hodgkin's lymphoma, leukemia, pancreatic, colorectal, and kidney cancers. We observed that use of hair straighteners was associated with a higher incidence of pancreatic cancers, thyroid cancers, and possibly non-Hodgkin's lymphoma. Little evidence of an association was observed for the other cancer types evaluated. These novel findings suggest that hair straighteners/chemical relaxers may be related to a higher risk of multiple cancer types.

Previous studies have identified associations between hair straightener/chemical relaxer use and cancers such as breast, ovarian, and uterine malignancies^{10,17,19,20,41}, although one study found no significant associations.⁴² In earlier analyses within the Sister Study cohort, we observed that frequent use of hair straighteners/relaxers (>4 time/year) compared to non-users, was associated with a higher incidence of breast (HR: 1.31, 95% CI:1.05,1.63)¹⁸, ovarian (HR: 2.19, 95% CI: 1.12, 4.27)¹⁹, and uterine cancer (HR: 2.55, 95% CI = 1.46, 4.45).²⁰ Similarly, in the Women's Circle of Health Follow-Up Study, regular use of hair straighteners/chemical relaxers was associated with an elevated risk of breast cancer (n=57; odds ratio: 1.74, 95% CI: 1.11, 2.74) among White women but not Black women (n=1311; odds ratio: 0.99, 95% CI: 0.79,1.26), even though regular use of these products were more common among Black women.¹⁶ Comparably, in the Black Women's Health Study, heavy use of relaxers containing lye were associated with an increased risk of ER+ breast cancer, when used frequently for 7 times/year (HR:1.37,95% CI:1.04,1.82), heavily for 15 years and 7+ times/yr (HR:1.32,95% CI:0.97,1.80) or when 10 scalp burns occurred (HR:1.32, 95% CI:0.97,1.79).¹⁰ Additionally, in the Black Women's Health Study, among postmenopausal women that used straighteners, elevated associations for uterine cancer were found among moderate users (n=123; HR:1.60, 95% CI: 1.01, 2.53), heavy users (n=85;HR:1.64, 95% CI: 1.01,2.64), and users for twenty or more years(n=116;HR:1.71,95% CI: 1.08,2.72).¹⁷

In addition to cancer outcomes, previous studies have also reported associations between using straighteners and other adverse health outcomes in women, including leiomyomas^{41,43}, early menarche⁴⁴, and reduced fecundability.⁹ Although these outcomes are hormone-sensitive and thus influenced by hormone-related mechanisms, it remains unclear how chemical constituents in hair straightening products may influence biological mechanisms associated with adverse health outcomes and their respective risk factors. For example, endocrine disruptors such as obesogens may exacerbate impaired metabolic function, chronic inflammation, and obesity, which are known risk factors in several cancers such as thyroid, pancreatic, kidney, colon/rectum, and others.⁴⁵

Mechanistic studies suggest that several chemical components in these products may affect carcinogenic pathways involved in the development of pancreatic, non-Hodgkin's lymphoma and thyroid cancers. For example, phthalates have been associated with disrupting pancreatic functionality via oxidative and beta-cell stress in animal models, key biological mechanisms associated with cancer development.⁴⁶ Additionally, formaldehyde releasing agents, which are prevalent in several straightener formulations^{14,47,48}, have been associated with hematopoietic stem cell toxicity and oxidative damage in bone marrow cells, a critical process implicated in the development of blood cancers such as non-Hodgkin's lymphoma.⁴⁹ Parabens, another chemical class commonly found in these products, have been shown to modulate the hypothalamic–pituitary–thyroid axis through altered gene expression involved in thyroid feedback and signaling in both animal and human studies.^{50–53} Additionally, hair products containing formaldehyde-releasing chemicals such as glyoxylic acid could lead to kidney injury via skin absorption and activation of formaldehyde through applying heat to the product.^{54,55} Our analyses also suggests a possible association between frequent use of straighteners and an elevated hazard of kidney cancer, however, confidence intervals were wide, and a monotonic dose-response

relationship was not present. Our null findings for the cancers grouped by organ system suggests possible heterogeneity by individual cancer types.

This analysis used data from a large prospective and well-characterized cohort study to investigate how use of these products is related to a range of different tumor types. Despite the large size of the cohort, we had small case numbers for some of the cancer types which made it difficult to determine how these associations varied by frequency of use or by race and ethnicity. Previous research from this study population with breast, uterine and ovarian cancers did support dose-response associations with increased frequency of use. Black women were more frequent users of hair straighteners, but our ability to conduct race-stratified analyses was greatly limited by the small number of Black participants with cancer. Given variations in the incidence of these tumors by race, especially pancreatic, stomach, liver and intrahepatic bile duct (IBD) for which incidence is higher in Black women^{56,57}, future research is warranted to explore these findings in a larger population of Black and Hispanic women, given their more frequent use of these products.

