Effect of Population Socioeconomic and Health System Factors on Medical Care of Childhood Cancer Survivors: A Report from the Childhood Cancer Survivor Study

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Purpose: To determine the independent contribution of population socioeconomic and health system factors on childhood cancer survivors' medical care and screening.

Methods: 7899 childhood cancer survivors in the United States and Canada enrolled in the Childhood Cancer Survivor Study (CCSS). Population-level factors were derived from U.S. Area Health Resource File or 201 Canadian Census. Health service utilization and individual-level factors were self-reported. Multivariable logistic regression was used to calculate the effect of population factors on medical care (any care vs. no care; risk-based care vs. general care) and indicated echocardiogram or mammogram, adjusting for individual sociodemographic and health status.

Results: After adjusting for individual factors, population factors had a nominal impact on childhood cancer survivors' medical care and screening. Higher population median income was associated with risk-based survivor-focused care versus general care (odds ratio [OR] 1.05, 95% confidence interval [CI], 1.01–1.09) among all participants, but not among U.S. residents only (OR 1.03, 95% CI, 0.99–1.07). For U.S. residents, the number of CCSS centers within the geographic area was associated with greater odds of receiving risk-based survivor-focused medical care (OR 1.12, 95% CI, 1.04–1.20). Areas with higher median income had higher rates of echocardiogram screening among survivors at risk of cardiomyopathy (for every \$10,000 increase in median income, there is a 12% increase in odds of echocardiogram screening; 95% CI 1.05–1.20). A positive relationship was identified between greater number of physicians and surgeons in the county of residence and recommended echocardiogram (for every additional 1000 physicians and surgeons: OR 1.12, 95% CI, 1.01–1.23). We found no association between population-level factors and mammography screening.

Conclusions: Population socioeconomic disparities moderately affect childhood cancer survivors' risk-based medical care and screening after accounting for individual sociodemographic and health factors.

Keywords: childhood cancer survivor, socioeconomic status, population-level factors, health disparities, screening

Introduction

ADULT SURVIVORS OF CHILDHOOD CANCER have a high incidence of chronic medical conditions as a result of their prior cancer therapy.^{1–3} For this reason, the Institute of Medicine and others have called for the provision of risk-based survivor-focused medical care that counsels survivors about health risks and screening recommendations tailored to the therapy they received.^{4–6} However, less than one-third of long-term survivors receive this type of care.⁷

We have previously reported associations between individual sociodemographic and health-related factors and the likelihood of receiving risk-based survivor-focused medical care and recommended cardiac or breast cancer screening, and showed that lower household income, lack of insurance, non-White race, and unemployment are associated with lack of medical care or receipt of general medical care instead of risk-based survivor-focused care.⁷

In large population-based studies, 5-year survival is more than 10% greater for people with cancer who reside in

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affluent census tracts than for those in poorer census tracts.⁸ In addition, area-level socioeconomic status (SES) disparities in cancer control exist with respect to the timing of diagnosis,^{8,9} stage at diagnosis/treatment,^{9,10} survival,^{11,12} and preventive care.¹³ Disparities in survival have been attributed, in part, to limited access to, and lower quality of, care for those living in poverty, even when taking into account individual factors.

Following screening recommendations and receiving consistent survivor-based care, which is targeted to specific individual-level risks, are likely to lead to early detection of late effects and recurrence. In the general population, lower breast and colon cancer screening rates have been observed in communities with higher rates of poverty.¹³ Mammography capacity, measured by number of mammography facilities, is lower in more impoverished communities and in those with greater population density, lower rates of insurance, and lower educational levels.¹⁴ Importantly, residents in communities with a lower mammography capacity have lower rates of screening mammograms.¹⁵

Whether similar population-level factors impact risk-based screening uptake and medical care among childhood cancer survivors is not known. Thus, this study was designed to evaluate the role of population-level socioeconomic and health system factors on childhood cancer survivors' risk-based medical care and screening practices, independent of individual-level factors.

Methods

Childhood Cancer Survivor Study

The Childhood Cancer Survivor Study (CCSS), described in detail in prior publications, is a retrospectively assessed and prospectively followed cohort of individuals who were diagnosed with cancer before age 21 years, were treated at one of 26 cancer centers in the United States and Canada between 1970 and 1986, and had survived at least 5 years from diagnosis at the time of cohort assembly.^{16,17} Among 20,720 eligible survivors, 17,703 were contacted and 14,366 (81.2%) enrolled. Participants and nonparticipants did not differ by sex, age at diagnosis or at the time of study initiation, cancer type, or treatment.^{16,18}

Medical records were abstracted to obtain treatment information, and participants completed baseline and follow-up questionnaires (available at www.stjude.org/ccss). The study was approved by the Institutional Review Board at each participating institution and informed consent was obtained from each participant or consenting parent/guardian.

This analysis includes individuals who completed the 2003 follow-up survey and had complete data for all individual-level factors (described below) and linkable data for population-level factors. Figure 1 provides a flow diagram of study participants leading to our sample size of 7899 for this analysis, consisting of 7286 U.S. residents and 613 Canadian residents.

