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ORIGINAL PAPER

# Impact of hysterectomy and bilateral oophorectomy prevalence on rates of cervical, uterine, and ovarian cancer among American Indian and Alaska Native women, 1999–2004

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**Abstract**
*Objective* To present more accurate incidence rates of cervical, uterine, and ovarian cancer by geographic region in American Indian/Alaska Native (AI/AN) women.
*Methods* The authors used data from central cancer registries linked to Indian Health Service (IHS) patient registration database, the Behavioral Risk Factor Surveillance System, IHS National Data Warehouse, and the National Hospital Discharge Survey. Cancer incidence rates were adjusted for hysterectomy and oophorectomy prevalence and presented by region for non-Hispanic White (NHW) and AI/AN women.
*Results* AI/AN women had a higher prevalence of hysterectomy (23.1%) compared with NHW women (20.9%). Correcting cancer rates for population-at-risk significantly increased the cancer incidence rates among AI/AN women: 43% for cervical cancer, 67% for uterine cancer, and 37% for ovarian cancer. Risk-correction led to increased differences in cervical cancer incidence between AI/AN and NHW women in certain regions.
*Conclusions* Current reporting of cervical, uterine, and ovarian cancer underestimates the incidence in women at risk and can affect the measure of cancer disparities. Improved cancer surveillance using methodology to correct for population-at-risk may better inform disease control priorities for AI/AN populations.

**Keywords** Hysterectomy · American Indian/Alaska Native · Cervical cancer · Incidence

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the Indian Health Service.

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## Introduction

Cancer incidence rates should reflect the rate of cancer among individuals at risk [1]. Removal of the uterus (hysterectomy) or ovaries (oophorectomy) eliminates a woman's risk of uterine or ovarian cancer [2], while hysterectomy with removal of the cervix substantially lowers the risk of cervical cancer [3]. Failure to adjust the denominator of these cancer rates for women who have had a hysterectomy and/or oophorectomy may lead to underestimations in cancer rates [1, 4, 5]. These corrections are significant because hysterectomy is the second most common surgery performed in women [6].

Previous studies used a variety of data sources to estimate hysterectomy prevalence and cancer incidence rates in women of all races in the United States [7–10]. To date, no study has focused on these corrections in AI/AN women at a regional level, an important consideration because several recent reports have shown that wide regional variation in cancer burden is characteristic of AI/AN populations [11, 12]. Additionally, AI/AN gynecologic cancer rates are more severely impacted by these corrections because of their comparatively high hysterectomy prevalence. In a previous study, AI/AN women had a higher hysterectomy prevalence than other racial groups in 19 of 31 states with reportable numbers [13]; another found that AI/AN women had the highest prevalence of hysterectomy in women under 40 years old [14]. Our aim is to present, by geographic region, the rates of cervical, uterine, and ovarian cancer in AI/AN women adjusted for population-at-risk using updated estimates of cancer incidence and hysterectomy and oophorectomy prevalence in this population. Improved cancer incidence data may strengthen the evaluation of cancer control efforts, particularly for cervical cancer for which established prevention and early detection measures exist.

## Materials and methods

### Cancer incidence

In the United States, two federal programs fund central cancer registries: the National Program of Cancer Registries (NPCR) of the Centers for Disease Control and Prevention (CDC) and the Surveillance, Epidemiology, and End Results (SEER) Program of the National Cancer Institute (NCI). Together, these registries covered 100% of the US population. Primary cancer site and histology data are coded according to the International Classification of Diseases for Oncology (ICD-O) edition in use at the time of diagnosis and are converted to the Third Edition [15]. Incident cancer cases diagnosed from 1999 to 2004 from central cancer registries that met the *United States Cancer Statistics* standard for high-quality data were included in this analysis (see footnote to Table 2 for list of registries) [16].

Only invasive cancers of the cervix (ICD-O-3 C530–C539), uterus (ICD-O-3 C540–C549, C559), and ovaries (ICD-O-3 C569) are included in our analysis. Lymphomas, mesothelioma, and Kaposi's sarcoma were excluded from the analysis.

To reduce the racial misclassification of AI/AN cases as non-native, all case records from the NPCR and SEER central cancer registries were linked with the Indian Health Service (IHS) patient registration database as described elsewhere [17]. The IHS provides medical services to AI/AN persons who are eligible members of federally recognized tribes.

To further improve on race classification, we restricted our analyses to counties designated by the IHS as "Contract Health Service Delivery Areas" (CHSDA) as described elsewhere [17]. Although less geographically representative, analyses restricted to CHSDA counties are presented in this report for the purpose of improving accuracy for cancer incidence for AI/AN women.

The analyses were completed for all regions combined and by individual IHS regions: Alaska, Pacific Coast, Northern Plains, Southern Plains, Southwest, and East (Fig. 1). The rationale for regional analyses for cancer, and other health outcomes, for AI/AN has been described elsewhere [17].

### Estimating hysterectomy prevalence

The Behavioral Risk Factor Surveillance System (BRFSS) was the primary source of hysterectomy prevalence among self-identified AI/AN and non-Hispanic White (NHW) women [18]. Women who reported "an operation to remove the uterus/womb" were identified in BRFSS as having had a hysterectomy. No questions on the date of the surgery, the type of procedure, or the reason for hysterectomy are asked. We limited analysis of the BRFSS data to the years 1999, 2000, 2002, 2004, and 2006 when the question on hysterectomy status was included in the survey questionnaire for all states.

Since some hysterectomy procedures leave the cervix intact (subtotal hysterectomy), adjustment was needed to accurately estimate the proportion of women with a history of hysterectomy still at the risk of cervical cancer. Similarly, only those hysterectomies accompanied by bilateral oophorectomy, a procedure in which both ovaries are removed, were utilized to adjust the rate of ovarian cancer. No estimate for the procedure bilateral oophorectomy alone was available because no reliable and comparable data source for NHW and AI/AN women exists.