Our questionnaire focused on hair straightener use in the 12 months prior to enrollment, which we consider a proxy for usual use during adulthood. Because participants included in this analysis were cancer-free at enrollment, recall bias is not a concern. However, some amount of exposure misclassification is likely, as we were not able to account for long term usage patterns, which may be more relevant for carcinogenesis.⁷ This may in part contribute to the lack of statistically significant monotonic relationships with more frequent hair straightener use, in comparison to our previous analyses of breast,¹⁸ ovarian,¹⁹ and uterine cancers,²⁰ which exhibited dose response associations with increasing frequency of use. We dichotomized frequency of use (4 times/year and >4 times/year) uniformly across these different outcomes in order to maximize our power to detect associations but it is possible that these are not the most relevant cutpoints for these tumors.

The questionnaire did not ascertain specific formulations of hair straighteners nor distinguish between use of lye or no-lye formulations. Based on the formulation of the products, absorption of the chemical constituents on the scalp may increase or decrease due to their differences in alkalinity, and their potential to cause the development of scalp lesions or burns which may increase likelihood of chemical absorption in the blood.⁴¹ Additionally, the study question included a reference to “pressing products,” which participants may have interpreted as using a flat iron, with or without hair products, to straighten hair. Thus, some participants may have been misclassified as users of straighteners despite not being exposed to the harsher chemicals of concern. This potential misclassification would likely bias our effect estimates toward the null. Furthermore, in our study we note that majority of our participants are non-Hispanic White women, all with a family history of breast cancer, which limits the generalizability of these findings to the more diverse population of US women.

In this large US-based prospective study, we demonstrate new evidence suggesting that use of hair straighteners/chemical relaxers may be related to a higher incidence of pancreatic cancer, thyroid cancer, and possibly non-Hodgkin’s lymphoma. These novel findings expand the scope of the adverse health outcomes that have been associated with these products.

Future research is needed to confirm these findings and to identify specific constituents in these products that contribute to cancer incidence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data Availability:

All data necessary to reproduce the current analysis are available following the procedures as outlined on the Sister Study website (<https://sisterstudy.niehs.nih.gov/English/data-requests.htm>)

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Table 1.

Characteristics of Sister Study participants by hair straightener/chemical relaxer use in the 12 months prior to enrollment (enrolled 2003–2009).

	Never Use (N=41,734)	Ever Use (N=4,553)	Overall (N=46,287)
Age at baseline			
Median (IQR)	55.9 (13.1)	51.7 (12.0)	55.5 (13.1)
Educational attainment, No.(%)			
High school or less	6462 (15%)	599 (13%)	7061 (15%)
Some college	13923 (33%)	1619 (36%)	15542 (34%)
College or above	21349 (51%)	2335 (51%)	23684 (51%)
Race and ethnicity, No.(%)			
Black ^a	1041 (2.5%)	2998 (66%)	4039 (8.7%)
Hispanic ^b	1743 (4.2%)	360 (7.9%)	2103 (4.5%)
Other ^c	1124 (2.7%)	58 (1.3%)	1182 (2.6%)
Non-Hispanic White	37826 (91%)	1137 (25%)	38963 (84%)
Smoking Status			
Never	23380 (56%)	2863 (63%)	26243 (57%)
Past or current	18354 (44%)	1690 (37%)	20044 (43%)

Exclude women withdrew from the study (n=9), had an invasive cancer diagnosis before enrollment (n=2847), had an unclear timing of invasive diagnosis relative to enrollment (n=261), had a confirmed or uncertain situ cancer diagnosis before enrollment or unclear timing (n=110), who did not contribute any follow-up time (n=269), who did not answer any hair straightener use questions (n=1077), had any missing in the covariates in main models (i.e., race, age, education, smoking) (n=24).

^aAfrican American or Black, including those identified as Hispanic or Latina.

^bHispanic or Latina non-African American or Black.

^cIncluding Asian, Pacific Islander, or American Indian/Alaska Native.

^dWhite participants, not including those identified as Hispanic or Latina

Table 2.

Associations between ever use of hair straightener/chemical relaxer in the 12 months prior to enrollment and cancer incidence in the Sister Study

Incident Cancers ^a	Cancer Cases	Age & race-adjusted HR(95% CI) ^b	Main model HR (95% CI) ^c
Melanoma			
Never	561	1.00	1.00
Ever	17	0.91 (0.54, 1.55)	0.92 (0.54, 1.55)
Thyroid			
Never	203	1.00	1.00
Ever	22	1.70 (1.01, 2.88)	1.71 (1.01, 2.89)
Lung			
Never	348	1.00	1.00
Ever	28	1.12 (0.65, 1.94)	1.11 (0.65, 1.90)
Any Lymphoid/ Hematopoietic^d			
Never	449	1.00	1.00
Ever	39	1.29 (0.83, 2.03)	1.29 (0.83, 2.03)
Non-Hodgkin's Lymphoma			
Never	292	1.00	1.00
Ever	21	1.62 (0.94, 2.80)	1.62 (0.94, 2.80)
Leukemia			
Never	150	1.00	1.00
Ever	11	1.28 (0.55, 2.97)	1.28 (0.55, 2.96)
Any Digestive Cancer^e			
Never	447	1.00	1.00
Ever	35	0.97 (0.60, 1.57)	0.97 (0.60, 1.56)
Pancreatic			
Never	126	1.00	1.00
Ever	12	2.69 (1.26, 5.73)	2.66 (1.25, 5.66)
Colorectal			
Never	232	1.00	1.00
Ever	17	0.66 (0.34, 1.28)	0.66 (0.34, 1.28)
Any Urinary Cancer^f			
Never	187	1.00	1.00
Ever	20	1.00 (0.51, 1.93)	0.98 (0.51, 1.91)
Kidney			
Never	111	1.00	1.00
Ever	18	1.63 (0.78, 3.41)	1.60 (0.76, 3.36)