Participant Flow Diagram

FIG. 1. Participant flow diagram.

Primary outcomes

As noted in previous studies,⁷ a series of questions was constructed to characterize the medical care received by survivors and determine whether this care focused on the previous cancer and the risk of future health problems arising from its therapy. Participants were asked whether they had visited a healthcare provider (physician or nurse) within the preceding 2 years, whether the visit was related to their previous cancer, and whether their healthcare provider had given them advice on how to reduce their risks or discussed or ordered screening tests for cancer-related sequelae.

Responses to these questions were used to categorize healthcare into one of four mutually exclusive groups: (1) no healthcare, (2) general medical care (patient reported one or more medical visits, none of which was related to their previous cancer), (3) general survivor-focused care (patient reported at least one visit related to their previous cancer, but did not report receiving advice on how to reduce risks or that screening tests for cancer-related sequelae were discussed or ordered), and (4) risk-based, survivor-focused care (survivor-focused care that included advice about how to reduce risks or discussion or ordering of screening tests for cancer-related sequelae). The hierarchy was constructed to classify levels of medical care related specifically to the prior cancer and its risks, and is not intended to imply a level of quality of care for health issues unrelated to the previous cancer.

Each participant was classified according to the highest category of care received during the 2-year study period. The assigned level of care was independent of who delivered the care (cancer specialist or primary care clinician) or where the care was received (cancer center or community setting). In addition, we classified a subset of the cohort as being at high risk for developing a cardiomyopathy (survivors who had received 300 mg/m² or more of an anthracycline or any anthracycline dose plus chest radiation) or breast cancer (females who had received radiation to the chest and who were 27 years old), two late effects for which there is consensus concerning the need for regular surveillance with an echocardiogram or mammogram, respectively.^{19–21}

Individual-level factors

Individual-level factors were derived from the 2003 CCSS follow-up survey. Sociodemographic information included sex, race/ethnicity (White, Non-Hispanic, Hispanic, Black, other), age at cancer diagnosis, age at the time of survey completion, household income (<\$40,000, \$40,000–\$79,000, ≥\$80,000), highest education level (did not complete high school, high school graduate, college or vocational school graduate), health insurance status (yes, no, Canadian health insurance), and employment status (unemployed, employed/student/caring for home).

Health-related factors included perceived emotional and physical health and presence of chronic medical conditions, graded using the National Cancer Institute Common Terminology Criteria for Adverse Events, where 0 is no chronic condition, 1 is mild, 2 is moderate, 3 is severe/disabling, and 4 is life-threatening.¹ Measures of perceived health status included poor emotional health (yes/no), cancer-related anxiety (none, a small amount vs. moderate, a lot, extreme), cancer-related pain (none, a small amount, vs. moderate, a lot, extreme), and poor physical health (yes/no); the val-

idity and derivation of these variables have been published previously.^{22–24}

Population-level factors

For U.S. residents, population-level data were obtained from the 2007 Area Health Resource File (AHRF), a database that contains county-specific healthcare and economic measures (maintained by the U.S. Department of Health and Human Services Health Resources and Services Administration; <http://ahrh.hrsa.gov>). For each CCSS participant, his/her county of residence was linked to county-level data in the AHRF using the participant's county of residence at the time of follow-up based on Federal Information Processing Standard (FIPS) codes. FIPS codes identify counties in the United States. Key county-level measures from the AHRF were examined all from 2005; the full list is shown in a Supplementary Table S1 (Supplementary Data are available online at www.liebertpub.com/jayao). A series of models was first estimated with all individual-level measures.

Population-level measures were then added, one at a time, to assess significance. The following significant population-level variables from the AHRF database were included collectively in the final models: population density (unit = 1000 per mile²), total population size (unit = 1000), and number of physicians and surgeons (unit = 1000), all based on the participant's county of residence. Additional population-level data included median income according to the 2000 U.S. Census for the zip code of residence at the time of follow-up and number of CCSS participating institutions within a 100-mile radius of the participant's zip-code of residence. Area poverty percentage was considered, but not included in the analysis due to high collinearity with median income measures.

For Canadian residents, comparable population-level data were obtained using the 2001 Forward Sortation Area (FSA) at the time of follow-up. We used the first three characters of the postal code to identify the FSA for each individual and the FSA was linked to the Canadian census data provided by Statistics Canada, which provided information about population density and median income of the area of residence.¹⁷ For the analysis, Canadian median income was converted to equivalent U.S. dollars based on the exchange rate on 1/2/2001 of 1 Canadian dollar to 0.6683 U.S. dollars. Additional measures (population size, number of physicians/surgeons, and distance to a CCSS participating institution) were not available for Canadian residents.

Statistical analysis

Individual- and population-level factors were described using percentages for categorical variables and means/standard deviations for continuous variables, and displayed for the total sample and separately for U.S. and Canadian residents. Logistic regression was used to model each primary outcome: (1) receiving any medical care versus no medical care, (2) receiving risk-based survivor-focused medical care versus general medical care, (3) having had a recommended echocardiogram among participants at risk for cardiomyopathy, and (4) having had a recommended mammogram among participants at risk for breast cancer based on their prior cancer therapy. Two nested models were estimated for each outcome (where the nested models did or did not include sandwich variance adjusted standard errors).