The National Hospital Discharge Survey (NHDS) collects data on inpatient utilization, including treatment and procedures received during hospitalization and discharge diagnoses, from non-federal short-stay hospitals [19]. The NHDS data from 1999 to 2005 were used to generate adjustment factors to estimate the proportion of hysterectomies that removed the cervix (ICD-9-CM code 68.3) and hysterectomies that were accompanied by bilateral oophorectomy (ICD-9-CM codes: 65.5–65.6 and 68.3–68.9) for NHW women.

Similar adjustments to hysterectomy prevalence data for AI/AN were necessary; however, NHDS had limited numbers of AI/AN women. We therefore queried years

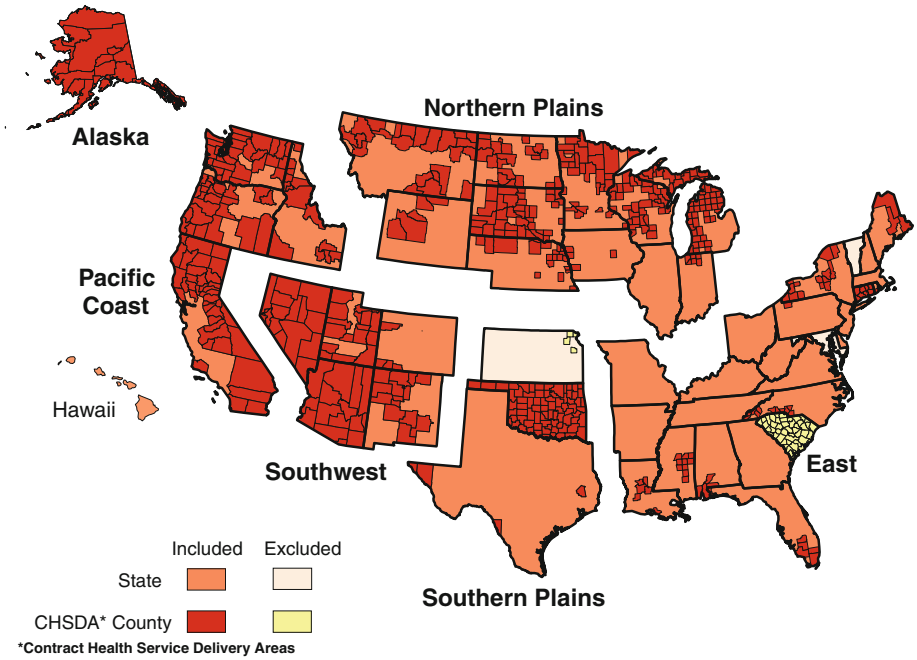


**Fig. 1** States and IHS Contract Health Service Delivery Areas (CHSDA) counties by Indian Health Service Region

**Table 1** Adjustment of hysterectomy prevalence by hysterectomy type to assess the impact of hysterectomy prevalence on the rates of cervical, uterine, and ovarian cancer among AI/AN and NHW women in the United States, 1999–2004

| | Type of hysterectomy needed for cancer rate correction | Data source for adjustment of hysterectomy prevalence by hysterectomy type | |
|---|---|---|---|
| | | AI/AN | Non-Hispanic White |
| Cervical cancer | All hysterectomy except subtotal hysterectomy | National Data Warehouse (NDW) | National Hospital Discharge Survey (NHDS) |
| Uterine cancer | All types of hysterectomy | None needed | None needed |
| Ovarian cancer | Only hysterectomy accompanied by bilateral oophorectomy | National Data Warehouse (NDW) | National Hospital Discharge Survey (NHDS) |

*AI/AN* American Indians/Alaska Natives, *NHW* Non-Hispanic White

2002–2005 from the IHS National Data Warehouse (NDW), which contains registration and encounter-based patient data from IHS/Tribal/Urban facilities, using methods similar to those described above for NHDS [20]. The hysterectomy prevalence for both NHW and AI/AN women was corrected by the appropriate hysterectomy subtype adjusted by age, as summarized in Table 1.

## Correcting population estimates for hysterectomy prevalence

Population estimates used to derive denominators in the rate calculations were obtained from the NCI's publicly available web-based statistical resources [21] as described elsewhere [17].

To derive the appropriate denominator, by region and age group, to calculate the cervical cancer rates, the population estimates were adjusted downward in proportion to the prevalence of hysterectomy (further adjusted for subtotal hysterectomy as described above). Similarly, denominators to calculate uterine cancer rates were adjusted for the prevalence of hysterectomy alone, without further adjustment by the type of hysterectomy. Finally, denominators for the ovarian cancer rates were adjusted for BRFSS prevalence of hysterectomy further adjusted for the proportion of hysterectomy accompanied by bilateral oophorectomy. The denominators in the rate calculations were adjusted by age, region, and county-specific hysterectomy and oophorectomy prevalence.

## Statistical analyses

All rates, expressed per 100,000 population per year, were directly age-adjusted, using SEER*Stat software [22], to

the 2000 US standard population [23]. Using the corrected incidence rates, standardized rate ratios (RR) were calculated for AI/AN populations using NHW rates for comparison. Rate ratios are calculated in SEER*Stat prior to rounding of rates and may not equal RR calculated by the reader from rounded rates presented in the tables. Confidence intervals (CI) for age-adjusted rates and standardized rate ratios (RR) were calculated based on methods described by Tiwari et al. [24] using SEER*Stat 6.3.6. The CDC and IHS Institutional Review Boards determined the protocol to be public health practice, not research, and therefore not requiring IRB approval.

