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Catastrophic health expenditures and food insecurity among older cancer survivors in the United States



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Abstract

Background Cancer patients face a costly trade-off between medical care and basic necessities including food. This study aims to explore whether catastrophic health expenditures lead to food insecurity among older cancer survivors in the US.

Methods Longitudinal study of individuals aged 50 or older who were diagnosed with cancer during 2000–2020 and their follow-up measurements selected from the Health and Retirement Study. Data consists of 2505 cancer survivors and 11,614 person-year observations for an average of 4.6 observations per participant. Catastrophic health expenditures were defined as out-of-pocket costs exceeding 5%, 10%, or 15% of household income. Participants were classified as food insecure if they experienced insufficient access to food due to financial limitations. This study utilized fixed effects ordered logistic regression to implement a within-subject research design.

Results Of the 2505 cancer survivors, 77 (3.1%) were moderately food insecure and 73 (2.9%) were severely food insecure. In ordered logistic regression, all three measures of catastrophic health expenses were associated with a higher odds of food insecurity. These associations were more pronounced for males, ethnic minorities, survivors without college education, those in fair or poor health, retirees, and survivors with below-median income.

Conclusions The prevalence of food insecurity among older cancer survivors was relatively low, with 6% of the sample experiencing food insecurity. Multivariate regression analyses revealed that a major predictor of food insecurity among older cancer survivors is catastrophic health costs. Given the health benefits of secure food access, older cancer survivors should consult care providers about their financial capacity to afford recommended cancer treatments while maintaining healthy diets. Policymakers should also consider interventions to reduce out-of-pocket financial burden on older cancer survivors, as improved financial security may enhance treatment outcomes and lower cancer-related mortality.

Keywords Out-of-pocket healthcare costs, Catastrophic health spending, Financial hardship, Food insecurity, Food insufficiency

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Background

Financial burden of cancer treatment is becoming a major social and healthcare issue in the US. Recent advances in treatment and novel therapies have improved treatment outcomes, yet this increased efficacy comes at a significant cost [1]. Many anticancer medications cost more than \$10,000 out-of-pocket for a year, even with financial support from Medicare [2]. Novel cancer therapies often charge six-figure sums to already financially distressed patients [3]. Consequently, many cancer patients seek copayment support from government programs or community-based services to maintain access to care and alleviate financial hardships [4, 5].

A pilot study found the significant financial burden associated with cancer treatment, leading to the term "financial toxicity of cancer care" [6]. Indeed, an increasing number of cancer patients face excessive out-ofpocket costs and experience financial strain as a result. For example, cancer survivors are more likely to accrue unsecured debt, sell or refinance their homes, and exhaust household savings to fulfill their treatment needs [7–13]. A significant portion of cancer survivors alter their lifestyle or cut back spending on basic necessities including food [6, 14, 15]. The extreme financial distress manifested by medical financial hardship has been linked to a higher risk of mortality [16].

Proper nutrition is important for cancer patients undergoing treatment, as it influences treatment efficacy and recovery process. Nutritionally balanced diets bolster the immune system and enhance a patient's capacity to endure physically demanding cancer treatments, such as chemotherapy, radiation, and surgery [17, 18]. Adequate food access and healthy eating habits lower the likelihood of cancer recurrence and cancer-related mortality [19, 20]. Despite the health benefits of adequate food, US adult cancer survivors have shown relatively low adherence to national dietary guidelines [21] and have not met the evidence-based dietary recommendations for cancer prevention [22]. The overall diet quality is found to be low for adult cancer survivors in the US, with significant disparities observed across demographic and socioeconomic groups [23].

Food insecurity refers to the "inability to acquire nutritionally adequate and safe foods in socially acceptable ways" due to resource constraints [24]. The 2023 USDA report estimated that about one in ten households in the US has experienced some degree of "reduced food intake" or "disrupted eating patterns" [25]. Food insecurity is a validated risk factor for chronic conditions, including diabetes, hypertension, and cardiovascular disease [26–29], as well as for inflammatory responses due to chronic stress [26, 30]. Previous research has shown that food insecure patients are less likely to comply with prescribed treatments due to financial concerns related to food insecurity [15]. Such decisions can potentially compromise treatment effectiveness and diminish quality of life [31].

Currently, there is limited knowledge about how excessive medical costs during post-treatment periods affect food access for older cancer survivors. Existing studies have documented the limited food access of cancer patients or the financial strain associated with cancer treatment [14], but they have not examined the direct link between out-of-pocket costs and food insecurity. Understanding the extent to which medical costs impact food access is critically important for developing targeted interventions to prevent nutritional deficiencies during post-treatment periods [32]. In this study, the concept of catastrophic health expenditure is employed to measure the excessive financial burden faced by cancer survivors. Catastrophic health expenditure refers to out-of-pocket medical costs that exceed a household's financial capacity, making it difficult to afford medical expenses without drawing on savings, selling assets, or borrowing [33]. This study uses a cost measure that includes all out-of-pocket medical expenses to examine the implications of both direct and indirect medical costs associated with cancer. The empirical analysis leverages the longitudinal structure of the data to assess changes in food insecurity in response to incurring catastrophic health expenditures.