HR: Hazard Ratio; CI: Confidence Interval.

^aOnly cancers that have more than 100 incidences after enrollment were included in the analyses.

^bAge as the timescale, and adjusted for race and ethnicity (Black, non-Hispanic White, Hispanic or other).

^cAdjusted for educational attainment (high school or less, some college, college or above) and smoking status (never, past or current).

^dIncluding non-Hodgkin's lymphoma, Hodgkin's lymphoma, multiple myeloma, leukemia, myelodysplastic syndrome, polycythemia vera.

^eIncluding colon, rectal, appendiceal, small intestinal, anal, pancreatic, liver, intrahepatic bile duct, stomach, and esophageal cancers.

^fIncluding kidney, bladder, renal pelvis, ureter, and urethra cancers.

Table 3.

Associations between frequent use of hair straightener/chemical relaxer use in the 12 months prior to enrollment and cancer incidence in the Sister Study

Incident Cancers ^a	Cancer Cases	Main Model HR (95% CI) ^b
Melanoma		
4 times/year	13 (2.2%)	1.24 (0.70, 2.21)
>4 times/year	4 (0.7%)	.. ^d
p-for-trend ^c		.. ^d
Thyroid		
4 times/year	12 (5.3%)	1.74 (0.93, 3.25)
>4 times/year	10 (4.4%)	1.66 (0.80, 3.46)
p-for-trend ^c		0.07
Lung		
4 times/year	15 (4.0%)	1.18 (0.63, 2.19)
>4 times/year	13 (3.5%)	1.02 (0.51, 2.04)
p-for-trend ^c		0.87
Any Lymphoid or Hematopoietic^e		
4 times/year	17 (3.5%)	1.17 (0.67, 2.03)
>4 times/year	22 (4.5%)	1.44 (0.83, 2.51)
p-for-trend ^c		0.19
Non-Hodgkin's Lymphoma		
4 times/year	10 (3.2%)	1.47 (0.74, 2.91)
>4 times/year	11 (3.5%)	1.83 (0.89, 3.75)
p-for-trend ^c		0.07
Leukemia		
4 times/year	3 (1.9%)	.. ^d
>4 times/year	8 (5.0%)	1.93 (0.73, 5.07)
p-for-trend ^c		.. ^d
Any Digestive Cancer^f		
4 times/year	15 (3.1%)	0.88 (0.49, 1.59)
>4 times/year	20 (4.1%)	1.08 (0.60, 1.92)
p-for-trend ^c		0.89
Pancreatic		
4 times/year	7 (5.1%)	2.86 (1.21, 6.76)
>4 times/year	5 (3.6%)	2.36 (0.82, 6.84)
p-for-trend ^c		0.04
Colorectal		
4 times/year	6 (2.4%)	0.51 (0.21, 1.27)
>4 times/year	11 (4.4%)	0.81 (0.37, 1.77)
p-for-trend ^c		0.45

Incident Cancers ^a	Cancer Cases	Main Model HR (95% CI) ^b
Any Urinary Cancer^g		
4 times/year	8 (3.9%)	0.85 (0.37, 1.95)
>4 times/year	12 (5.8%)	1.13 (0.52, 2.47)
p-for-trend ^c		0.81
Kidney		
4 times/year	7 (5.4%)	1.35 (0.54, 3.34)
>4 times/year	11 (8.5%)	1.92 (0.80, 4.58)
p-for-trend ^c		0.14

HR: Hazard Ratio; CI: Confidence Interval.

^aOnly cancers that have more than 100 incidences after enrollment were included in the analyses.

^bAge as the timescale, and adjusted for race and ethnicity (Black, non-Hispanic White, Hispanic or other), educational attainment (high school or less, some college, college or above), smoking status (never, past or current).

^cAssessed using Wald tests for ordinal variables of hair straightener use frequency.

^dData not presented as small number of cases (<5) within any stratum in the model.

^eIncluding non-Hodgkin's lymphoma, Hodgkin's lymphoma, multiple myeloma, leukemia, myelodysplastic syndrome, polycythemia vera.

^fIncluding colon, rectal, appendiceal, small intestinal, anal, pancreatic, liver, intrahepatic bile duct, stomach, and esophageal cancers.

^gIncluding kidney, bladder, renal pelvis, ureter, and urethra cancers.