The first model specification included the county/FSA variables as well as all individual-level factors, including sex, race/ethnicity, age at cancer diagnosis, age at survey, annual household income, education level, employment, health insurance, emotional health, cancer-related anxiety, cancer-related pain, physical health, chronic medical conditions, and country of residence.

The second model specification included only the county/FSA variables, thereby allowing us to see how adjustments for the individual-level factors affected the associations detected for county/FSA variables. All models were run for all participants (U.S. and Canadian residents combined) and separately for U.S. residents only, as three population-level factors (population size, number of physicians/surgeons, and proximity to CCSS institution) were available for U.S. residents, but not for Canadian residents. Tables 3 and 4 display the models for all participants based upon the two population-level factors that were available in both countries (population density and median income).

When these models with the two population-level factors were run separately for U.S. residents alone, the results did not differ from the combined group (data not shown). All population-level factors reported in multivariate models are included simultaneously in the same model. All hypothesis testing is based on two-tailed tests with a type I error of 0.05.

Results

A majority of the 7899 participants were White, non-Hispanic, had graduated from high school or college, had an annual household income over \$40,000, and were employed, in school or caring for the home (Table 1). Only 11.8% were unemployed and 11.1% were uninsured. About 8%–9% reported poor emotional health or at least moderate cancer-related anxiety or cancer-related pain. In contrast, nearly one quarter reported poor physical health and had severe/disabling, or life-threatening chronic medical conditions (grade 3 or 4). Aside from insurance coverage, which was universal among Canadian residents, sociodemographic variables were similar in U.S. and Canadian residents, as shown in Table 1.

Population-level factors are also shown in Table 1, averaged across all participants. The average population density per square mile was higher in Canada than in the United States (4480 vs. 1380), but the average median income per geographic area (zip code or Canadian FSA) was similar in both countries (\$48,400 in United States. vs. \$38,500 in Canada), given high standard deviations.

Participants' medical care and risk-based screening practices within the preceding 2 years are displayed in Table 2. Results for U.S. and Canadian residents were similar, although the lack of differences may be largely due to the small Canadian sample size. Although most participants received some medical care (88.8%), only 18% received recommended risk-based survivor-focused medical care. Among those at elevated risk of cardiomyopathy, less than 30% received an indicated echocardiogram in the prior 2 years, and among those at elevated risk of breast cancer, only 40% received an indicated mammogram.

As shown in Table 3, increasing area-level income was found to be associated with the receipt of any medical care versus no medical care when no individual-level factors were included. However, after individual-level controls were in-

troduced, these community variables became insignificant for the full sample and the U.S.-only subsample.

A significant effect of population median income and population density on the receipt of risk-based survivor-focused care versus general medical care was found for the full sample with no individual-level factors included. The association of income on the receipt of risk-based survivor-focused care persisted after controlling for individual-level factors (for each additional \$10,000: odds ratio [OR] 1.05, 95% confidence interval [CI], 1.01–1.09). For the U.S. residents, the effect of median income was attenuated. However, increasing numbers of physicians/surgeons as well as additional CCSS centers within the geographic area were associated with greater odds of receiving risk-based survivor-focused medical care.

As shown in Table 4, population median income was also associated with odds of receiving an indicated echocardiogram among participants at risk of cardiomyopathy secondary to their prior cancer therapy, for all models estimated. Each \$10,000 increase in median population income was associated with about a 14% increase in odds of receiving an indicated echocardiogram (OR 1.14, 95% CI, 1.06–1.22), after adjusting for individual-level factors for the full sample. This effect persisted after accounting for additional population-level factors that were available for U.S. residents. There was an additional positive relationship between greater number of physicians and surgeons in the county of residence and recommended echocardiogram uptake (for every additional 1000 physicians and surgeons: OR 1.12, 95% CI, 1.01–1.23).

In contrast, population factors were not associated with mammography screening among participants at risk of breast cancer secondary to prior cancer therapy, after adjusting for all individual-level factors.

Discussion

In this study of nearly 8000 long-term survivors of childhood cancer, we show that in the United States, higher median income in a community was associated with a survivor receiving survivor-focused care and screening, independent of individual health-related and sociodemographic factors. Prior studies have focused on the role of individual-level factors in predicting health behaviors, medical care, and screening practices among childhood cancer survivors.

To our knowledge, this is the first study to investigate the additional contribution of population-level factors such as community median income, population density, number of physicians/surgeons, and proximity to specialized CCSS cancer centers. Building upon our prior work, this analysis suggests that, in this population of childhood cancer survivors, health utilization patterns are more influenced by individual sociodemographic and health-related factors than by population socioeconomic status and health system factors.