Methods

Study sample

This research conducted a secondary analysis of data drawn from the Health and Retirement Study (HRS), a longitudinal cohort study of American adults aged 50 and above [34]. The HRS began in 1992 and has been conducted biennially by the University of Michigan with support from the National Institute of Aging. Participants have been interviewed on a wide range of topics including income, work, retirement, health, and healthcare, enabling researchers to understand health and wellbeing in later life. All participants have provided written informed consent at the time they agreed to join the study and prior to each interview. For the current study, we used the RAND HRS Longitudinal File 2020 (Mar 2023 V1), match-merged with the food insecurity questions in the HRS core dataset module Q. The study sample was restricted to participants who reported a cancer diagnosis in the 2000-2020 HRS and their follow-up measurements. Excluding missing data, participants below age 50, and singletons (with no follow-up measurements) leads to the baseline sample of 2505 cancer survivors (Fig. 1). The regression analyses were based on 11,614 personyears observations for an average of 4.6 observations for each participant. The follow-up measurements are summarized in Table A1 of Appendix.



Fig. 1 Selection of the study sample from the health and retirement study, 2000–2020

Catastrophic health expenditure

Catastrophic health expenditure occurs when a household's out-of-pocket payments exceed a certain percentage of a household's income [33]. Researchers operationalized catastrophic health expenditure as household out-of-pocket costs surpassing a predetermined share of annual non-subsistence income (excluding spending on basic needs) [33, 35]. The specific thresholds vary between 5% and 40% depending on research objectives and data [36, 37]. For this study, we considered thresholds of 5%, 10%, and 15% to construct binary indicators of catastrophic health expenditure. This study applied lower thresholds than previous research because it focuses on a particularly vulnerable population - older cancer survivors - where a small amount of out-of-pocket spending can greatly affect basic needs like food security. This population typically has more limited financial resources, making them more susceptible to financial strain even at relatively lower levels of healthcare expenditure.

Out-of-pocket health costs were measured across the following categories: hospital costs, nursing home costs, doctor visit costs, dental costs, outpatient surgery costs, average monthly prescription drug costs, home health care costs, and special facility costs. Participants reported their personal spending on each category for the last two years. These reports were normalized to an annual scale and aggregated by household to derive household-level cost estimates. Household income is the self-reported total income of both spouses for the last calendar year, which includes labor income, private pensions, Social Security, transfer payment, capital gain, and other sources of income. Both measures were imputed by the RAND corporation to address missingness in data [38].

Food insecurity

An ordinal measure of household food security was constructed using a 2-item screener in the HRS [39]. Participants were asked, "In the last 2 years, have you always had enough money to buy the food you need?". Those who responded 'no' were further probed, "In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money to buy food?". An affirmative response to the first screening question was considered to indicate secure food access or food security. The responses of 'no' to both questions were assumed to represent moderate food insecurity. Finally, participants who denied having enough money in the first question but affirmed reduced food intake in the follow-up were categorized as experiencing severe food insecurity. The food insecurity variable is coded as 0 for food security, 1 for moderate food insecurity, and 2 for severe food insecurity.

Statistical analysis

This study used multivariable ordered logistic regression adjusted for fixed effects on individual level [40] to estimate the longitudinal association between catastrophic health expense and the categorical variable of household food insecurity. Fixed effects regression exploits within-subject variation over time to capture changes in outcome variable in relation to changes in independent variables over the same period. By de-meaning data at the individual level, it effectively removes the impact of time-invariant individual characteristics and reduces the potential for omitted variable bias due to unobserved time-invariant confounders. Interpretation of the coefficients is restricted to temporal relationships and do not extend to cross-sectional (between-individual) variations. All regression analyses were baseline adjusted and control for time-of-survey (month and year) dummies and Census division fixed effects. Results report adjusted odds ratios and their respective 95% confidence intervals. Estimates are regarded as statistically significant when the *p*-value is below 0.05 in a two-sided test. Regressions are estimated using *feologit* in Stata, a userprovided command for fixed effects ordered logistic regression [40]. Data handling and modeling were conducted between November 15 and December 31, 2023.