## Results

The prevalence of hysterectomy in AI/AN versus NHW women by region is displayed in Fig. 2. Hysterectomy prevalence was highest among AI/AN and NHW women living in the Southern Plains region (26%) and lowest among women in Alaska (18%). AI/AN women had an overall higher prevalence of hysterectomy compared with NHW women in all regions except Alaska and the Southern Plains. Among AI/AN women, prevalence was lowest in the younger age groups of 18–29 years (1%) and 30–39 years (5%) and highest in the 60–69 year age group (52%). Prevalence of hysterectomy tended to be higher among AI/AN than NHW in all age categories except 30–39 and 70+ years (Fig. 3). Estimates for the proportion of all hysterectomies that were subtotal hysterectomy were similar in AI/AN (4%) and NHW women (6%). NHW women had a higher proportion of hysterectomy accompanied by bilateral oophorectomy (55%) compared with AI/AN women (35%).

The uncorrected and corrected cervical cancer incidence rates among AI/AN women are shown in Fig. 4 and reveal a 43% increase in overall cervical cancer incidence rate after correction for hysterectomy where the cervix was removed for AI/AN women. The largest increases were found in the Southwest (72%, from 7.8 uncorrected to 13.4 corrected per 100,000) and East (58%, 7.1 to 11.2 per 100,000). For uterine cancer, the percent change resulting from the correction for hysterectomy status ranged from 51% in Alaska to 76% in the Southern Plains; the overall increase in uterine cancer rate was 67% among AI/AN women (Table 2). Corrected ovarian cancer rates were approximately one-third higher than uncorrected rates for AI/AN women across all regions (Table 2). The largest increases were noted in the Southwest and East.

AI/AN women had higher rates of cervical cancer than NHW women in all regions, and an overall 5% increase in the difference (assessed by an increase in rate ratio of AI/AN:NHW) of cervical cancer incidence between these racial/ethnic groups was found (Table 2). A 20% increase in disparities for cervical cancer was noted in the East and Southwest, while disparities decreased slightly in Alaska (−6%), the Southern Plains (−3%), and Pacific Coast (−3%). Uterine cancer rates in AI/AN were lower than NHW in all regions except the Southern Plains. Correction

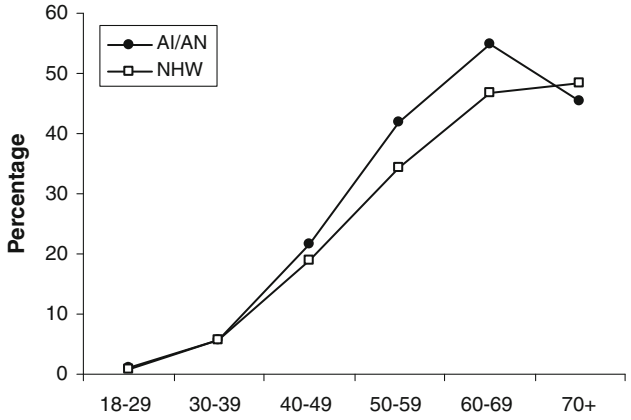


**Fig. 3** Hysterectomy prevalence by age group for the American Indians/Alaska Natives and non-Hispanic White populations—BRFSS, CHSDA counties, 1999–2006. *AI/AN* American Indians/Alaska Natives, *BRFSS* Behavioral Risk Factor Surveillance System, *CHSDA* Contract Health Service Delivery Areas, *NHW* non-Hispanic Whites

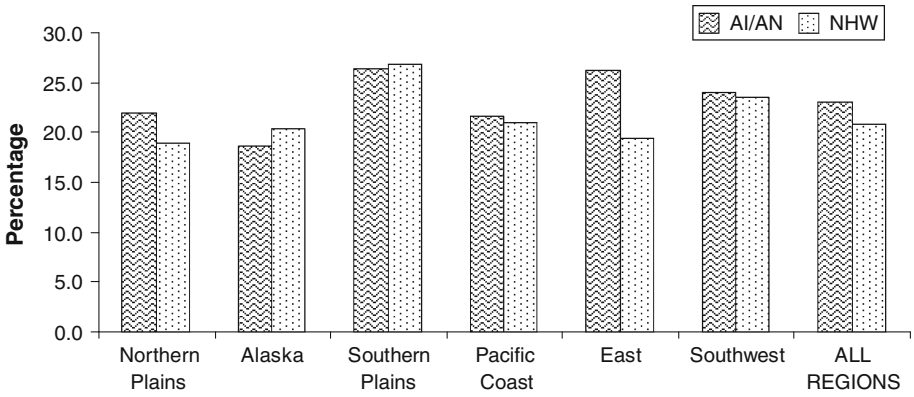


**Fig. 2** Hysterectomy prevalence by Indian Health Service Region for the American Indians/Alaska Natives and non-Hispanic White populations—BRFSS, CHSDA counties, 1999–2006. *AI/AN* American Indians/Alaska Natives, *BRFSS* Behavioral Risk Factor Surveillance System, *CHSDA* Contract Health Service Delivery Areas, *NHW* non-Hispanic Whites