Also building upon our prior work, this analysis suggests that some of the variation in geographical areas is a consequence of differences in individuals who reside there, as we have shown for some models reported in Table 3. The additional impact of population-level characteristics such as SES and supply of physicians,^{25,26} over and above individual differences, provides important context to consider when understanding care of cancer survivors. We note that our assessment of the role of geographic or spatial characteristics is based on county-level data.

TABLE 1. CHARACTERISTICS OF THE STUDY POPULATION (FROM 2003 CCSS SURVEY⁷) ACCORDING TO INDIVIDUAL AND POPULATION FACTORS

	<i>All participants</i> (n = 7899)		<i>U.S. residents</i> (n = 7286)		<i>Canadian residents</i> (n = 613)		<i>p value</i> (U.S. vs. Canadian residents)
	n	% or mean	n	% or mean	n	% or mean	
<i>Individual factors</i>							
Sex							n.s.
Male	3928	49.7%	3613	49.6%	315	51.4%	
Female	3971	50.3%	3673	50.4%	298	48.6%	
Race/ethnicity							<0.01
White, non-Hispanic	6838	86.6%	6294	86.4%	544	88.7%	
Hispanic	124	1.6%	124	1.7%	0	0%	
Black	208	2.6%	203	2.8%	5	0.8%	
Other	729	9.2%	665	9.1%	64	10.4%	
Age, years							
At diagnosis, mean ± SD	7899	8.2 ± 5.9	7286	8.3 ± 5.9	613	7.1 ± 5.0	n.s.
At survey, mean ± SD	7899	31.7 ± 7.6	7286	31.9 ± 7.7	613	30.2 ± 6.7	
Annual household income							< 0.01
<\$40,000	2456	31.1%	2307	31.7%	149	24.3%	
\$40,000–\$79,000	2539	32.1%	2343	32.2%	196	32.0%	
≥ \$80,000	1818	23.0%	1656	22.7%	162	26.4%	
Unknown	1086	13.7%	980	13.5%	106	17.3%	
Education level							< 0.01
Less than high school	341	4.3%	285	3.9%	56	9.1%	
High school graduate	4104	52.0%	3848	52.8%	256	41.8%	
College graduate	3454	43.7%	3153	43.3%	301	49.1%	
Employment status							<0.05
Unemployed	935	11.8%	844	11.6%	91	14.8%	
Employed, student, caring for home	6964	88.2%	6442	88.4%	522	85.2%	
Health insurance status							< 0.01
Yes	6492	82.2%	6436	88.3%	56	9.1%	
No	880	11.1%	850	11.7%	30	4.9%	
Canadian health insurance	527	6.7%	0	0.0%	527	86.0%	
Poor emotional health							n.s.
No	7250	91.8%	6685	91.8%	565	92.2%	
Yes	649	8.2%	601	8.2%	48	7.8%	
Cancer-related anxiety							n.s.
None, a small amount	7191	91.0%	6635	91.1%	556	90.7%	
Moderate, a lot, extreme	708	9.0%	651	8.9%	57	9.3%	
Cancer-related pain							n.s.
None, a small amount	7255	91.8%	6682	91.7%	573	93.5%	
Moderate, a lot, extreme	644	8.2%	604	8.3%	40	6.5%	
Poor physical health							n.s.
No	6024	76.3%	5559	76.3%	465	75.9%	
Yes	1875	23.7%	1727	23.7%	148	24.1%	
Chronic medical conditions							n.s.
Grade 0, 1, 2	5983	75.7%	5506	75.6%	477	77.8%	
Grade 3, 4	1916	24.3%	1780	24.4%	136	22.2%	
<i>Population factors</i>							
Population density per square mile	7899	1620 ± 5167 (0.00003–66.94)	7286	1380 ± 4988 (0.0007–66.94)	613	4480 ± 6289 (0.00003–59.19)	<0.01
Population size (number)			7286	784,000 ± 153,000 (2000–905,000)			
Median income of living area ^a	7899	\$47,600 ± \$17,500	7286	\$48,400 ± \$17,700 (\$9400–\$185,000)	613	\$38,500 ± \$11,200	<0.01
Number of physicians/surgeons (1000/county)			7286	2.27 ± 4.3 (0–23.45)			
Number of CCSS centers within 100 miles			7286	1.2 ± 1.1 (0–4)			

2001 Canadian Census was the source for the population factors at the level of the FSA.

U.S. population factors were obtained from the 2007 Area Health Resource File, U.S. Department of Health and Human Services Health Resources and Services Administration.

^aMedian income according to 2000 U.S. Census data per zip code.

CCSS, Childhood Cancer Survivor Study; FSA, Forward Sortation Area; n.s., nonsignificant.