Covariates

Covariates include individual, socioeconomic, and clinical factors that could be correlated with healthcare expenses and food insecurity. These variables are age, marital status (married; separated, divorced, or widowed; never married), number of household members, self-rated health (excellent; very good; good; fair; poor), chronic health indicators (high blood pressure, diabetes, heart problems, stroke, and lung problem), Center for Epidemiologic Studies Depression (CES-D) scale, Activities of Daily Living (ADL) score, health insurance coverage (no insurance; Medicare or Medicaid only; employer-provided insurance only; other single insurance; multiple coverage), employment status (retired; not retired), the log of household income, month- and yearof-survey dummies, and Census division fixed effects. Heart problems include heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems. Lung problem refers to chronic lung disease except asthma. All monetary figures (income and outof-pocket medical costs) were standardized to 2020 US dollars using the consumer price index for all urban consumers. The time-invariant characteristics of participants (sex, race/ethnicity, and education background) were reported in the descriptive analyses of the study sample.

Results

Sample characteristics

The baseline sample included 2505 respondents who were diagnosed with cancer in the 2000–2020 waves of the HRS, for a weighted sample size of 11,156,667. The food insecurity category includes 150 respondents, 77 of whom are moderately food insecure, and 73 are severely food insecure. The majority of the sample was non-Hispanic White (78.1%), married (66.7%), retired (73.2%), and high school graduates (82.2%). Approximately 5.1% and 21.6% of survivors reported excellent or very good health, with the remaining 73.3% reporting good, fair, or poor health conditions. The cancer survivors had a number of chronic conditions, with high blood pressure being the most common (63.7%). Regarding health insurance, 65.7% reported having a single health insurance plan, 32% had multiple coverages, and 2.4% had no

health insurance. Most cancer survivors lived in food secure households (94.0%), while 6.0% were in food insecure households, with 3.1% reporting moderate food insecurity and 2.9% reporting severe food insecurity. The weighted mean of the out-of-pocket medical costs was \$3467 per household, with a standard deviation of \$6096. Nearly 39% of the cancer survivors spent more than 5% of their household income on healthcare, 21.2% spent over 10%, and 13.1% spent over 15%. The sample characteristics are presented by food insecurity and for the full sample (Table 1).

Catastrophic health expenditure and food insecurity

Table 2 presents the fixed effects ordered logistic regression analysis of food insecurity on catastrophic medical spending. After adjustment for covariates, spending more than 5% of household income on healthcare was associated with 1.72 times higher odds of being in a more severe food insecurity group versus a food security group (95% CI, 1.27-2.34). Similarly, after adjusting for covariates spending over 10% of household income was associated with a 1.53-fold increase in the odds of falling into a more severe food insecurity group versus a food security group (95% CI, 1.21–2.10). We also found that spending over 15% on healthcare was associated with 1.52 times higher odds of being in a higher category of food insecurity versus being in the food secure category (95% CI, 1.06-2.19), compared to those spending less. The associations remained statistically significant in the baseline and partially-adjusted models, controlling for a subset of covariates (Table A2).

In addition to catastrophic health expenses, we found a number of covariates associated with food insecurity. For example, in the first regression poor self-rated health (OR = 2.51; 95% CI, 1.04–6.08), CES-D scale (OR = 1.15; 95% CI, 1.06–1.25), and having employer-provided health insurance coverage (OR = 0.31; 95% CI, 0.10-1.00) were associated with food insecurity.

Catastrophic health expenditure and food insecurity by sociodemographic characteristics

Table 3 presents results from the split-sample analyses by demographic and socioeconomic characteristics. For male cancer survivors, out-of-pocket costs exceeding 5% of income was associated with 2.24 times increase in the odds of falling into a more severe food insecurity group versus a food security group (95% CI, 1.30–3.86). The male survivors who spent over 10% (OR = 2.23; 95% CI, 1.30–3.81) or 15% (OR = 2.47; 95% CI, 1.29–4.74) of household income were also more likely to become food insecure. For non-Hispanic African Americans, Hispanics, and other races, out-of-pocket costs exceeding 5% of income (OR = 1.87; 95% CI, 1.16–3.02), 10% of income (OR = 1.90; 95% CI, 1.16–3.11), and 15% of income