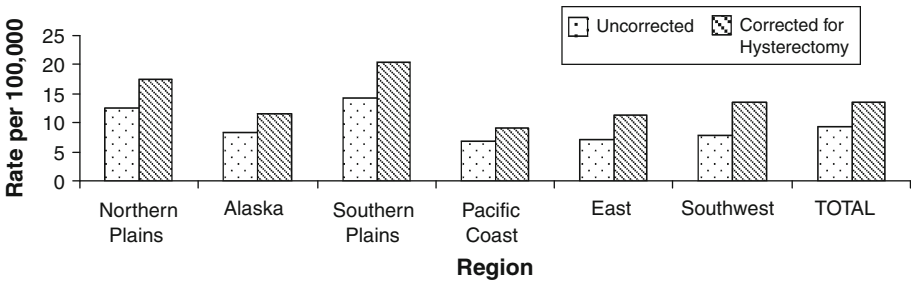


**Fig. 4** Uncorrected and corrected rates per 100,000 persons of cervical cancer by Indian Health Service Region for American Indians/Alaska Natives, CHSDA counties, 1999–2004. *CHSDA* Contract Health Service Delivery Areas

for hysterectomy status had no significant effect on the rate ratio of nationwide uterine cancer rates for AI/AN compared with NHW. Though rates of ovarian cancer are generally lower among AI/AN women when compared with NHW women, correction for oophorectomy status brought nationwide AI/AN rates of ovarian cancer 20% closer to NHW rates.

## Discussion

In our study, risk-corrected cervical, uterine, and ovarian cancer incidence rates were substantially higher for AI/AN and NHW women than cancer rates traditionally reported that are uncorrected for hysterectomy and oophorectomy status. Given the importance of regional differences in cancer occurrence in AI/AN [12], including cervical cancer [25], we present our current findings by IHS region to further aid in their interpretation. The East and Southwest experienced the largest increases in AI/AN rates for the 3 gynecologic cancers examined after correction for estimated prevalence of hysterectomy and oopherectomy. Furthermore, we found that risk-correction affected the differences in measures of incidence of these cancers for AI/AN compared with NHW women, most notably with substantially larger cervical cancer disparities in the East and Southwest regions. The effects of risk-correction on cancer incidence rates underscore the need to more accurately describe the impact of these cancers on women truly at risk.

Consistent with previous studies, we found the hysterectomy prevalence for AI/AN women to be higher than for NHW women [13, 14]. Several explanations have been suggested for the higher prevalence of hysterectomy in AI/AN women. Greater use of hysterectomy for sterilization among AI/AN in the 1960s and 1970s may be a contributing factor [26]. Also, predictors for hysterectomy, such as limited education, low socioeconomic status, high parity, and history of miscarriage, are more commonly found in the AI/AN population [27–29]. Indications for hysterectomy differ by age; uterine leiomyoma is most common indication for women aged 35–54 years, whereas uterine prolapse and cancer are the most common indications for women aged 55 years or older [30]. Few studies have been published on indications specifically for AI/AN women, but the higher hysterectomy prevalence is not explained by higher rates of uterine fibroids among AI/AN (1.8%) compared with NHW (1.9%) [31].

Our analysis revealed an overall increase in cervical cancer incidence rates of 43% among AI/AN women after risk-correction for hysterectomy. In a previous study using US data from 1990 to 1992, risk-correction for the point prevalence of hysterectomy increased the cervical cancer incidence rate by 38% [1]. A more recent study on the impact of hysterectomy on race-specific gynecological cancer rates reported that the risk-corrected compared with uncorrected incidence rates were 45.6% higher for cervical cancer in American Indians/Alaska Native (AI/AN) women [4]. Though substantial progress has been achieved in cervical cancer control in AI/AN women, our analysis revealed an increased disparity in cervical cancer incidence between AI/AN and NHW women, especially in certain regions, than previously reported for this time period. In addition to this finding, AI/AN women are on average diagnosed at more advanced stages of cervical cancer than NHW women [25, 32] underscoring the need to maintain and strengthen efforts to screen and provide adequate follow-up for abnormal results. For those women who have not undergone hysterectomy, screening for prevention and early detection of cervical cancer is critical.

Estimating the actual population-at-risk is especially important in cervical cancer for evaluating the impact of cervical cancer screening, which has been conducted through Pap cytology [33, 34]. The majority of newly diagnosed cervical cancer cases can be attributed to a lack of, or infrequent, screening [35]. Recent BRFSS data suggest a lower prevalence of cervical cancer screening in AI/AN women compared with NHW [36]. The higher incidence of cervical cancer incidence rates among AI/AN after risk-correction underscores the continued need for culturally sensitive population-based screening programs as well as promotion of the HPV vaccines recommended in the United States [37].

Uterine cancer is the most commonly diagnosed malignancy of the female reproductive system across all races in the United States [38]. Few studies have examined

**Table 2** Uncorrected and corrected gynecologic cancer incidence by Indian Health Service Region for American Indians/Alaska Natives[a] and non-Hispanic Whites, CHSDA counties, 1999–2004