TABLE 2. MEDICAL CARE AND SCREENING PRACTICES WITHIN THE PRECEDING 2 YEARS

	Total (n = 7899)		U.S. residents (n = 7286)		Canadian residents (n = 613)		p value (compared U.S. and Canadian residents)
	n	%	n	%	n	%	
<i>Medical care practices</i>							
Medical care within preceding 2 years							<0.01
None	884	11.2	828	11.4	56	9.1	
Any medical care	7015	88.8	6458	88.6	557	90.9	
General medical care	4524	57.3	4210	57.8	314	51.2	
Survivor-focused care	1072	13.6	958	13.1	114	18.6	
Risk-based survivor-focused care	1419	18.0	1290	17.7	129	21.0	
<i>Screening practices^a</i>							
Echocardiogram, if elevated cardiac risk							n.s.
Yes	474	28.2	446	28.5	28	24.4	
No	1203	71.8	1116	71.5	87	75.6	
Mammogram, if elevated breast cancer risk							n.s.
Yes	158	40.5	145	41.1	13	35.1	
No	232	59.5	208	58.9	24	64.9	

^aPertains to cancer screening within the preceding 2 years among survivors at elevated risk of cardiomyopathy (for echocardiogram, n = 1677) or breast cancer (for mammogram, n = 390) based on prior cancer therapy.

TABLE 3. MEDICAL CARE PRACTICES ACCORDING TO POPULATION FACTORS, ADJUSTED FOR INDIVIDUAL SOCIODEMOGRAPHIC AND HEALTH-RELATED FACTORS

	No individual-level controls				Includes individual-level controls			
	No variance adjustment		Variance adjusted		No variance adjustment		Variance adjusted	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<i>Any medical care vs. no medical care</i>								
All participants								
Population density (per 1000 mile ²)	1.00	0.99–1.02	1.00	1.00–1.01	1.00	0.98–1.01	1.00	0.99–1.01
Median income of County/FSA (U.S. \$10,000)	1.13	1.08–1.18	1.13	1.07–1.19	1.04	0.99–1.09	1.04	0.99–1.10
U.S. residents only								
Population density (per 1000 mile ²)	1.00	0.98–1.02	1.00	0.99–1.01	1.00	0.98–1.02	1.00	0.99–1.01
Population size, county (1000)	0.99	0.97–1.01	0.99	0.97–1.01	0.99	0.97–1.01	0.99	0.98–1.01
Median income of County/FSA (U.S. \$10,000)	1.15	1.09–1.20	1.15	1.08–1.21	1.05	0.99–1.10	1.05	0.99–1.11
Number of physicians & surgeons (1000)	1.03	0.96–1.11	1.03	0.96–1.11	1.02	0.95–1.10	1.02	0.95–1.10
Number of CCSS centers within 100 miles	1.00	0.92–1.08	1.00	0.93–1.08	1.02	0.94–1.11	1.02	0.95–1.10
<i>Risk-based survivor-focused care vs. general medical care</i>								
All participants								
Population density (per 1000 mile ²)	1.02	1.01–1.03	1.02	1.01–1.03	1.01	1.00–1.02	1.01	1.01–1.02
Median income of County/FSA (U.S. \$10,000)	1.05	1.01–1.08	1.05	1.01–1.09	1.05	1.01–1.09	1.05	1.01–1.09
U.S. residents only								
Population density (per 1000 mile ²)	1.00	0.99–1.02	1.00	0.99–1.01	1.00	0.99–1.01	1.00	0.99–1.01
Population size, county	0.99	0.97–1.00	0.99	0.97–1.00	0.99	0.97–1.00	0.99	0.97–1.00
Median income of County/FSA (U.S. \$10,000)	1.03	1.00–1.07	1.03	0.99–1.08	1.03	0.99–1.07	1.03	0.99–1.07
Number of physicians & surgeons (1000)	1.06	1.00–1.12	1.06	1.01–1.11	1.06	1.00–1.12	1.06	1.01–1.11
Number of CCSS centers within 100 miles	1.11	1.04–1.18	1.11	1.04–1.18	1.12	1.04–1.20	1.12	1.05–1.19

Models that adjusted for individual characteristics include participants' gender, race/ethnicity, age, household income, education, employment status, insurance status, poor emotional health, cancer-related anxiety, cancer-related pain, poor physical health, and chronic medical condition status.

CI, confidence interval; OR, odds ratio.

TABLE 4. RISK-BASED SCREENING PRACTICES ACCORDING TO POPULATION FACTORS, ADJUSTED FOR INDIVIDUAL SOCIODEMOGRAPHIC AND HEALTH-RELATED FACTORS