Table 1 Baseline characteristics of the HRS participants diagnosed with cancer

	Participants, No. (%)	All		
Characteristics	Food insecure (n = 150) ^a	Food secure (<i>n</i> = 2355)	P val.	(n=2505)
Age, median (IQR) ^a	66 (11)	68 (13)		68 (13)
Sex			0.031	
Female	89 (59.3)	1184 (50.3)		1273 (50.8)
Male	61 (40.7)	1171 (49.7)		1232 (49.2)
Race/ethnicity			< 0.001	
NH African American	47 (31.3)	306 (13.0)		353 (14.1)
Hispanics	18 (12.0)	137 (5.8)		155 (6.2)
Other races	3 (2.0)	37 (1.6)		40 (1.6)
NH White	82 (54.7)	1875 (79.6)		1957 (78.1)
Education			< 0.001	
Less than high school	50 (33,3)	396 (16.8)		446 (17.8)
High school graduate	59 (39,3)	815 (34.6)		874 (34.9)
Some college	26 (17.3)	551 (23.4)		577 (23.0)
College graduate	15 (10.0)	593 (25.2)		608 (24.3)
Marital status		/	< 0.001	
Never married	3 (2 0)	67 (2 9)		70 (2.8)
Separated divorced widowed	72 (48 0)	693 (29.4)		765 (30 5)
Married	75 (50.0)	1595 (67.7)		1670 (66 7)
No. of household members, mean (SD) ^b	2 04 (1 27)	2 10 (0 98)	0.086	2 10 (1 00)
Self-rated health	2.01(1.27)	2.10 (0.90)	< 0.001	2.10 (1.00)
Excellent	2 (1 3)	125 (5 3)	0.001	127 (5.1)
Very good	13 (8 7)	529 (22 5)		542 (21.6)
Good	A1 (27 3)	525 (22.5) 844 (35.8)		885 (35 3)
Fair	53 (35 3)	594 (25.2)		647 (25.8)
Poor	41 (27.3)	263 (11.2)		304 (12.1)
High blood prossure		205 (11.2)	0.007	50+(12.1)
Voc	105 (70.0)	1400 (62.2)	0.097	1505 (62 7)
No	45 (20.0)	965 (26 7)		010 (26 2)
Diabatas	45 (50.0)	805 (50.7)	< 0.001	910 (50.5)
Voc	55 (26 7)	515 (21 0)	< 0.001	570 (22.0)
No	05 (62 2)	10/0 (70 1)		1025 (77.2)
Heart problems	95 (05.5)	1040 (70.1)	0.002	1955 (77.5)
Voc	61 (40 7)	683 (20.0)	0.002	744 (20.7)
No	01 (40.7)	1672 (71.0)		1761 (70.2)
INO Stroko	69 (59.5)	1072 (71.0)	0.000	1701 (70.5)
Stroke	21 (14 0)	166 (7 1)	0.002	107 (7 E)
ies No.	21 (14.0)	100 (7.1)		107 (7.5) 2219 (02.5)
lung disease	129 (80.0)	2169 (95.0)	< 0.001	2516 (92.5)
Lung disease	42 (28 0)	200 (12 2)	< 0.001	221 (12 2)
Tes No.	42 (20.0)	209 (12.5)		331 (13.2) 2174 (96.9)
INO	108 (72.0)	2000 (87.7)	-0.001	21/4 (80.8)
CES-D scale ⁻ , mean (SD)	3.09 (2.58)	1.33 (1.85)	< 0.001	1.43 (1.94)
ADL score", mean (SD)	0.77 (1.38)	0.23 (0.67)	< 0.001	0.26 (0.74)
Health Insurance coverage	12 (0.0)	40 (2.0)	< 0.001	
No insurance	12 (8.0)	48 (2.0)		00 (2.4)
iviedicare or iviedicaid only	0 (C O)	820 (35.1)		911 (36.4)
Employer-provided insurance only	9 (0.0)	302 (12.8)		311(12.4)
Other single insurance	2U (13.3)	402 (17.1)		422 (16.9)
Iviuluple coverage	24 (16.0)	/// (33.0)	0.074	801 (32.0)
Employment status	41 (27 2)		0.876	
NOT retired	41 (27.3)	630 (26.8)		6/1 (26.8)
Ketired	109 (/2./)	1/25 (73.3)		1834 (73.2)

Table 1 (continued)

	Participants, No. (%)			All	
Characteristics	Food insecure	Food secure	Pval.	(n = 2505)	
	$(n = 150)^{a}$	(n=2355)			
OOP medical costs ^c , mean (SD)	2241 (2968)	3542 (6228)	0.025	3467 (6096)	
Total income (\$1000) ^c , mean (SD)	51.6 (95.6)	91.8 (170.5)	0.002	89.5 (167.4)	
OOP medical costs/total income > 0.05			0.142		
Yes	67 (44.7)	910 (38.6)		977 (39.0)	
No	83 (55.3)	1445 (61.4)		1528 (61.0)	
OOP medical costs/total income > 0.1			0.002		
Yes	47 (31.3)	484 (20.6)		531 (21.2)	
No	103 (68.7)	1871 (79.5)		1974 (78.8)	
OOP medical costs/total income > 0.15			0.037		
Yes	28 (18.7)	300 (12.7)		328 (13.1)	
No	122 (81.3)	2055 (87.3)		2177 (86.9)	

Abbreviation: HRS, Health and Retirement Study; IQR, interquartile range; NH, Non-Hispanic; CES-D, Center for Epidemiologic Studies Depression; ADL, Activities of Daily Living; OOP, out-of-pocket. Notes: ^a The food insecurity category includes 77 moderately food insecure households and 73 severely food insecure households. ^b Statistics weighted using the individual weights provided by the RAND HRS. ^c Statistics weighted using the household weights provided by the RAND HRS.