| IHS region | Uncorrected rates | | | | Corrected rates | | | | % Increase |
|---|---|---|---|---|---|---|---|---|---|
| | AI/AN rate[b] | NHW rate | Rate ratio (AI/AN: NHW)[c] | 95% CI for rate ratio | AI/AN rate[b] | NHW rate | Rate ratio (AI/AN: NHW)[c] | 95% CI for rate ratio | Uncorrected to corrected cancer rate[d] |
| Cervical cancer | | | | | | | | | |
| Northern Plains | 12.5 | 7.4 | 1.69* | 1.29, 2.18 | 17.4 | 9.5 | 1.84* | 1.38, 2.39 | 39.2 |
| Alaska[e] | 8.4 | 6.2 | 1.37 | 0.77, 2.29 | 11.4 | 8.8 | 1.29 | 0.68, 2.29 | 35.7 |
| Southern Plains | 14.1 | 9.1 | 1.54* | 1.25, 1.87 | 20.4 | 13.7 | 1.49* | 1.20, 1.82 | 44.7 |
| Pacific Coast | 6.9 | 7.0 | 0.98 | 0.74, 1.27 | 9.0 | 9.4 | 0.95 | 0.71, 1.26 | 30.4 |
| East | 7.1 | 7.3 | 0.97 | 0.53, 1.62 | 11.2 | 9.7 | 1.16 | 0.59, 2.01 | 57.7 |
| Southwest | 7.8 | 7.3 | 1.07 | 0.85, 1.32 | 13.4 | 10.5 | 1.28 | 0.96,1.66 | 71.8 |
| Total | 9.4 | 7.4 | 1.28* | 1.15, 1.42 | 13.4 | 9.9 | 1.35* | 1.20, 1.52 | 42.6 |
| Uterine cancer | | | | | | | | | |
| Northern Plains | 19.5 | 26.6 | 0.74* | 0.58, 0.92 | 30.7 | 41.8 | 0.73* | 0.58, 0.91 | 57.4 |
| Alaska[e] | 13.6 | 22.8 | 0.60* | 0.39, 0.88 | 20.5 | 39.9 | 0.51* | 0.33, 0.77 | 50.7 |
| Southern Plains | 22.4 | 19.4 | 1.16 | 0.98, 1.36 | 39.5 | 39.7 | 1.00 | 0.84, 1.17 | 76.3 |
| Pacific Coast | 16.7 | 23.6 | 0.71* | 0.58, 0.85 | 26.2 | 41.6 | 0.63* | 0.52 0.76 | 56.9 |
| East | 15.2 | 25.4 | 0.60* | 0.40, 0.86 | 26.6 | 40.8 | 0.65* | 0.42, 0.96 | 75.0 |
| Southwest | 16.7 | 19.5 | 0.86* | 0.74, 0.99 | 29.0 | 36.0 | 0.81* | 0.67, 0.96 | 73.7 |
| Total | 18.1 | 23.6 | 0.77* | 0.71, 0.83 | 30.2 | 40.4 | 0.75* | 0.69, 0.81 | 66.9 |
| Ovarian cancer | | | | | | | | | |
| Northern Plains | 11.0 | 14.0 | 0.79 | 0.57, 1.04 | 14.3 | 15.7 | 0.91 | 0.67, 1.21 | 30.0 |
| Alaska[e] | 7.3 | 13.5 | 0.54* | 0.29, 0.92 | 9.3 | 15.3 | 0.60 | 0.32, 1.05 | 27.4 |
| Southern Plains | 14.7 | 13.9 | 1.05 | 0.86, 1.28 | 20.3 | 16.4 | 1.24* | 1.01, 1.51 | 38.1 |
| Pacific Coast | 10.0 | 14.9 | 0.67* | 0.52, 0.85 | 12.8 | 17.1 | 0.75* | 0.58, 0.95 | 28.0 |
| East | 5.9 | 14.8 | 0.40* | 0.19, 0.72 | 8.4 | 16.6 | 0.51* | 0.24, 0.91 | 42.4 |
| Southwest | 12.5 | 13.6 | 0.92 | 0.76, 1.10 | 18.4 | 15.7 | 1.17 | 0.96, 1.42 | 47.2 |
| Total | 11.5 | 14.4 | 0.80* | 0.72, 0.88 | 15.7 | 16.4 | 0.96 | 0.86, 1.06 | 36.5 |

*Source*: Cancer registries in CDC's NPCR and NCI's SEER Program

Years of data and registries used: 1999–2004 (33 states): AK, AL, AZ, CA, CO, CT, FL, IA, ID, IN, LA, MA, ME, MI, MN, MT, NC, NE, NM, NV, NY, OK, OR, PA, RI, TX, UT, WA, WI, WY; 1999 and 2002–2004: ND; 2001–2004: SD; 2003–2004: MS

Percent regional coverage of AI/AN in CHSDA counties to AI/AN in all counties: Alaska = 100%; East = 15.4%; Northern Plains = 51.5%; Southern Plains = 69.0%; Pacific Coast = 45.0%; Southwest = 88.1%

*AI/AN* American Indians/Alaska Natives, *CDC* Centers for Disease Control and Prevention, *CHSDA* Contract Health Service Delivery Areas, *CI* confidence interval, *IHS* Indian Health Service, *NCI* National Cancer Institute, *NHW* non-Hispanic Whites, *NPCR* National Program of Cancer Registries, *SEER* Surveillance, Epidemiology, and End Results Program

* RR is statistically significant ($p < 0.05$)

[a] AI/AN race is reported by NPCR and SEER registries or through linkage with the IHS patient registration database. AI/AN persons of Hispanic origin are included

[b] Rates are per 100,000 persons per year and are age-adjusted to the 2000 US standard population (19 age groups—Census P25-1130)

[c] Rate ratios (RR) are calculated in SEER*Stat prior to rounding of rates and may not equal RR calculated from rates presented in table

[d] Calculated as uncorrected rate ratio/corrected rate ratio × 100 for AI/AN women

[e] Rates and rate ratios for Alaska in the CHSDA counties section are the same as those in the all counties section because all counties in Alaska are CHSDA counties

uterine cancer rates among AI/AN women; most published studies are limited to subpopulations or older data [28, 39, 40]. In our study, correction for hysterectomy status increased the national AI/AN incidence rate of uterine cancer by 67% with the most substantial rises in those over 65 years old. This change is even more striking than those in an earlier study of impact of hysterectomy on uterine cancer incidence from 1960 to 1973, in which risk-correction increased the rates by 20–45% with the greatest increases in women over 60 years [41]. Also consistent

with previous studies, we found AI/AN women to have lower rates of uterine cancer compared with NHW women, even after correction for hysterectomy status [28, 39, 40]. The reason for the lower burden of uterine cancer in AI/AN women is unclear. Some risk factors for uterine cancer such as obesity (OR $\geq$ 4.0) and diabetes (OR $\geq$ 1.2) are more prevalent among AI/AN women [42, 43]. This paradox is also observed for uterine cancer among African American women [44]. However, unlike African American women who tend to have more advanced disease than NHW women [45], AI/AN women are diagnosed with uterine cancers of similar grade and stage as NHW women [40]. Some factors that have been associated with lower risk—such as increased parity [46] and smoking [43, 47] are more common in AI/AN women and point to our limited knowledge about risk factors for uterine cancer among AI/AN women. Correction for hysterectomy status had no effect on the overall uterine cancer incidence rate ratio for AI/AN to NHW women.