	<i>No individual-level controls</i>				<i>Includes individual-level controls</i>			
	<i>No variance adjustment</i>		<i>Variance adjusted</i>		<i>No variance adjustment</i>		<i>Variance adjusted</i>	
	<i>OR</i>	<i>95% CI</i>	<i>OR</i>	<i>95% CI</i>	<i>OR</i>	<i>95% CI</i>	<i>OR</i>	<i>95% CI</i>
<i>Received indicated echocardiogram vs. no echocardiogram^a</i>								
All participants								
Population density (per 1000 mile ²)	1.01	0.99–1.02	1.01	1.00–1.01	1.00	0.98–1.02	1.00	0.99–1.01
Median income of County/FSA (U.S. \$10,000)	1.13	1.07–1.20	1.13	1.07–1.20	1.14	1.06–1.22	1.14	1.06–1.22
U.S. residents only								
Population density (per 1000 mile ²)	0.99	0.97–1.01	0.99	0.98–1.01	0.99	0.97–1.01	0.99	0.97–1.00
Population size, county (1000)	0.96	0.93–0.98	0.96	0.93–0.98	0.96	0.93–0.99	0.96	0.94–0.99
Median income of County/FSA (U.S. \$10,000)	1.11	1.05–1.19	1.11	1.05–1.18	1.11	1.03–1.20	1.11	1.03–1.19
Number of physicians & surgeons (1000)	1.14	1.04–1.24	1.14	1.04–1.25	1.12	1.01–1.23	1.12	1.01–1.23
Number of CCSS centers within 100 miles	1.00	0.88–1.13	1.00	0.89–1.12	0.97	0.84–1.12	0.97	0.85–1.11
<i>Received indicated mammogram vs. no mammogram^b</i>								
All participants								
Population density (per 1000 mile ²)	1.01	0.99–1.03	1.01	1.00–1.02	1.01	0.98–1.03	1.01	0.99–1.02
Median income of County/FSA (U.S. \$10,000)	1.07	0.95–1.21	1.07	0.95–1.21	1.02	0.88–1.18	1.02	0.89–1.17
U.S. residents only								
Population density (per 1000 mile ²)	1.00	0.96–1.04	1.00	0.97–1.03	1.01	0.97–1.06	1.01	0.98–1.05
Population size, county (1000)	0.99	0.94–1.05	0.99	0.94–1.05	1.03	0.96–1.09	1.03	0.97–1.08
Median income of County/FSA (U.S. \$10,000)	1.06	0.92–1.21	1.06	0.93–1.20	1.03	0.88–1.21	1.03	0.88–1.20
Number of physicians & surgeons (1000)	1.04	0.85–1.26	1.04	0.83–1.29	0.91	0.72–1.14	0.91	0.74–1.11
Number of CCSS centers within 100 miles	1.03	0.82–1.29	1.03	0.80–1.32	1.01	0.78–1.32	1.01	0.77–1.33

Models that adjusted for individual characteristics include participants' gender, race/ethnicity, age, household income, education, employment status, insurance status, poor emotional health, cancer-related anxiety, cancer-related pain, poor physical health, and chronic medical condition status.

^aAmong 1677 participants at risk of cardiomyopathy based on cancer therapy.

^bAmong 390 participants at risk of breast cancer based on cancer therapy.

This level of spatial aggregation was based, in part, because large quantities of data are available at this level of analysis, and the county (or Forward Sortation district) is a useful and practical basis on which to assess the community in which individuals live and seek medical care. Conducting the study at another level of analysis is encouraged, although data availability at different spatial levels (especially for medical resource indicators) is beyond the scope of this article.

Survivors' use of general medical care versus no medical care was not associated with any population-level factors after adjusting for individual-level measures. In the CCSS cohort, general outpatient medical care, physical examinations, cancer-related medical visits, and cancer center visits were more likely among those with insurance and with a higher educational level than among those with no insurance or a lower educational level.⁶ In subsequent analyses of the CCSS cohort, minority survivors were more likely to have lower educational attainment, income, and rates of insurance coverage compared to non-Hispanic Whites; however, after adjusting for these markers of socioeconomic status, race and ethnicity were not independently associated with adverse health outcomes.²⁷

In this study, we observed a small, but statistically significant impact of median population income on risk-based

survivor-focused care versus general medical care among all participants, which was mitigated by the inclusion of additional population measures in the U.S.-only population. In the U.S.-only model that included population size, number of physicians/surgeons, and number of CCSS participating centers within 100 miles, in addition to population density and population median income, the prior effect of median income was replaced by a small, but significant effect of proximity to a CCSS center.

This suggests that, within the United States, closer proximity to a CCSS center may have a greater impact on risk-based survivor-focused care than affluence of the population. However, we do not know if participants received their risk-based survivor-focused care at one of these CCSS centers, or if they received this care in a primary care or community health setting. In either case, proximity to CCSS centers may be indicative of a greater awareness of cancer survivor-specific risks and long-term follow-up guidelines within these communities. For survivors who do not live near one of these CCSS centers, this further emphasizes the importance of disseminating information about childhood cancer survivors' health risks and screening recommendations to primary care providers so that they can provide appropriate risk-based care and surveillance.

Recent surveys of general internists suggest that many remain uncomfortable providing risk-based survivor-focused medical care to long-term adult survivors of childhood cancer.^{28,29} Outreach and education for these providers are particularly important given the well-described association between receiving a physician recommendation for risk-based screening and completion of recommended mammogram,^{30–32} echocardiogram, and bone density screening.^{30,33}

In the general population, cancer screening rates vary according to population-level factors, with lower breast cancer screening rates in communities with lower mammogram capacity,¹⁵ and lower breast and colon cancer screening rates in communities with higher area-level poverty rates.¹³ Similarly, we reported a small, but significant association between indicated echocardiography screening and both higher median income of the area of residence and greater number of physicians and surgeons, regardless of whether we adjusted for individual-level factors. This is consistent with the previously observed link between markers of area poverty and lower rates of screening, and may be related to cardiology specialist availability, hospitals with echocardiogram expertise, or another unmeasured factor related to community affluence.