Table 2	Association	between c	atastrophic	medical	costs and	food	insecurity,	fixed e	ffects	ordered I	ogistic re	egression	results

	$\theta = 5\%$				$\theta = 10\%$			$\theta = 15\%$			
	OR	95% CI	Pval.	OR	95% CI	Pval.	OR	95% CI	P val.		
Catastrophic health expenditure	1.72	(1.27–2.34)	< 0.01	1.53	(1.11–2.10)	0.01	1.52	(1.06–2.19)	0.02		
Age	1.43	(0.78-2.63)	0.24	1.47	(0.81-2.68)	0.21	1.47	(0.81-2.68)	0.21		
Age squared	1.00	(1.00-1.00)	0.23	1.00	(1.00-1.00)	0.19	1.00	(1.00-1.00)	0.19		
Marital status											
Never married	Ref.			Ref.			Ref.				
Separated, divorced, widowed	1.16	(0.34-3.91)	0.81	1.28	(0.38-4.33)	0.69	1.23	(0.36-4.19)	0.74		
Married	0.79	(0.20-3.17)	0.74	0.88	(0.22-3.57)	0.86	0.86	(0.21-3.49)	0.84		
No. of household members	0.99	(0.82-1.19)	0.92	0.99	(0.83-1.20)	0.95	0.99	(0.83-1.19)	0.94		
Self-rated health											
Excellent	Ref.			Ref.			Ref.				
Very good	1.43	(0.69–2.99)	0.34	1.44	(0.69–2.98)	0.33	1.41	(0.68-2.93)	0.35		
Good	1.89	(0.86-4.17)	0.11	1.91	(0.87-4.17)	0.11	1.91	(0.87-4.17)	0.11		
Fair	2.00	(0.88-4.53)	0.10	2.02	(0.90-4.51)	0.09	2.02	(0.91-4.52)	0.09		
Poor	2.51	(1.04–6.08)	0.04	2.57	(1.08–6.17)	0.03	2.56	(1.07-6.12)	0.04		
Chronic health conditions											
High blood pressure	0.91	(0.51-1.62)	0.75	0.92	(0.52-1.64)	0.78	0.97	(0.54–1.72)	0.91		
Diabetes	1.23	(0.64-2.35)	0.54	1.12	(0.57–2.19)	0.74	1.12	(0.57-2.19)	0.75		
Heart problems	0.75	(0.42-1.35)	0.34	0.78	(0.44-1.39)	0.41	0.77	(0.43-1.38)	0.38		
Stroke	0.89	(0.40-2.00)	0.78	0.88	(0.39–1.97)	0.75	0.87	(0.39–1.95)	0.73		
Lung disease	0.98	(0.51-1.89)	0.95	0.97	(0.51-1.86)	0.93	0.98	(0.51-1.88)	0.94		
CES-D scale	1.15	(1.06-1.25)	< 0.01	1.14	(1.05-1.24)	< 0.01	1.14	(1.05-1.24)	< 0.01		
ADL score	1.09	(0.92-1.28)	0.32	1.09	(0.92-1.28)	0.31	1.08	(0.92-1.28)	0.34		
Health insurance coverage											
Medicare or Medicaid only	Ref.			Ref.			Ref.				
No insurance	1.83	(0.90-3.72)	0.09	1.87	(0.91–3.83)	0.09	1.88	(0.91-3.88)	0.09		
Employer-provided insurance only	0.57	(0.21-1.58)	0.28	0.61	(0.22-1.72)	0.35	0.60	(0.22-1.67)	0.33		
Other single insurance	1.34	(0.83-2.17)	0.24	1.39	(0.86–2.26)	0.18	1.36	(0.83-2.23)	0.22		
Multiple coverage	1.01	(0.64-1.60)	0.95	1.03	(0.65-1.62)	0.90	1.02	(0.65-1.59)	0.95		
Employment status											
Not retired	Ref.			Ref.			Ref.				
Retired	1.21	(0.72-2.02)	0.47	1.22	(0.72-2.05)	0.47	1.21	(0.71-2.04)	0.48		
Log of total income	0.96	(0.87-1.05)	0.38	0.95	(0.86-1.04)	0.28	0.95	(0.86-1.05)	0.30		

Abbreviation: OR, odds ratio; CI, confidence interval; OOP, out-of-pocket; CES-D, Center for Epidemiologic Studies Depression; ADL, Activities of Daily Living. Regressions adjusted for month- and year-of-survey and Census division of residence