Using uncorrected estimates, ovarian cancer is the seventh most common cancer and the leading cause of death from gynecologic cancers among AI/AN women [28]. While ovarian cancer incidence decreased in white and non-Hispanic women, rates remained stable in AI/AN women from 1995 to 2004 [28]. With correction for bilateral oophorectomy status in our study, ovarian cancer rates among AI/AN women were 37% higher. Similar to cervical cancer, AI/AN women are more often diagnosed at a more distant stage than NHW women [48]. The high mortality and relative frequency of ovarian cancer underscores the importance of continuing the search for better methods for early detection and treatment. Adequate monitoring of oophorectomy prevalence and, hence, more accurate measures of ovarian cancer incidence will be critical to evaluate future ovarian cancer prevention and early detection efforts.

Though we presented findings based on the most representative and accurate data available on AI/AN and NHW populations, our findings should be considered in light of several limitations. First, cancer incidence estimates are restricted to the 624 CHSDA counties, where 56% of the US AI/AN population reside [17]. Despite restriction of the analysis to CHSDA counties and registry linkages described elsewhere [17], race misclassification likely continues to influence cancer surveillance data, such as in this report. Second, incidence rates for these cancers are based on small case numbers, particularly when stratified by region, county, and age group, which diminish the stability of the estimates. Third, use of BRFSS for estimating hysterectomy prevalence is limited to respondents with landline telephones and to persons who speak English; both characteristics are limited in some rural AI/AN populations. BRFSS also relies on self-report of hysterectomy status and cross-sectional cumulative prevalence of hysterectomy, rather than age-specific hysterectomy rates. Furthermore, BRFSS led to some small sample cell sizes when stratified by age and region.

Other limitations relate to assumptions required to adjust gynecologic cancer rates for hysterectomy and oophorectomy status. We assumed that the proportion of hysterectomies and/or oophorectomies undertaken for gynecologic cancers was very small compared with those done for other indications and will therefore not substantially impact the denominator adjustment. In a previous study using NHDS from 1988 to 1997, the majority of hysterectomies (83.1%) were performed for benign conditions and only 9.7% were for the primary diagnosis of cervical neoplasia [49]. Also the distribution of hysterectomy types change over time. There is evidence that the rate of hysterectomy and the indications for hysterectomy have changed little over the last decade [50, 51], but actual proportions of prophylactic oophorectomy at the time of hysterectomy increased from 1979 to 2004 [52]. Additionally, the hysterectomy subtype estimates were derived from two different data sources, IHS NDW for AI/AN and NHDS for NHW, which may introduce bias if surveillance accuracy differs between the two sources. Though we utilized the longest time frame of data available and some historical procedures are captured in both systems, we used only more recent data from NDW (2002–2005) and NHDS (1999–2005) to determine the proportions of hysterectomies that were subtotal or accompanied by oophorectomy in AI/AN and NHW women. In spite of these limitations, our estimates of these procedures in NDW were similar to findings in previous studies, which included data for the general population of women [6, 52–54] and AI/AN women specifically [7]. Finally, NHDS did not have a "NHW" designation for race/ethnicity, so "white" was used as the best available estimate for the NHW hysterectomy corrections to enable comparisons between AI/AN- and NHW-adjusted cancer rates. "White" and NHW are terms that may describe epidemiologically different populations, and approximately 18% of "white" individuals also identified as Hispanic [55].

Current methods of calculating cervical, uterine, and ovarian cancer incidence underestimate the rates of these cancers in women at risk. Our study utilized more accurate and regionally specific hysterectomy and bilateral oophorectomy-corrected surveillance methods for AI/AN and NHW women. Wide regional variation is characteristic of AI/AN cancer incidence and gynecologic care practices, such as use of hysterectomy. Because of these differences and the anticipated increase in cancers diagnosed in the AI/AN population [56], region-specific data that are corrected for true population-at-risk are necessary to characterize the cancer burden among AI/AN women [28].

Though such corrections have not been systematically used in any country [5], we recommend continued monitoring of AI/AN gynecologic cancer incidence rates using these enhanced surveillance methods. Risk-correction should also be considered when assessing cancer disparities, as illustrated by the regional increases in cervical cancer disparity between AI/AN and NHW after hysterectomy correction. For all races, additional questions in national surveys, such as BRFSS, are needed to provide more accurate national data on prevalence of hysterectomy and bilateral oophorectomy and indications for these procedures. Improved surveillance data are needed to better inform disease control priorities for reducing AI/AN health disparities and to track progress toward that goal. In addition, more accurate rates will identify the real needs of these women for early detection, treatment, and survivorship cancer services.

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**Conflict of interest** None.