In contrast, our analysis of mammography screening differs from prior assessments in the general population. After adjusting for individual-level factors, mammography practices were not associated with population-level factors. While it is possible that our smaller number of participants at high risk of breast cancer ($n=390$) was not sufficient to detect a true association, the literature suggests that individual-level factors may simply be more important in this specific population. Among childhood cancer survivors at high risk of breast cancer, a multitude of individual-level factors impact mammography screening, including health beliefs, physician–patient communication, and personality traits.^{31,32,34}

Because of variations in health insurance coverage in the United States and its association with SES, we suspected that insurance status might account for the community SES effects in our sample. However, if this was the case, we should have seen an attenuation of our findings of the effects of median area income on care when we included Canadian survivors with universal access to healthcare. We found no difference in this association between the two populations, suggesting that factors other than health insurance are influencing access to care in low-income persons.

Although this analysis provides novel information about the role of population-level factors on childhood cancer survivors' medical care and risk-based screening practices, there are several limitations to note. First, as in prior CCSS, the cohort in general represents a more socioeconomically advantaged population compared to the general population, with respect to individual income, education, insurance, and employment status. Similarly, U.S. participants in this study had a slightly higher median income of their area of residence, compared to the general U.S. population median income (U.S. \$48,400 in our study vs. \$41,994 in general population), while Canadian residents had a lower area median income than the general Canadian population (converted to U.S. dollars, \$38,500 in our study vs. \$46,469 in general population).

A variety of population-level factors were assessed in this study; however, other population-level factors may be associated with medical care or screening practices that were not available for this analysis. In addition, our analysis of the

Canadian residents (about 8% of the study participants) was limited by incomplete comparable measures for Canada, although comparable income and population density measures did allow for assessment of the entire study population. The Canadian sample was simply underpowered to report Canada-only results; indeed, the generally robust effects of area-level income were largely insignificant in its association with any of the outcomes. Certainly, future analyses would be useful to see how community-level factors may play a role in the context of universal health insurance.

Another limitation is that individual-level factors were evaluated by self-report, while population-level factors were limited to publicly available database information. Given the consideration of numerous county-level variables to be included, of which a small number of significant ones were permitted in the analyses, our results should be considered provisional given the multiple comparisons undertaken. Finally, we acknowledge that younger survivors would likely have different factors influencing their medical care (e.g., parental factors) and that more recently treated survivors may have different healthcare patterns.

In summary, this analysis suggests that population-level health disparities remain an important concern nationwide and have some influence over care practices for childhood cancer survivors. Given the limited breadth and power of population factors for this sample, however, it is likely a more complicated picture and primary focus should remain on individual-level factors, including insurance, employment, education, and health beliefs. Importantly, these are potentially modifiable factors that can be targeted by individual-level interventions to shape health beliefs, population-level policies to improve insurance coverage, and community-wide strategies to improve educational and employment opportunities to give this vulnerable population the best chance for long-term health and well-being by improving risk-based medical care and screening practices.

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References

1. Oeffinger KC, Mertens AC, Sklar CA, et al. Chronic health conditions in adult survivors of childhood cancer. *N Engl J Med*. 2006;355:1572–82.
2. Armstrong GT, Kawashima T, Leisenring W, et al. Aging and risk of severe, disabling, life-threatening, and fatal events in the childhood cancer survivor study. *J Clin Oncol*. 2014;32:1218–27.