	$\theta = 5\%$				$\theta = 10\%$			$\theta = 15\%$			
	OR	95% CI	P val.	OR	95% CI	Pval.	OR	95% CI	P val.		
Gender: female	1.43	(0.93–2.20)	0.10	1.18	(0.77–1.83)	0.45	1.13	(0.70–1.82)	0.61		
Gender: male	2.24	(1.30–3.86)	< 0.01	2.23	(1.30–3.81)	< 0.01	2.47	(1.29–4.74)	< 0.01		
Race: Non-Hispanic White	1.56	(1.04–2.35)	0.03	1.53	(0.96–2.44)	0.07	1.51	(0.93–2.43)	0.09		
Race: Black, Hispanic, and others	1.87	(1.16–3.02)	0.01	1.90	(1.16–3.11)	0.01	2.00	(1.11–3.62)	0.02		
Education: high school or less	1.85	(1.27–2.69)	< 0.01	1.68	(1.10–2.55)	0.02	1.60	(1.01–2.53)	0.05		
Education: some college or more	1.64	(0.87–3.09)	0.13	1.06	(0.57–1.96)	0.86	1.25	(0.64–2.44)	0.51		
Self-rated health: fair or poor	1.91	(1.23–2.96)	< 0.01	2.02	(1.28–3.19)	< 0.01	1.67	(1.04–2.70)	0.04		
Self-rated health: good or better	1.50	(0.98–2.29)	0.06	1.06	(0.66–1.71)	0.80	1.27	(0.73–2.22)	0.40		
Single or no health insurance	1.97	(1.41–2.76)	< 0.01	1.58	(1.11–2.26)	0.01	1.47	(0.98–2.23)	0.07		
Multiple insurance coverages	1.45	(0.70–2.99)	0.31	1.87	(0.88–3.97)	0.10	2.28	(0.93–5.60)	0.07		
Employment: retired	1.96	(1.36–2.84)	< 0.01	1.74	(1.21–2.51)	< 0.01	1.72	(1.12–2.64)	0.01		
Employment: not retired	1.38	(0.74–2.58)	0.32	1.08	(0.56–2.07)	0.82	0.97	(0.49–1.91)	0.92		
Total income: below median	2.17	(1.47–3.20)	< 0.01	1.99	(1.36–2.91)	< 0.01	1.63	(1.05–2.53)	0.03		
Total income: upper median	1.13	(0.69–1.84)	0.62	0.87	(0.43–1.76)	0.70	1.23	(0.59–2.57)	0.58		

Table 3 Association between catastrophic medical costs and food insecurity by sociodemographic characteristics, fixed effects ordered logistic regression results

Note: Regressions adjusted for age, age squared, marital status, self-rated health, chronic health conditions, CES-D scale, ADL score, health insurance coverage, employment status, log of total income, month- and year-of-survey, and Census division of residence

(OR = 2.00; 95% CI, 1.11-3.62) were associated with increased odds of moving from food secure to food insecure (either moderate or severe). These three measures of catastrophic health expenditure showed a significant association with food insecurity among cancer survivors who have a high school education or less (OR = 1.85; 95%) CI, 1.27–2.69 for θ =5%; OR = 1.68; 95% CI, 1.10–2.55 for θ =10%; OR = 1.60; 95% CI, 1.01–2.53 for θ =15%), those who rated their health as fair or poor (OR = 1.91; 95% CI, 1.23–2.96 for θ =5%; OR = 2.02; 95% CI, 1.28–3.19 for θ =10%; OR = 1.67; 95% CI, 1.04–2.70 for θ =15%), retirees (OR = 1.96; 95% CI, 1.36–2.84 for θ = 5%; OR = 1.74; 95% CI, 1.21–2.51 for $\theta = 10\%$; OR = 1.72; 95% CI, 1.12–2.64 for θ =15%), and participants with below median income in the sample (OR = 2.17; 95% CI, 1.47–3.20 for θ =5%; OR = 1.99; 95% CI, 1.36–2.91 for θ = 10%; OR = 1.63; 95% CI, 1.05–2.53 for θ =15%). Overall, the associations between catastrophic medical costs and food insecurity were more pronounced for males, ethnic minorities, the less educated, those in poor health, retirees, and the lower income group.

Discussion

This study contributes to the growing research on the financial toxicity of cancer care, by demonstrating the dual challenges cancer survivors face in terms of treatment financing and adequate food access. While previous research has documented the rising cost of cancer care [1] and the competing demands between medical services and basic needs [6, 9–11, 41], a direct link between out-of-pocket financial burdens and food security has not been comprehensively examined. A cancer diagnosis incurs catastrophic out-of-pocket medical costs, not only during acute treatment phases but also through extended

follow-up care, exerting a lasting influence on household finances [7]. Within the US cancer survivor population, the prevalence of food insecurity was between 4.0 and 26.2% for adult survivors and 4.0–83.6% for patients undergoing active treatment [42]. In this study, we have posited that out-of-pocket health expenses lead to restrained food access after cancer diagnosis, and evaluated this hypothesis through a longitudinal analysis of food security and healthcare expenses in the US from 2000 to 2020.