## References

1. Merrill RM, Feuer EJ (1996) Risk-adjusted cancer-incidence rates (United States). Cancer Causes Control 7(5):544–552
2. Finch A, Beiner M, Lubinski J, Lynch HT, Moller P, Rosen B et al (2006) Salpingo-oophorectomy and the risk of ovarian, fallopian tube, and peritoneal cancers in women with a BRCA1 or BRCA2 mutation. JAMA 296(2):185–192
3. Cervical cancer screening guidelines. Available from: http://www.cdc.gov/cancer/cervical/pdf/guidelines.pdf. Last accessed 10 June 2010
4. Merrill RM, Layman AB, Oderda G, Asche C (2008) Risk estimates of hysterectomy and selected conditions commonly treated with hysterectomy. Ann Epidemiol 18(3):253–260
5. Luoto R, Raitanen J, Pukkala E, Anttila A (2004) Effect of hysterectomy on incidence trends of endometrial and cervical cancer in Finland 1953–2010. Br J Cancer 90(9):1756–1759
6. Keshavarz H, Hillis SD, Kieke BA, Marchbanks PA (2002) Hysterectomy surveillance—United States, 1994–1999. MMWR CDC Surveill Summ 51:1–8
7. Merrill RM (2006) Impact of hysterectomy and bilateral oophorectomy on race-specific rates of corpus, cervical, and ovarian cancers in the United States. Ann Epidemiol 16(12):880–887
8. Wu JM, Wechter ME, Geller EJ, Nguyen TV, Visco AG (2007) Hysterectomy rates in the United States, 2003. Obstet Gynecol 110(5):1091–1095
9. Zhang Y, Lee ET, Cowan LD, North KE, Wild RA, Howard BV (2005) Hysterectomy prevalence and cardiovascular disease risk factors in American Indian women. Maturitas 52(3–4):328–336
10. Alderson M, Donnan S (1978) Hysterectomy rates and their influence upon mortality from carcinoma of the cervix. J Epidemiol Community Health 32(3):175–177
11. Espey DK, Wu XC, Swan J, Wiggins C, Jim MA, Ward E et al (2007) Annual report to the nation on the status of cancer, 1975–2004, featuring cancer in American Indians and Alaska Natives. Cancer 15:2119–2152
12. Wiggins CL, Espey DK, Wingo PA, Kaur JS, Wilson RT, Swan J et al (2008) Cancer among American Indians and Alaska Natives in the United States, 1999–2004. Cancer 113(5 Suppl):1142–1152
13. Behavioral Risk Factor Surveillance System. Hysterectomy status by state, race/ethnicity, and age, 1996–2000. Survey Data, National Center for Chronic Disease Prevention and Health Promotion, Centers of Disease Control and Prevention, US Department of Health and Human Services. Available from: http://www.nuff.org/health_hysterectomystatistics2.htm. Last accessed 10 June 2010
14. Howard BV, Kuller L, Langer R, Manson JE, Allen C, Assaf A et al (2005) Risk of cardiovascular disease by hysterectomy status, with and without oophorectomy: the Women's Health Initiative Observational Study. Circulation 111(12):1462–1470
15. Fritz A, Percy C, Jack A (2000) International classification of diseases of oncology. World Health Organization, Geneva
16. US Cancer Statistics Working Group (2007) United States cancer statistics: 2004 incidence. Department of Health and Human Services, Centers for Disease Control and Prevention and National Cancer Institute, Atlanta
17. Espey DK, Wiggins CL, Jim MA, Miller BA, Johnson CJ, Becker TM (2008) Methods for improving cancer surveillance data in American Indian and Alaska Native populations. Cancer 113(5 Suppl):1120–1130
18. Centers for Disease Control, Prevention (2003) Public health surveillance for behavioral risk factors in a changing environment: recommendations from the Behavioral Risk Factor Surveillance Team. MMWR Morb Mortal Wkly Rep 52:1–11
19. National Hospital Discharge Survey, Centers for Disease Control and Prevention. Available from: http://www.cdc.gov/nchs/nhds.htm. Last accessed 13 July 2011
20. National Data Warehouse, Indian Health Service. Available from: http://www.cdc.gov/nchs/nhds.htm. Last accessed 13 July 2011
21. National Cancer Institute (2011) Surveillance, epidemiology, and end results (SEER) program. Statistical resources. US population data 1969–2004. Available from: http://seer.cancer.gov/resources. Last accessed 13 July 2011
22. Surveillance Research Program SEER*Stat software. National Cancer Institute, DCCPS, Surveillance Research Program, Cancer Statistics Branch, Bethesda. Available from: http://www.seer.cancer.gov/seerstat. Last accessed 13 July 2011
23. Anderson R, Rosenberg H (1998) Age standardization of death rates: implementation of the year 2000 standard. Natl Vital Stat Rep 47(3):16
24. Tiwari RC, Clegg LX, Zou Z (2006) Efficient interval estimation for age-adjusted cancer rates. Stat Methods Med Res 15(6):547–569
25. Becker TM, Espey DK, Lawson HW, Saraiya M, Jim MA, Waxman AG (2008) Regional differences in cervical cancer incidence among American Indians and Alaska Natives, 1999–2004. Cancer 113(5 Suppl):1234–1243
26. Lawrence J (2000) The Indian Health Service and the sterilization of Native American women. Am Indian Q 24(3):400–419
27. Brett KM, Marsh JV, Madans JH (1997) Epidemiology of hysterectomy in the United States: demographic and reproductive factors in a nationally representative sample. J Womens Health 6(3):309–316
28. Espey DK, Wu XC, Swan J, Wiggins C, Jim MA, Ward E et al (2007) Annual report to the nation on the status of cancer,