3. Hudson MM, Ness KK, Gurney JG, et al. Clinical ascertainment of health outcomes among adults treated for childhood cancer. *JAMA*. 2013;309:2371–81.
4. Hewitt M, Greenfield S, Stoval E. From cancer patient to cancer survivor: lost in transition. Washington, DC: National Academies Press; 2005.
5. Hewitt M, Weiner SL, Simone JV. Childhood cancer survivorship: improving care and quality of life. Washington, DC: National Academies Press; 2003.
6. Oeffinger KC, Mertens AC, Hudson MM, et al. Health care of young adult survivors of childhood cancer: a report from the Childhood Cancer Survivor Study. *Ann Fam Med*. 2004;2: 61–70.
7. Nathan PC, Greenberg ML, Ness KK, et al. Medical care in long-term survivors of childhood cancer: a report from the childhood cancer survivor study. *J Clin Oncol*. 2008;26: 4401–9.
8. Singh GK, Miller BA, Hankey BF, et al. Changing area socioeconomic patterns in U.S. cancer mortality, 1950–1998: Part I—all cancers among men. *J Natl Cancer Inst*. 2002;94:904–15.
9. Bus P, Aarts MJ, Lemmens VE, et al. The effect of socioeconomic status on staging and treatment decisions in esophageal cancer. *J Clin Gastroenterol*. 2012;46:833–9.
10. Byers TE, Wolf HJ, Bauer KR, et al. The impact of socioeconomic status on survival after cancer in the United States: findings from the National Program of Cancer Registries Patterns of Care Study. *Cancer*. 2008;113:582–91.
11. Schootman M, Jeffe DB, Reschke AH, Aft RL. Disparities related to socioeconomic status and access to medical care remain in the United States among women who never had a mammogram. *Cancer Causes Control*. 2003;14:419–25.
12. Ward E, Jemal A, Cokkinides V, et al. Cancer disparities by race/ethnicity and socioeconomic status. *CA Cancer J Clin*. 2004;54:78–93.
13. Schootman M, Jeffe DB, Baker EA, Walker MS. Effect of area poverty rate on cancer screening across US communities. *J Epidemiol Commun Health*. 2006;60:202–7.
14. Elkin EB, Atoria CL, Leoce N, et al. Changes in the availability of screening mammography, 2000–2010. *Cancer*. 2013;119:3847–53.
15. Elkin EB, Ishill NM, Snow JG, et al. Geographic access and the use of screening mammography. *Med Care*. 2010;48:349–56.
16. Robison LL, Mertens AC, Boice JD, et al. Study design and cohort characteristics of the Childhood Cancer Survivor Study: a multi-institutional collaborative project. *Med Pediatr Oncol*. 2002;38:229–39.
17. Robison LL, Armstrong GT, Boice JD, et al. The Childhood Cancer Survivor Study: a National Cancer Institute-supported resource for outcome and intervention research. *J Clin Oncol*. 2009;27:2308–18.
18. Mertens AC, Walls RS, Taylor L, et al. Characteristics of childhood cancer survivors predicted their successful tracing. *J Clin Epidemiol*. 2004;57:933–44.
19. Armenian SH, Hudson MM, Mulder RL, et al. Recommendations for cardiomyopathy surveillance for survivors of childhood cancer: a report from the International Late Effects of Childhood Cancer Guideline Harmonization Group. *Lancet Oncol*. 2015;16:e123–36.
20. Henderson TO, Amsterdam A, Bhatia S, et al. Systematic review: surveillance for breast cancer in women treated with chest radiation for childhood, adolescent, or young adult cancer. *Ann Intern Med*. 2010;152:444–55, W144–54.
21. Mulder RL, Kremer LC, Hudson MM, et al. Recommendations for breast cancer surveillance for female survivors of childhood, adolescent, and young adult cancer given chest radiation: a report from the International Late Effects of Childhood Cancer Guideline Harmonization Group. *Lancet Oncol*. 2013;14:e621–9.
22. Hudson MM, Mertens AC, Yasui Y, et al. Health status of adult long-term survivors of childhood cancer: a report from the Childhood Cancer Survivor Study. *JAMA*. 2003;290:1583–92.
23. Derogatis LR. BSI-18: Administration, scoring, and procedures manual. Minneapolis, MN: NCS Assessments; 2001.
24. Ware JE, Jr., Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care*. 1992;30:473–83.
25. Chamberlain LJ, Pineda N, Winestone L, et al. Increased utilization of pediatric specialty care: a population study of pediatric oncology inpatients in California. *J Pediatr Hematol Oncol*. 2014;36:99–107.
26. Chen PG, Mehrotra A, Auerbach DI. Do we really need more physicians? Responses to predicted primary care physician shortages. *Med Care*. 2014;52:95–6.
27. Castellino SM, Casillas J, Hudson MM, et al. Minority adult survivors of childhood cancer: a comparison of long-term outcomes, health care utilization, and health-related behaviors from the childhood cancer survivor study. *J Clin Oncol*. 2005;23:6499–507.
28. Suh E, Daugherty CK, Wroblewski K, et al. General internists' preferences and knowledge about the care of adult survivors of childhood cancer. A cross-sectional survey. *Ann Intern Med*. 2014;160:11–7.
29. Sima JL, Perkins SM, Haggstrom DA. Primary care physician perceptions of adult survivors of childhood cancer. *J Pediatr Hematol Oncol*. 2014;36:118–24.
30. Steele JR, Wall M, Salkowski N, et al. Predictors of risk-based medical follow-up: a report from the Childhood Cancer Survivor Study. *J Cancer Surviv*. 2013;7:379–91.
31. Oeffinger KC, Ford JS, Moskowitz CS, et al. Breast cancer surveillance practices among women previously treated with chest radiation for a childhood cancer. *JAMA*. 2009;301: 404–14.
32. Cox CL, Oeffinger KC, Montgomery M, et al. Determinants of mammography screening participation in adult childhood cancer survivors: results from the childhood cancer survivor study. *Oncol Nurs Forum*. 2009;36:335–44.
33. Cox CL, Hudson MM, Mertens A, et al. Medical screening participation in the childhood cancer survivor study. *Arch Intern Med*. 2009;169:454–62.
34. Smith SM, Ford JS, Rakowski W, et al. Inconsistent mammography perceptions and practices among women at risk of breast cancer following a pediatric malignancy: a report from the Childhood Cancer Survivor Study. *Cancer Causes Control*. 2010;21:1585–95.

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