Using within-subject research design and cancer survivors in the 2000-2020 Health and Retirement Study representing about 11 million US older adults, this study found that about 6% have experienced some degree of food insecurity, and catastrophic medical expenditures is associated with higher odds of food insecurity. These findings indicate an immediate compromise in food security in response to catastrophic health expenditures, as the analyses exploit co-occurrence of food insecurity and copayment burden observed in a 2-year period. To my knowledge, this is one of the few studies to quantify within-person associations between out-ofpocket medical spending and food access among older cancer survivors and document the immediate financial repercussions of cancer treatment as measured by food insecurity.

The findings are in line with the existing research on medical financial hardship due to cancer treatments. Previous studies have shown that cancer survivors cut back their spending on basic necessities such as utilities and housing [6, 9-11, 41] and exhaust their savings and assets to pay off medical bills [6, 12, 13, 43]. Financial hardship due to cancer care has been documented in both objective domains (such as medical debt and bankruptcy) and

subjective domains (like worry about paying medical bills) [44–46], as well as in the form of forgoing or delaying further treatments to mitigate out-of-pocket cost burden [6]. Older cancer survivors still experience financial pressures from cancer care, although they receive financial support from Medicare and Social Security [47]. In this study, we found that cancer survivors incurring excessive medical costs struggle to afford food and nutritious meals. This dual challenge of healthcare financing and food access was observed in both survivors with single or no health insurance and multiple coverage holders. This finding suggests that the current financial protection measures provided by Medicare and Medicaid are insufficient to guard against the financial burdens of cancer care, and additional interventions should be considered to alleviate financial stress experienced by cancer survivors. Previous research showed that older survivors voluntarily reallocate their savings toward cash and cashequivalent assets to accumulate a financial buffer against cancer-related expenses, in the absence of adequate financial protection [13].

The subgroup analyses indicate that cancer survivors who were at risk of food insecurity in response to catastrophic health expenditures were males, ethnic minorities, survivors without college education, those in fair or poor health, retirees, and survivors with below-median income. Compared with college-educated cancer survivors, the less educated group may not be as prepared for unexpected medical costs or have lower financial literacy to navigate through financial challenges associated with cancer care [48]. Similarly, resource constrained survivors and ethnic minorities may have limited assets and savings to cope with medical emergencies. Retirees typically face greater age-related health issues but often lack sufficient cash reserves to pay off sudden, unexpected charges [49]. Furthermore, cancer survivors with poorer baseline health are more likely to develop cancer-related complications and comorbidities, which could further escalate healthcare costs [50]. These findings emphasize the need for targeted, nuanced interventions that address the specific challenges faced by these groups, focusing on both food insecurity and the financial burden of healthcare.

Interestingly, although the association between catastrophic health costs and food insecurity was stronger among male cancer survivors, the overall prevalence of food insecurity was higher among females. This suggests that while men may experience a sharper increase in food insecurity in response to catastrophic health costs, women are more vulnerable to food insecurity overall. Given this gender difference, policies for men should focus on reducing the likelihood of sudden, large out-ofpocket costs when dealing with cancer. For women, however, policies should prioritize addressing the structural financial disadvantages they face, such as wage gaps and caregiving responsibilities. By considering both the immediate financial disruptions for men and the broader socioeconomic challenges faced by women, policy interventions can be more effectively designed to address the dual burden of catastrophic health costs and food insecurity.

As cancer care becomes more expensive, it is crucial to engage patients in discussions about the financial implications of proposed treatments. The American Society of Clinical Oncology (ASCO) has set up a task force focused on providing data about various treatment options, which could help providers to engage in cost-related discussions with patients [51]. A transparent conversation about cost at the outset of treatment planning is a critical element of patient-centered care, and it can also enhance the cost effectiveness of treatment [52, 53]. Despite its clinical importance, having to discuss financial issues with care providers is quite rare and constitutes only 42% of provider-patient interactions [54]. In future clinical settings, providers should be able to present the expected value of care along with potential costs to the patient using a structured tool like the ASCO Value Framework [55]. This proactive approach would enable patients to find efficient ways to manage cancer and make informed decisions regarding their treatment planning over the long term.