1975–2004, featuring cancer in American Indians and Alaska Natives. Cancer 110(10):2119–2152
29. Erekson EA, Weitzen S, Sung VW, Raker CA, Myers DL (2009) Socioeconomic indicators and hysterectomy status in the United States, 2004. J Reprod Med 54(9):553–558
30. Whiteman MK, Hillis SD, Jamieson DJ, Morrow B, Podgornik MN, Brett KM et al (2008) Inpatient hysterectomy surveillance in the United States, 2000-2004. Am J Obstet Gynecol 198(1): 34.e1–34.e7
31. Luman ET, Ryman TK, Sablan M (2009) Estimating vaccination coverage: validity of household-retained vaccination cards and parental recall. Vaccine 27(19):2534–2539
32. Espey D, Paisano R, Cobb N (2005) Regional patterns and trends in cancer mortality among American Indians and Alaska Natives, 1990–2001. Cancer 103(5):1045–1053
33. Saslow D, Runowicz CD, Solomon D, Moscicki AB, Smith RA, Eyre HJ et al (2003) American Cancer Society guideline for the early detection of cervical neoplasia and cancer. J Low Genit Tract Dis 7(2):67–86
34. ACOG Practice Bulletin No. 109 (2009) Cervical cytology screening. Obstet Gynecol 114(6):1409–1420
35. Sung HY, Kearney KA, Miller M, Kinney W, Sawaya GF, Hiatt RA (2000) Papanicolaou smear history and diagnosis of invasive cervical carcinoma among members of a large prepaid health plan. Cancer 88(10):2283–2289
36. Steele CB, Cardinez CJ, Richardson LC, Tom-Orme L, Shaw KM (2008) Surveillance for health behaviors of American Indians and Alaska Natives-findings from the behavioral risk factor surveillance system, 2000–2006. Cancer 113(5 Suppl):1131–1141
37. Markowitz LE, Dunne EF, Saraiya M, Lawson HW, Chesson H, Unger ER (2007) Quadrivalent human papillomavirus vaccine: recommendations of the advisory committee on immunization practices (ACIP). MMWR Recomm Rep 56(RR-2):1–24
38. US Cancer Statistics Working Group (2010) United States cancer statistics: 1999–2006 incidence and mortality web-based report. Department of Health and Human Services, Centers for Disease Control and Prevention, and National Cancer Institute, Atlanta. Available from: http://www.cdc.gov/uscs. Last accessed 10 June 2010
39. Schiff M, Key CR, Gilliland FD, Becker TM (1997) Ethnic differences in uterine corpus cancer incidence and mortality in New Mexico's American Indians, hispanics and non-Hispanic whites. Int J Epidemiol 26(2):249–255
40. Sabatino SA, Stewart SL, Wilson RJ (2009) Racial and ethnic variations in the incidence of cancers of the uterine corpus, United States, 2001–2003. J Womens Health (Larchmt) 18(3): 285–294
41. Lyon JL, Gardner JW (1977) The rising frequency of hysterectomy: its effect on uterine cancer rates. Am J Epidemiol 105(5): 439–443
42. Weiss JM, Saltzman BS, Doherty JA, Voigt LF, Chen C, Beresford SA et al (2006) Risk factors for the incidence of endometrial cancer according to the aggressiveness of disease. Am J Epidemiol 164(1):56–62
43. Welty TK, Lee ET, Yeh J, Cowan LD, Go O, Fabsitz RR et al (1995) Cardiovascular disease risk factors among American Indians. The Strong Heart Study. Am J Epidemiol 142(3): 269–287
44. Jemal A, Thomas A, Murray T, Thun M (2002) Cancer statistics, 2002. CA Cancer J Clin 52(1):23–47
45. Hicks ML, Phillips JL, Parham G, Andrews N, Jones WB, Shingleton HM et al (1998) The National Cancer Data Base report on endometrial carcinoma in African–American women. Cancer 83(12):2629–2637
46. North KE, MacCluer JW, Cowan LD, Howard BV (2000) Gravidity and parity in postmenopausal American Indian women: the Strong Heart Study. Hum Biol 72(3):397–414
47. Amant F, Moerman P, Neven P, Timmerman D, Van Limbergen E, Vergote I (2005) Endometrial cancer. Lancet 366(9484): 491–505
48. Goodman MT, Howe HL, Tung KH, Hotes J, Miller BA, Coughlin SS et al (2003) Incidence of ovarian cancer by race and ethnicity in the United States, 1992–1997. Cancer 97(10 Suppl): 2676–2685
49. Saraiya M, Lee NC, Blackman D, Smith MJ, Morrow B, McKenna MA (2001) Self-reported Papanicolaou smears and hysterectomies among women in the United States. Obstet Gynecol 98(2):269–278
50. Lepine LA, Hillis SD, Marchbanks PA, Koonin LM, Morrow B, Kieke BA et al (1997) Hysterectomy surveillance—United States, 1980–1993. MMWR CDC Surveill Summ 46(4):1–15
51. Falcone T, Walters MD (2008) Hysterectomy for benign disease. Obstet Gynecol 111(3):753–767
52. Lowder JL, Oliphant SS, Ghetti C, Burrows LJ, Meyn LA, Balk J (2010) Prophylactic bilateral oophorectomy or removal of remaining ovary at the time of hysterectomy in the United States, 1979–2004. Am J Obstet Gynecol 202(6):538.e1–538.e9
53. Howe HL (1984) Age-specific hysterectomy and oophorectomy prevalence rates and the risks for cancer of the reproductive system. Am J Public Health 74(6):560–563
54. Parker WH, Broder MS, Chang E, Feskanich D, Farquhar C, Liu Z et al (2009) Ovarian conservation at the time of hysterectomy and long-term health outcomes in the nurses' health study. Obstet Gynecol 113(5):1027–1037
55. US Census Bureau (2009) USA quickfacts. Available from: http://www.quickfacts.census.gov. Last accessed 30 Oct 2009
56. Smith BD, Smith GL, Hurria A, Hortobagyi GN, Buchholz TA (2009) Future of cancer incidence in the United States: burdens upon an aging, changing nation. J Clin Oncol 27(17):2758–2765