While the data offer food access and healthcare spending in a longitudinal structure, it does not have detailed clinical information such as cancer types, stage, time since diagnosis, and specific treatment received. Treatment costs may be initially high (due to surgeries, chemotherapy, etc.) but could decrease over time as survivors transition into less intensive treatment or maintenance care. Consequently, individuals recently diagnosed may face higher costs that lead to food insecurity, while long-term survivors may have stabilized their finances. Given that this sample includes both long-term survivors and those recently diagnosed, it is difficult to determine how food insecurity evolves alongside the financial burden at different stages of cancer survivorship. A further challenge is the potential ambiguity in the food insecurity questions. The first question ("buy the food you need") could be interpreted as referring to either the amount or the nutritional quality of food, while the second question ("eat less than you felt you should") more explicitly addresses food quantity. This difference could have influenced participants' responses and affected the consistency of how food insecurity is measured in terms of both food quantity and nutritional adequacy. Third, the health costs in the HRS data are not specific to cancer but also include costs related to other diseases. Readers should note that the effects of catastrophic health costs reflect both the direct treatment costs of cancer and the

associated costs from comorbid conditions. Lastly, food insecurity may have been misreported due to potential recall bias and social desirability bias. The self-reported experience of food access over the past two years could have been influenced by poor memory or by recalling similar experiences outside the specified time frame. Some participants may have under-reported their food insecurity out of fear of being judged as lacking autonomy or being reliant on welfare benefits when disclosing their actual food situation [56].

Government interventions to address food insecurity in the US include federal programs such as the Supplemental Nutrition Assistance Program (SNAP) and The Emergency Food Assistance Program (TEFAP), as well as community programs that offer free meals through local food banks or by direct delivery to homes. These programs were shown to enhance the health and healthcare use of disadvantaged households [57-59] and moderate the health impact of food insecurity [26, 39], although their efficacy for cancer survivors has not yet been systematically explored. Recognizing the financial consequences of cancer, researchers have argued for the systematic screening tool to identify patients with unmet social needs including food insecurity [60] and directly addressing food insecurity in the care setting [32]. Clinicians may consider implementing food pantry intervention in hospitals, as it can provide immediate food assistance to cancer patients in need, such as older patients, immigrants, and patients with advancedstage cancer [61]. Addressing the food insecurity of cancer patients would require a holistic approach, involving long-term support from federal food assistance programs and a mix of community and hospital-based programs that fulfill the immediate nutritional needs of distressed cancer patients.

While documenting the longitudinal association between catastrophic health expenditure and food insecurity is an important first step, the current knowledge is insufficient to understand how this dual challenge impacts care outcome and the quality of life among older survivors. Previous research showed that financial toxicity is directly linked to decreased adherence to medical treatment and increased psychological distress, both of which detrimentally affect survivors' quality of life [62]. In parallel, inadequate food access could lead to malnutrition and a weakened immune system, which are important determinants of physical health and recovery capabilities [39, 63]. These factors combined could undermine the survivors' capacity to manage co-morbidities and result in a lower health-related quality of life as measured by standardized instruments that assess both physical and emotional health [14]. Currently, the literature does not tell us much about how these challenges affect quality of life over the long-term and eventually mortality outcomes. Future studies that track financial and health challenges of food insecure cancer survivors for their lifetime would provide further insights into how this dual challenge affects their treatment outcomes and overall quality of life.

Conclusions

Cancer survivors suffer from financial strain due to high medical costs and lost productivity. They frequently exhaust their savings, deplete assets, and accrue excessive debt to cover medical bills [6, 12, 13, 43-45]. In this population-based study, we provided longitudinal evidence on the difficult tradeoff faced by older cancer survivors between out-of-pocket burdens and food access. The findings show that incurring catastrophic health expenditures is associated with limited access to food among older cancer survivors, and this dual challenge is more prevalent for the disadvantaged sociodemographic groups. Given the clinical importance of adequate food access for cancer treatment, the out-of-pocket burden of cancer care and food insecurity should be incorporated into patient-physician interactions and subsequent treatment schedules. Government interventions and healthcare policies should identify the most vulnerable patient groups and address their concerns regarding food access and healthcare financing.

Abbreviations

- HRS Health and Retirement Study
- CES-D Center for Epidemiologic Studies Depression
- ADL Activities of Daily Living
- ASCO American Society of Clinical Oncology
- SNAP Supplemental Nutrition Assistance Program
- TEFAP The Emergency Food Assistance Program

Supplementary Information

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Supplementary Material 1

Author contributions

TYP is the sole author of this manuscript. He designed the study, conducted analyses, and wrote the manuscript.

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Data availability

The datasets of the current study are publicly available at the Health and Retirement Study data portal (https://hrsdata.isr.umich.edu/data-products/public-survey-data).

Declarations

Ethics approval and consent to participate Not applicable. **Consent for publication**

Not applicable.

Competing interests

The author declares no competing interests.

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